Desire for Greener Land

Options for Sustainable Land Management in Drylands

World Overview of Conservation Approaches and Technologies

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DESIRE – Desertification Mitigation and Remediation of Land - a Global Approach for Local Solutions
WOCAT – World Overview of Conservation Approaches and Technologies

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Preface

Humankind currently faces interconnected, worldwide challenges of feeding our rapidly growing population while simultaneously preserving our natural resource base, adapting to climate change, and creating or maintaining favourable living conditions for present and future generations.

The world's population is growing exponentially. It is expected to rise from seven to more than nine billion people in the next few decades. Currently, around one-seventh of the world's population – the so-called "bottom billion" – does not have a secure food supply, while an expanding middle class in rapidly developing countries is placing increasing pressure on the limited natural resources available for food production. Projections indicate that agricultural production will have to increase by about 70% by 2050 in order to keep pace with population growth. This has far-reaching implications for the way we use and manage our agricultural lands.

Food production depends on the availability of fertile land, water, favourable climatic conditions, and related ecosystem services. At present, humans are overexploiting natural resources in many regions of the globe in order to obtain short-term benefits. This is leading to clearance of land, an increase in degraded ecosystems, and declining biodiversity. Additionally, global warming is causing anomalies in rainfall patterns and is increasing the occurrence of extreme weather events like prolonged droughts, floods, and cyclones. In this way, climate change is aggravating pressure on land and water resources, increasing people's vulnerability by affecting ecosystem resilience and food production potentials, particularly in marginal regions like the drylands in arid, semi-arid, and sub-humid climatic zones.

Desertification is land degradation in drylands that results from climate variation and human impact. It leads to losses of biological productivity, threatened livelihoods, and out-migration of dryland inhabitants. Over 250 million people and an estimated 10–20% of dryland areas are directly affected by desertification, and about one billion people in over 100 countries are at risk as land degradation continues to worsen. These people include many of the world's poorest and most marginalised citizens.

Combatting desertification is considered essential to ensure the long-term productivity of inhabited drylands, and the United Nations Convention to Combat Desertification (UNCCD) is the international treaty to promote action through local programmes and international, scientific partnerships. Preferably, degradation assessments involve both local land users and scientists in developing scientifically sound solutions to land degradation problems, solutions that are relevant and appropriate at that particular scale. What is needed is an approach that combines scientific rigor and accuracy with relevance and sensitivity to local perspectives and contexts.

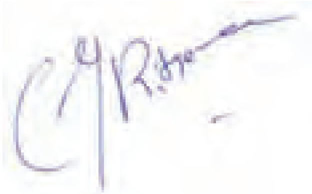
Recently, it was acknowledged by international policy and scientific fora that Sustainable Land Management (SLM) might be the key to addressing land degradation and desertification, while also contributing to increased food production, mitigating climate change, and preserving our natural resource base. SLM strategies are interventions at the local to regional scale that aim to increase productivity, improve people's livelihoods, and preserve ecosystems. As such, they are particularly relevant in dryland regions.

In the EU-funded DESIRE project (www.desire-project.eu) – "Desertification mitigation and remediation of land – A global approach for local solutions" – specific attention was paid to exploring the potentials of SLM strategies to prevent and combat degradation and desertification in a range of dryland areas around the world. To that end, a project consortium was established comprising 26 partners from academic, NGO, and governmental backgrounds; study sites were identified and embedded from 13 countries; and project activities were implemented between 2007 and 2012. The total project budget amounted to nearly nine million Euros, of which around seven million were contributed by the European Commission, with the remainder contributed by the governments of France, Italy, Spain, Mexico and the Netherlands.

DESIRE designed a global, widely applicable, methodological framework for identifying, prioritising, testing, evaluating and disseminating SLM technologies in close collaboration with local stakeholders. Such an integrative and interdisciplinary framework that involves stakeholders is needed to obtain a full understanding of the complex interplay of biophysical and socio-economic causes of desertification. Only through such an understanding is it possible to develop mitigation and restoration methods that are physically effective as well as socio-economically acceptable. The framework includes assessment of potentials for upscaling as well as of related costs and benefits, by means of innovative, coupled biophysical and economic models. A subsequent larger scale demonstration phase would additionally allow implementing selected technologies and approaches in real-life situations, assessing the cost-effectiveness of measures to restore soil functions and mitigate land degradation, and finally enhancing the adoption of SLM. To date, various national and international governmental bodies – including the UNCCD – have embraced this integrated methodological framework, endorsing its continued use and implementation. The results of the scientific innovations achieved within the DESIRE project are due to be published in three special issues of international scientific journals. In addition, the online DESIRE Harmonised Information System (http://www.desire-his.eu/) houses the complete story of DESIRE research in each of the 17 study areas. Material is presented using various formats, and the language used is less scientific in order to address a wider audience. Multiple translations are available. The project's broad definition of stakeholders, from schoolchildren to national policymakers, means that dissemination of results and ideas must also include these audiences. DESIRE has produced posters and audiovisual products for those without access to the internet.

The present DESIRE publication describes the methodology that was applied in the different study sites to identify, prioritise, test, and evaluate promising SLM strategies. It also describes ways of extending the results for application at a wider spatial scale, enabling estimation of related costs and the benefits of implementation. All of the DESIRE SLM case studies are presented using harmonised formats, previously developed by partners in the WOCAT network (www.wocat.net). The SLM case studies presented encompass interventions addressing cropping management, water management, cross-slope barriers, grazing land management, and forest management. Special attention is given to stakeholder participation and dissemination, embedded in the project approach from start to finish. Another key emphasis is assessing the state of degradation and conservation by means of a recently developed mapping methodology. Two detailed examples are presented that show application of the full cycle of DESIRE activities – in the Chinese and Turkish study sites – and demonstrate the strengths, advantages, and potentials of the developed methodology.

Globally, sustainable use and management of our land is still the exception rather than the rule. Thus, it is crucial that we exchange knowledge about SLM as well as promote and enable its implementation by practitioners in the field. We trust that this publication will be of interest to a wide range of audiences and especially those concerned about drylands. We hope this volume will contribute to protecting our environment and help to create a healthy and sustainable basis for current and future generations.



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Executive summary

The need for Sustainable Land Management

Current global developments call for more thoughtful management of our land. These developments include: the increased demand for land-based agricultural products for a growing world population; the increasing scarcity of water, fuel, and minerals; the impacts of global climate change, increased commodity prices in the agricultural sector, and growing competition for land resources. Globally, large areas of land are being affected by land degradation, partly resulting from unsustainable land use. This is particularly the case in dryland areas, which are especially vulnerable to overexploitation, inappropriate land use, and climate change. Bad land management – including overgrazing and inappropriate irrigation and deforestation practices – often undermines land's productivity. In dryland areas, land degradation is referred to as desertification. It encompasses soil erosion by water and wind, physical soil deterioration (e.g. compaction, crusting, and sealing), chemical soil deterioration (e.g. fertility decline and salinization), biological degradation (e.g. biomass and vegetation cover decline as well as forest fires), and water degradation (e.g. aridification).

Sustainable Land Management (SLM) is the key to these challenges, and it is the subject of this book. SLM is a form of land management that is targeted towards improving or stabilising agricultural productivity, improving people's livelihoods, and improving ecosystems. SLM strategies seek to combine and optimise the ecological, technical, institutional, socio-cultural, economic, and scientific aspects of land management in response to desertification. This book is aimed at land users and practitioners, agricultural specialists and scientists, students and teachers in environmental science, as well as concerned citizens. It is also intended for policymakers interested in the potential of SLM strategies to improve productivity, people's livelihoods, and ecosystems in their regions of interest.

The DESIRE response to desertification

This book presents options for SLM in drylands that grew out of the EU-funded DESIRE project (2007–2012)[1]. Further, it explains an approach – developed in the DESIRE project – for establishing promising SLM strategies in response to desertification. The DESIRE approach consists of five steps: (1) establishing land degradation and SLM context and sustainability goals; (2) identifying, evaluating, and selecting SLM strategies; (3) trialling and monitoring SLM strategies; (4) upscaling SLM strategies; and (5) disseminating the knowledge gathered in the previous steps. The DESIRE approach was applied in 17 areas affected by desertification, accounting for a wide variety of biophysical and socioeconomic conditions found worldwide. The DESIRE approach can be applied by agricultural advisors, government institutions, or in any project that aims to combat land degradation. To date, it has been incorporated in publications and initiatives by the United Nations Convention to Combat Desertification (UNCCD), the UN Food and Agriculture Organisation (FAO), and the Global Environment Facility (GEF).

Thanks to its potential for identifying needs and sharing knowledge in SLM, the WOCAT[2] methodology is an important cornerstone of the DESIRE approach. Within the DESIRE project, WOCAT tools[3] were adapted to map the current status of land degradation and conservation. Further, the tools were integrated with a stakeholder learning approach and a decision support system for identifying, documenting, and selecting SLM strategies. The WOCAT databases and tools, updated with the SLM options presented in this book, are available online to a worldwide audience. Information on SLM options is now being standardised and collated, facilitating the exchange of land management strategies to combat desertification.

This book presents guidelines for setting up and structuring land-degradation mitigation projects, using the DESIRE project as a model. It discusses the potential of using the WOCAT-based methods and tools in such projects (chapter 1.1), presents an analysis of the spatial context of SLM (chapter 1.2), and introduces the SLM strategies applied in the DESIRE project (chapter 1.3). Further, it presents recommendations and policy points based on the analyses (chapter 1.4) and case studies from all the DESIRE study sites; this also covers the spatial context of land degradation, existing SLM practices, and the SLM technologies and approaches implemented (Part 2).

Four key requirements emerged from the project, which appear essential for successful application of the DESIRE approach: (1) an integrated, multidisciplinary project setup; (2) close collaboration between scientists and stakeholders from start to finish; (3) a sound scientific basis, for example through field experimentation and state-of-the-art modelling, and, (4) from day one, a continuous dissemination and communication process between stakeholders, policymakers, and scientists. Requirements (1), (2), and (4), in particular, are relatively new in the world of applied environmental science. They proved indispensable in the DESIRE project.

Mapping land degradation and SLM

During the project, mapping of land degradation and current SLM showed that land degradation in the 17 DESIRE study sites mainly occurred as water erosion on cultivated land and land under mixed use. Degradation was found to be increasing in most sites, primarily caused by inappropriate soil management. Indirectly, land degradation appeared to be caused most frequently by population pressure, insecure land tenure, and poverty in combination with aspects of governance, institutional functioning, and politics.

The SLM measures already found to exist in the study sites mainly comprised grazing land management technologies and conservation agriculture. Combinations of SLM measures appeared to perform better than applying one type of measure by itself.

Land degradation negatively affected ecosystem services for almost all degraded areas. Provision of ecosystem services – such as production of food, fodder, wood, water, and energy – was most affected in areas of mixed land use, followed by areas of cultivated land and grazing land. High negative

impacts were observed regarding regulation of ecosystem services – such as regulation of water and nutrient flows, carbon sequestration, pollination, and pest control – indicating that these require particular attention when developing and implementing remediation strategies.

SLM measures appeared most effective on cultivated land, but positive impacts from SLM on ecosystem services were also recorded for relatively large areas of forest and grazing land. Overall, there appears to be scope for improving SLM contributions to ecosystem services in cultivated land.

SLM technologies and approaches

There were 38 case studies investigated in the DESIRE project; 30 for SLM technologies and eight for SLM approaches. The physical practices used in the field to control land degradation and enhance productivity – the SLM technologies, in other words – could be divided into five groups: cropping management, water management, cross-slope barriers, grazing land management, and forest management. They addressed all the main types of land degradation. Most of them were applied on cropland, although grazing land is equally important – perhaps even more important in spatial terms – in drylands. Depending on the kind of degradation addressed, agronomic, vegetative, structural, or management measures were used, or some combination of these. Most of the technologies aimed to prevent or mitigate degradation; only a few were described as intended for rehabilitation. This reflected the state of land degradation in the study sites, which had not passed thresholds of extreme loss of productivity or provision of ecosystem services. The main functions of the SLM technologies assessed included their ability to increase infiltration capacity, control runoff, and improve ground cover. Most of the technologies were applied by small-scale land users, a group that is often underestimated regarding investment and innovation, not to mention their role in worldwide agricultural production. Individual and regulated communal land ownership and land use rights facilitated the implementation of SLM, confirming the results of previous studies.

The SLM technologies positively affected biophysical processes relevant for agricultural production and positively affected the ecological services of the land. Water harvesting technologies and more efficient use of irrigated water showed the greatest potential and benefits. Most of the applied technologies appear resilient to expected climatic variations and half of them provide off-site benefits, such as reduced damage to neighbouring fields, public or private infrastructure, and reduced downstream flooding. This opens up the possibility of promoting SLM technologies to protect goods and services by means of reward schemes aimed at farming communities. It also highlights the capacity of SLM technologies to support disaster risk reduction.

Low-cost technologies (mostly below 100 USD/ha) were mainly found in the groups of cropping management and grazing land management, though their maintenance costs can be considerable. The most expensive technologies (2,000–10,000 USD/ha) were related to water management; however, technologies in this group also bear the highest potential for increasing profits and their maintenance costs are usually relatively low, i.e., below 300 USD/ha/year. Analyses showed that nearly half of the land users earned most of their income outside of their farm. All the technologies were found to be profitable in the long run; however, half of them were found to be less profitable, or not profitable at all, in the short run. It was found that land users typically pay one-third of the implementation costs and all of the maintenance costs. This suggests that providing funding for implementation of technologies – e.g., through revolving funds or payments for ecosystem services – could be an effective way of enhancing adoption among land users, since the costs of implementation may make such measures unprofitable in the short run.

SLM approaches are understood as ways and means of supporting introduction, implementation, adaptation, and promotion of SLM technologies. Regarding the SLM approaches studied in the DESIRE project, SLM specialists often made the final decision to implement certain SLM measures; but this was always done in consultation with land users. All the approaches were set up using an existing advisory service system that ensures long-term continuation of approach activities. The approaches were perceived to have impacts on SLM that ranged from moderate to great, and most were found to enhance people's livelihoods, decrease poverty, and generally improve the situation of socially and economically disadvantaged groups. Land users' main reasons for implementing SLM measures were related to expectations of increased production, profitability, and/or payments or subsidies. Environmental consciousness played a minor role. Land users' motivation to implement SLM measures can likely be increased by making them more aware of environmental issues as well as short- and long-term advantages (such as increasing profitability), and enabling them to participate in assessing the benefits of SLM by including them in research.

Policy recommendations

The main policy recommendations to emerge from the DESIRE project and the investigations of SLM options are closely related to the approach presented in this book. The recommendations and the approach emphasise: collaboration of scientists with stakeholders; the need to link local knowledge with the latest technologies emerging from the scientific community, using a structured participatory process with stakeholders; the need to include stakeholder-defined criteria for selecting SLM options; and the benefits of performing standardised assessments using WOCAT tools. The latter could also be used as a tool in the reporting of countries to UNCCD, and thus can contribute directly to the implementation of the UNCCD convention. Policy briefs, fact sheets and key messages are available from the DESIRE Project Harmonised Information System (www.desire-his.eu/en/key-messages).

Above all, the DESIRE project and the SLM case studies documented in this book reveal the many ecological, economic, and social benefits of SLM. These benefits go beyond reducing land degradation and desertification. They also address global concerns about water scarcity, resource use efficiency, energy supply, food security, poverty alleviation, climate change, and biodiversity conservation. As such, investments in SLM appear indispensable and funding from both the private and the public sector is justified, especially on behalf of small-scale land users and marginalised population groups. This book aims to help decision makers and donors in their efforts to invest wisely in the sustainable management of land.

[1] Desertification Mitigation and Remediation of Land, www.desire-project.eu and www.desire-his.eu

[2] World Overview of Conservation Approaches and Technologies, www.wocat.net

[3] The WOCAT/LADA/DESIRE mapping questionnaire (QM), the WOCAT questionnaires for Technologies (QT) and Approaches (QA), and associated databases

Introduction

All over the world, land users are required to maximise the economic and social benefits from the land while fighting against land degradation and desertification. Sustainable Land Management (SLM) is the key answer to these challenges and provides the key theme for this book. Sustainable Land Management (SLM) is the management of land by human societies targeted at improving agricultural productivity, improving livelihoods and improving ecosystems[1].

Sustainable Land Management (SLM) is defined as the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions (WOCAT, 2007).

Current global developments call for a more thoughtful management of our land than ever before. These developments include the increase of the world population, requiring a doubling of the production of food, fodder and biomass for other purposes until 2050, and the increasing scarcity of resources like water, fuel and minerals. We look to the land to provide our food and biomass needs, as well as other resources, but there are clear limits on the amount of additional land and water that can be used for agriculture[2]. At the same time large parts of land in the world are being affected by degradation, as global drivers of change (e.g. climate change, increasing competition for land) interact strongly with local circumstances (e.g. soil fertility, water availability or socio-economic conditions), resulting in often complex scale interactions[3]. This applies particularly to dryland areas, where SLM deserves even greater attention.

The aim of this book is to present options for Sustainable Land Management in Drylands. It is written for land users and practitioners, agricultural specialists and scientists, students and teachers in environmental science, but also for policy makers interested in the potential of SLM strategies to improve productivity, livelihoods and ecosystems in their regions of interest. Finally, interested citizens of both rural and urban areas may find information and inspiration from this book on how to sustainably manage the land that provides benefits for us all.

Land degradation is a complex global environmental problem that can threaten future global food and energy security, water availability, capacities to adapt to and mitigate climate change and biodiversity conservation[4]. As a result, land degradation has the ability to adversely affect millions of livelihoods[5]. Desertification, being land degradation in drylands, is perceived to be one of the major problems that currently face mankind. The UNCCD (United Nations Convention to Combat Desertification), for example, states that one third of the Earth's land surface, along with 250 million people, are directly affected by desertification. Furthermore, 1 billion people in more than 100 countries are reported to be at risk[6].

Desertification is defined by the UNCCD (2007) as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic fluctuations and human activities. Desertification occurs because dryland ecosystems are vulnerable to over-exploitation, inappropriate land use and climate change. Poverty, political instability, deforestation, overgrazing and bad irrigation practices can all undermine the productivity of the land. Desertification is often regarded as a process that progressively increases, and that will ultimately result in a loss of the functions that ecosystems provide, either temporarily (if reversible) or permanently (if not reversible).

Desertification is a very broad term that encompasses all kinds of degradation processes in drylands, such as erosion by water and wind, soil compaction, overgrazing, salinization and forest fires. Furthermore, desertification is a problem that is usually caused by an interplay of different causes, including socio-economic and cultural factors. Desertification is therefore a complex problem that is also highly site-specific in the way in which it manifests itself.

Combatting desertification through SLM, by prevention, mitigation or rehabilitation, is essential to ensure the long-term productivity of inhabited drylands. The UNCCD highlights the importance of both scientific and civic society approaches and promotes action to combat desertification through both local programmes and academic partnerships. Actions must emphasise participation to enable local people

Russia, Anatoli Zeiliguer

[1] Liniger et al., 2011

[2] e.g. Fischer et al., 2001; Rockström et al., 2009

[3] Wilbanks and Kates, 1999

[4] see World Bank, 2008; MA, 2005; Neely et al., 2009; UNCBD, 1992

[5] Pretty and Ward, 2001

[6] UNCCD, 2007

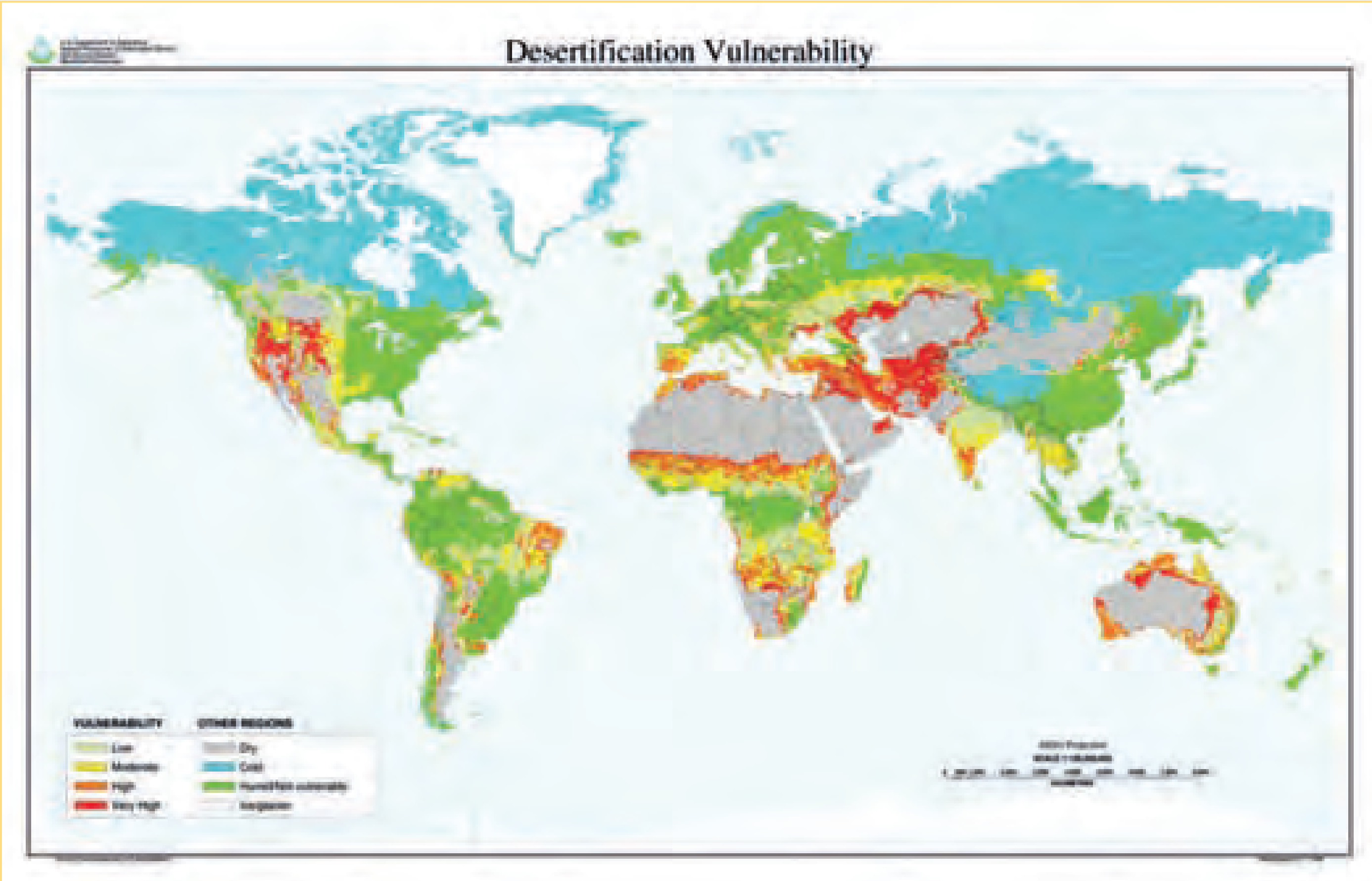

Figure 1: Desertification vulnerability (source: USDA)

and NGOs to reverse land degradation in an environment supported by governments and fully integrated into national policies. What is needed is an approach that combines scientific rigour and accuracy with relevance and sensitivity to local perspectives and context. Conservationists, scientists, authorities, land managers and local communities need to work together towards shared goals. Current management techniques should be adapted or replaced so they are better able to cope with a variable and changing climate, deal with increasing and competing demands and work towards decreasing the risk of land degradation. SLM strategies offer an opportunity to combine the technical, institutional, sociocultural, economic and scientific aspects of land management in response to desertification.

Recent research has generated important data, methodologies and models, which have been instrumental in deepening the understanding of the physical and human causes and effects of land degradation and desertification in Europe and the world (e.g. the Special Issue "Understanding Dryland Degradation Trends" resulting from the First Scientific Conference of the UNCCD)[7]. Many research projects have made 'scientifically based' suggestions and recommendations on ways to mitigate, stop or reverse the process of land degradation. However, the output has tended to be too fragmented for practical policy-making[8]. The EU-funded DESIRE project (2007-2012) tried to overcome these limitations by adopting an integrative approach in which local knowledge, generated from bottom-up, participatory approaches[9], was combined with knowledge gained through more top-down, science-led approaches. The philosophy behind the

Figure 2: Desire study sites; colour of margin indicates dominant desertification process

concept is that local stakeholders know the characteristics of their land and the way to work it, while scientists are able to suggest alternative techniques and evaluate their results. Both groups are then able to support and complement each other.

The main aim of the DESIRE project was to establish promising alternative land use and management strategies based on a close participation of scientists with stakeholder groups in 17 areas affected by desertification, located in 13 countries around the world. Such strategies are referred to as Sustainable Land Management strategies. The 17 selected study sites within the DESIRE projects (Figure 2) all showed individual bio-physical and socio-economic characteristics and desertification processes.

The integrative participatory approach used in DESIRE ensures both the acceptability and feasibility of SLM technologies, and gives them a sound scientific basis for the effectiveness at various scales. DESIRE developed its own methodological approach for this, which is discussed in chapter 1.1 of this book.

Within DESIRE, the WOCAT methodology played a prominent role. WOCAT (World Overview of Conservation Approaches and Technologies, www.wocat.net) is an established global network of SLM specialists. WOCAT's goal is to prevent and reduce land degradation through SLM technologies and their implementation approaches. The network provides tools that allow SLM specialists to identify needs of action and share their valuable knowledge in land management. The tools provided aim to assist these specialists in their search for appropriate SLM technologies and approaches and support them in making decisions, both in the field and at the planning level, as well as when up-scaling identified best practices (www.wocat.net).


Cape Verde, Gudrun Schwilch

[7] Land Degradation & Development, March/April 2011

[8] Engelen, 2003; DESIRE/Drynet/eniD, 2008

[9] (e.g. the Learning for Sustainability approach)

[10] i.e. the WOCAT questionnaires and databases on SLM technologies and approaches and the WOCAT-LADA-DESIRE Mapping questionnaire and database

In DESIRE, WOCAT methods and tools[10] were adapted and used to map the current status of land degradation and conservation and to select strategies that can be used to combat this degradation. The WOCAT questionnaires and databases of SLM technologies and approaches were used to document SLM strategies in a standardised way. This was part of a structured participatory process to identify, assess and select SLM strategies and involved two stakeholder workshops with a period of detailed evaluation and documentation in between. Data collected using the WOCAT questionnaires was entered into the online open-access WOCAT databases. These databases offer search facilities for agricultural advisors, land users and practitioners worldwide to find strategies that might be suitable for their own situation. It should be kept in mind, however, that because of the highly site-specific bio-physical and socio-economic circumstances, any SLM strategy that is selected should be adapted to the local conditions before implementation. In DESIRE, the WOCAT databases as well as the WOCAT questionnaires, completed for each DESIRE study sites during the evaluation period, were used in the selection process. This resulted in a selection of strategies to implement for testing. Thus, the existing WOCAT methodology was adapted and enhanced to make it more suitable as a practical tool in projects that combat degradation and desertification.

A number of SLM technologies and approaches and SLM maps resulted from the application of the 'DESIRE approach' in the 17 study sites. The aim of this book is to present these options for Sustainable Land Management in drylands, and to explain the 'DESIRE approach'. This DESIRE approach can be applied in any project that aims to combat degradation, and has so far been incorporated in publications and initiatives by UNCCD, FAO and GEF.

This book presents:

- Guidelines to set-up and structure land degradation mitigation projects, using the DESIRE project as an example (1.1)
- The potential of using the WOCAT-based methods and tools in such projects (1.1)
- An analysis of the spatial context of SLM (1.2) and the SLM strategies (1.3) applied in the DESIRE project
- Recommendations and policy points based on this analysis (1.4)
- Case studies of implemented SLM technologies and approaches from all DESIRE study sites (2.1)
- Mapping case studies of the spatial occurrence of land degradation and existing SLM practices (2.2)
- DESIRE methodology examples from Eskisehir (Turkey) and the Yan River Basin (China) (2.3)

The book demonstrates that managing land in a sustainable way is possible, also in drylands, and that this is best achieved in a concerted and joint effort of various stakeholders. Future projects and initiatives might learn and benefit from the experiences of the DESIRE project. It is therefore hoped that this book will contribute to increased use of SLM worldwide.


Italy, Gudrun Schwilch


Morocco, Gudrun Schwilch

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China, Hanspeter Liniger

[10] i.e. the WOCAT questionnaires and databases on SLM technologies and approaches and the WOCAT-LADA-DESIRE Mapping questionnaire and database

Part 1

Methodology, analysis and synthesis

Morocco, Gudrun Schwilch

Spain, Erik van den Elsen

1.1 The process of identifying and trialling options for SLM

Identifying and trialling options for sustainable land management – the methodology

As discussed in the introduction, the main aim of this book is to present options for SLM in drylands, which have been identified by the DESIRE project as a result of building on WOCAT methodology. However, before we begin to detail the outputs from DESIRE in detail, this chapter will describe the methodology used within the project.

The DESIRE project has worked to develop a comprehensive methodology in which existing WOCAT[1] and LADA[2] tools have been integrated with a stakeholder learning approach, a decision support system, mapping, trialling and monitoring in the field, scenario modelling and dissemination. The result is a methodological framework that has global relevance whilst remaining adaptable and flexible enough to cater for the variation of local situations. Based on the belief that neither science nor local experimentation alone can lead to sustainable solutions to combat desertification and land degradation processes, the WOCAT methodology is developed on several fundamental principles:

- A wealth of experience in SLM already exists, but has not yet been well enough tapped and shared (WOCAT, 2007). Before envisaging new technical solutions to combat desertification and land degradation processes, therefore, it is worthwhile to look at what is already applied locally.
- The key to success lies in a concerted effort, bringing together local experience and innovation with ecological and technical expertise, as well as taking into consideration local environmental conditions and the related socio-economic, legal and institutional framework. Linking scientific, technical expertise and local knowledge makes it possible to derive a range of alternative options, including current innovations and new or non-local solutions.
- Enhancing applicability, feasibility and ownership of solutions requires mutual learning of all stakeholders involved.

The methodology described in this chapter has been tested in several dryland areas around the world (two examples given in Part 2) and by sharing the lessons learned through this process, we hope the experiences of the DESIRE project can benefit those currently involved in sustainable land management, from local land users and practitioners to national and international policy makers. We also hope the information within this section will be of use to researchers, teachers and students who are looking to study and/or design similar SLM research projects. This first chapter will then outline the methodology used in DESIRE and provide direction to further information for those readers wishing to follow similar processes. Illustrated in Figure 1, the methodological framework will be described in the following five steps:

I. Establishing land degradation and SLM context and sustainability goals;
II. Identifying, evaluating and selecting SLM strategies;
III. Trialling and monitoring SLM strategies;
IV. Up-scaling SLM strategies; and finally
V. Disseminating the information.

I Setting the context

Introduction

Global investments in SLM have been huge in the past century. However, information as to how effective these investments have been is largely unknown. As a result, we still do not have a clear idea of just what condition our land is in and whether the implemented SLM strategies are, or to what extent have been, effective. Hence, before decisions can be made as to how we can best fund future SLM activities, we need to know exactly what we are dealing with:

- Where is land degradation taking place?
- What kind of degradation is taking place and at what intensity?
- How are land users currently addressing the problem? I.e. what sustainable land management practices are currently being used?

Since 1992, WOCAT has been striving to provide answers to these questions. Pulling together a global network of SLM specialists, the programme has put together a wealth of

Turkey, Sanem Açıkalın

[1] World Overview of Technologies and Approaches (www.wocat.org)

[2] Land Degradation Assessment in Dryland Areas (www.fao.org/nr/lada)

Figure 1: Methodological framework of the DESIRE approach.

worldwide information on SLM approaches, SLM technologies, and the areas they apply to. What's more, WOCAT has gathered this information using a standardised and internationally recognised methodology that is easy to understand and apply. This enables all SLM research projects to contribute to, and benefit from, an ever-growing knowledge-base.

Aims and objectives

While maps of soil and land degradation exist at national or regional level, the only global overview so far remains the GLASOD map by ISRIC and UNEP from 1991. Maps on the extent of soil and water conservation or sustainable land management are seriously lacking. As a result, policy makers and implementing institutions cannot have a good spatial overview of their and others' past and ongoing activities. With this in mind, and being driven by the key questions mentioned above, this initial stage of the methodology aims to produce a series of desertification context maps, detailing:

1. current land degradation status;
2. future land degradation risk; and
3. existing sustainable land management strategies.

Mexico, Christian Prat

Greece, Erik van den Elsen

Table 1: DESIRE Study Sites
17 study sites in total (two study sites located in Portugal).

Nr.	Country	Site	Size (km²)	Land use	Degradation
1	Spain	Guadalentin (Rambla de Torrealvilla)	250	Arable (irrigated / non-irrigated), forest, orchards	Erosion, salinisation
2	Portugal	a) Mação b) Góis	400	Mostly forest, some agriculture Shrubland and forest	Wildfires, erosion Wildfires, erosion
3	Italy	Rendina	410	Mainly arable (dry; cereals), olives, forest	Erosion, mass movements, sedimentation
4	Greece	Crete	1000	Widespread olives, shrub and bushland, pasture	Soil erosion, soil and water salinisation, water stress
5	Greece	Nestos	50	Irrigated agriculture, marshes	Salinisation
6	Turkey	Karapinar	150	Irrigated agriculture	Salinisation, groundwater level, wind erosion
7	Turkey	Eskisehir	90	Dryland / irrigated agriculture, pasture	Soil erosion, urbanisation, droughts
8	Morocco	Mamora/Sehoul	400	Decreasing cork oak, increasing agriculture and grazing	Erosion, biological degradation
9	Tunisia	Zeuss-Koutine	900	Rangeland, agriculture	Biological degradation, erosion by wind and water, drought
10	Russia	Djanybek	12370	Grassland, Artificial forest belts	Vegetation degradation, salinisation, erosion by wind and water
11	Russia	Novy-Saratov	29000	Irrigated agriculture	Salinisation, waterlogging
12	China	Loess plateau	7680	Arable farming, cash crops, grass planting and vegetables	Water erosion
13	Botswana	Boteti	34960	Mixed land use, grassland savannah	Vegetation degradation, wind erosion
14	Mexico	Cointzio	650	Cropland, forest, grassland	Soil erosion by water
15	Chile	Secano Interior	9100	Cereals, forest plantations	Soil erosion by water
16	Cape Verde	Ribeira Seca	70	Mainly rainfed agriculture	Soil erosion by water, drought

For more detailed information about DESIRE study sites, see the compilation and synthesis of DESIRE study site descriptions[3].

Methodology

Gaining a clear picture of the desertification context entails five main steps: (i) selecting study sites; (ii) identifying system boundaries and stakeholder priorities; (iii) analysing socio-economic context and drivers of change; (iv) determining current land degradation status, using the WOCAT-LADA-DESIRE Mapping Questionnaire; and (v) determining future land degradation risk, using an indicator survey.

i Select study sites

The selection of study sites will be dependent on a particular project's aims and objectives.

Within the DESIRE project, it was always the strategy to work with study sites in which research had been on-going for several years prior to the project, so that the work of the project could build on previous experience and benefit from existing datasets. However, this was just one of many criteria that resulted in DESIRE selecting 17 study sites distributed across the world from southern Europe, southern America and Africa

Morocco, Erik van den Elsen

[3] Available to download at http://www.desire-his.eu/en/study-site-contexts/desires-study-sites

to Russia and China (see Table 1). All located in semi-arid environments, the sites vary in size from less than 100 km² to several thousand km² and, most importantly, at the time of selection, were each affected by one or more desertification-related problems, including erosion (caused by wind and water), salinisation, vegetation degradation and wild fire.

ii Identify system boundaries and stakeholders' priorities

When the study sites have been selected, it is time to identify the key land use systems that are in place within and around these sites, as well as identifying the key players within those systems. Many of these key players, or stakeholders, will have conflicting views about land management solutions. It is valuable to be aware of any existing or potential conflicts during the planning phase of a project.

Within DESIRE, an inventory of relevant stakeholders in each of the study sites was achieved through a stakeholder mapping exercise. This process involves assessing the "stakes" of relevant groups and individuals and it led to the identification of a variety of key stakeholders for the DESIRE project, including Natural Resource Management (NRM) Institutions, land users, NGOs and policy makers. The variety of stakeholders involved with the DESIRE project is discussed further in the final section of this chapter.

iii Describe socio-cultural, economic, technological, political and environmental context, including drivers of change

To ensure a good understanding of the study site context, drivers and barriers as well as opportunities need to be assessed for each location. The strength of many applied land management practices is that they are well established, traditional systems that have proved to work under the prevailing conditions. However, in a world where change is the only constant, all systems and practices are under increasing pressure from population growth, market pressures, urbanisation, climate change and agricultural intensification. The overall relevance of each of these factors, therefore, must be examined in order to set the desertification context. This stage also includes the examination of policies, which can themselves be important drivers but also influence the impact of other drivers. For example, in the EU context the Common Agriculture Policy reform, and in particular the Water Framework Directive and the possibly upcoming Soil Framework Directive, will have a major influence on the ways to achieve sustainable agriculture in Europe.

Within DESIRE, the study site teams were asked what they considered to be the main desertification drivers in their area and to identify what the impacts of those drivers were. In most of the sites, it was reported that although local and national laws exist, implementation was often ineffective. As a result, it was often the case that conservation laws or policies were not adequately enforced. A lack of cross-sectoral planning and collaboration was also identified as a common problem and although the EU Common Agricultural Policy has led to some positive impacts in some locations, it resulted in the cultivation of unsuitable land in other places.

iv Determine current status, using the WOCAT-LADA-DESIRE mapping questionnaire

The WOCAT-LADA-DESIRE Mapping Questionnaire and online WOCAT-LADA-DESIRE Mapping Database[4] enable the production of a series of maps that illustrate what type of land degradation is taking place, where and why, and what is being done in terms of sustainable land management. The information needed for these maps is collected using the WOCAT-LADA-DESIRE Mapping Questionnaire[5]. Available for anyone to use[6], the questionnaire is completed by a team of local experts familiar with the area, including, where possible, agronomists, soil and water specialists and extension officers.

For each distinctive land use type, the WOCAT-LADA-DESIRE Mapping Questionnaire and Database helps users to evaluate (i) what type of land degradation is happening, where and why, and (ii) what forms of land conservation practices are being used. The steps of this process are as follows:

1. The area to be mapped is divided into distinctive land use systems (LUS).
2. The team gathers the necessary data on land degradation and conservation for each LUS.
3. For each LUS, the type, extent, degree, impact on ecosystem services, direct and indirect causes of degradation, as well as all land conservation practices, are determined.
4. Once collected, the data can be entered in the on-line WOCAT-LADA-DESIRE Mapping Database from which the various maps are generated.

v Determine future risk, using an indicator questionnaire

Desertification and land degradation are complex processes with causes that range from climate change to changes in land use or alterations in environmental legislation. The way in which an area responds to these pressures is determined by the resilience of the landscape (soil, water, vegetation)

Tunisia, Cyprien Hauser

Morocco, Erik van den Elsen

The basic spatial unit of evaluation: The Land Use System (LUS)

The principle of the WOCAT-LADA-DESIRE mapping methodology is that land degradation and SLM are mapped on predefined spatial units. Since land use and land use practices are considered the most influential factors for land degradation, these provide the starting point for the basic unit of evaluation; the Land Use System (LUS)[7].

The LUS units, in combination with administrative units, enable the user to evaluate trends and changes in time of the land degradation and conservation practices applied.

In the DESIRE project, the original LUS defining procedure from the LADA project was adapted to be applicable to small study sites. The procedure includes:

a) Definition of the main land use type, e.g. Cropland, Grazing land, Forest/woodland, Mixed, or Other.
b) Subdivision of main land use types, for example cropland into annual and perennial cropping and grazing into extensive or intensive grazing.
c) Further subdivisions based on physiographic or geomorphologic criteria, administrative units or socio-economic criteria.

and the local economy. As has been pointed out by the UNCCD[8], indicators can be valuable tools to help measure this resilience, and, as a result, can be useful in assessing how vulnerable an area is to desertification and how effective the actions being taken to mitigate that risk are. By using an appropriate number of indicators, complex processes such as soil erosion, soil salinization, and overgrazing may be effectively described without using complex mathematical expressions or models that require an excessive amount of data[9].

"An environmental indicator is a parameter, which provides information about the situation or trends in the state of environment, in the human activities that affect or are affected by the environment, or about relationships among such variables (USA EPA, 1995; EEA, 1998)."

Land degradation indicators are a sub-set of environmental indicators focusing on a particular trend in state of the land and associated human activities.

Within DESIRE, an Expert System has been developed to calculate desertification risk for various desertification processes, using a limited number of indicators for each process. Data on these indicators can be collected using the indicator questionnaire developed in the DESIRE project[10], and entered in the Expert System[11] to inspect the desertification risk of specific dryland areas. Because of the distribution of DESIRE study sites in dryland areas around the world, the expert system can be applied globally in other dryland areas.

For a more detailed description of the indicators identified in each of the DESIRE study sites and further reading on the expert system put in place to implement those indicators, see DESIRE report 2.1.1 and 2.2.2[12]. The process of developing the DESIRE Expert System is described in the box below.

DESIRE Expert System

To develop the Expert System, the DESIRE project:

a) Defined a practical number of indicators based on a shortlist of indicators available from literature, previous and ongoing research programmes.
b) Documented and developed a harmonised database of indicators used by different parties in the selected study areas, by conducting field surveys on prevailing land use types subject to desertification.
c) Compared and linked indicators and land management practices among the study sites.
d) Selected the most relevant indicators based on a statistical analysis of the harmonised database of indicators.
e) Developed equations to calculate desertification risk for different degradation processes in main land use categories, based on the indicator database.
f) Developed an expert system to calculate desertification risk using the developed equations.

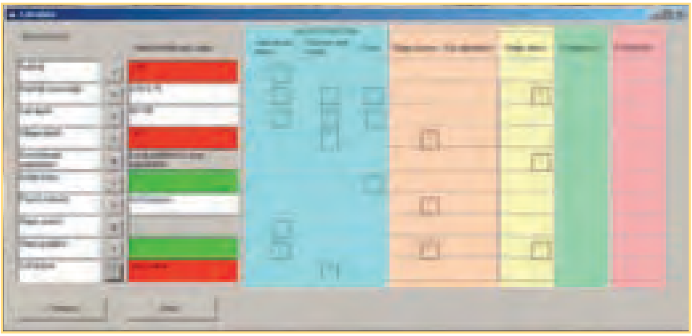

Figure 2: The DESIRE expert system using indicators for assessing desertification risk.

Morocco, Erik van den Elsen

[4] http://www.wocat.net/en/knowledge-base/slm-mapping.html

[5] For more information on this, see Liniger et al., 2008.

[6] The questionnaire can be downloaded at http://www.wocat.net/fileadmin/user_upload/documents/QM/MapQuest_V1.pdf

[7] For more information, see Nachtergaele et al, 2007

[8] United Nations Convention to Combat Desertification

[9] For further information about indictors and their uses, EEA, 1998

[10] Downloadable from http://tinyurl.com/bmgr65p

[11] Presented on the DESIRE online Harmonised Information System and downloadable at http://www.desire-his.eu/en/assessment-with-indicators/desertification-risk-assessment

[12] These are available to download at: http://www.desire-his.eu/

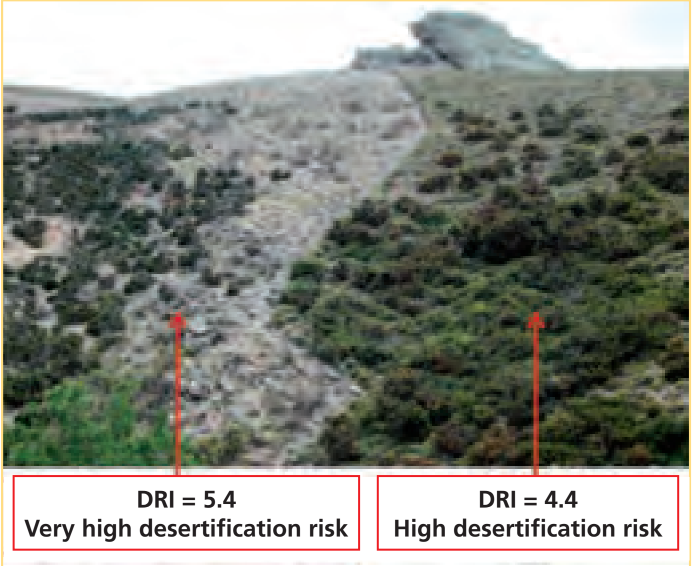

Figure 3: Landscapes in one landuse type with different desertification risk.

vi Collating all the information from steps I-V, determine current land degradation status, existing soil-water conservation, and future land degradation risk

The result of the first methodological step described above is a series of maps that document land degradation, as well as conservation status. In addition, the information gathered by the indicator questionnaire enables the related causes and impacts of land degradation to be assessed. Collating this information provides an informative picture of the distribution and characteristics of land degradation and conservation activities for a district, a province, a country, a region and, ultimately, world-wide. It is from this point that a three-part procedure for the identification, assessment and selection of SLM strategies can be carried out.

II Identifying, evaluating and selecting SLM strategies

Identifying SLM strategies, using a participatory learning process

Introduction

Land owners and farmers have been managing their land for centuries and, as a result, they often have a wealth of SLM knowledge and experience, as well as demonstrating, in some cases, truly innovative approaches to land management challenges. Before envisaging new technical solutions to combat desertification and land degradation, therefore, it is of real value to examine what is already applied locally. With this mind, it makes sense to listen to those people who know the land best when looking to identify existing SLM strategies. In other words, it is time to learn from the people who work on and manage the land on a day-to-day basis.

Aims and objectives

The aim at this stage is to work with stakeholders to identify promising SLM strategies for further assessment. Using a stakeholder workshop and taking a collective learning approach to this stage enables stakeholders to identify potential strategies and, as a result, fosters a sense of participation and input into the research process. In the case of the DESIRE project, a stakeholder workshop in the local context was seen as a vital step towards building a common vision of what can and needs to be done to achieve more sustainable land management.

Within DESIRE, the workshop programme followed a logical and consecutive sequence of specific exercises, each with its own objectives, method, procedure, and expected results[13]. Overall, the workshop objectives were as follows:

1. To initiate a mutual learning process among local and external participants by sharing experience and jointly reflecting on current and potential problems and solutions regarding land degradation and desertification.
2. To create a common understanding of problems, potentials and opportunities of the respective study site by integrating external and internal perceptions.
3. To strengthen trust and collaboration among stakeholders.
4. To identify existing and new strategies to prevent or mitigate land degradation and desertification.
5. To select strategies for further evaluation and documentation with the WOCAT methodology.


China, Hanspeter Liniger


Spain, Gudrun Schwilch

The outcome of this initial stakeholder workshop should be a set of SLM strategies (either existing or potential) that have been selected by the relevant stakeholders. It is fundamental to the success of stakeholder workshops such as these that the group is heterogeneous with regard to age, gender, ethnicity and activities related to land use. All those invited to participate in the DESIRE stakeholder workshops had experience in and knowledge about the specific rural environment, however, they came from a variety of backgrounds and expertise, from local farmers to regional and national decision-makers.

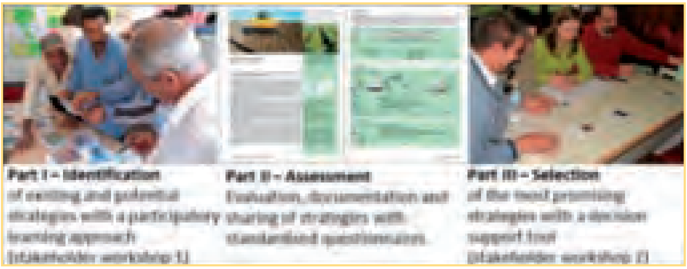

Figure 4: 3-part methodology.

Evaluating existing Sustainable Land Management strategies using WOCAT questionnaires

Introduction

Following the initial stakeholder workshop, the suggested strategies need to be documented and evaluated in a structured and standardised way to enable information to be shared as easily as possible with other land managers around the world.

Aims and objectives

The aim of this stage is to evaluate the effectiveness of the identified SLM strategies, both in terms of the technical measures applied in the field, i.e. SLM technologies, and the ways and means of support that help to introduce, implement, adapt, and promote those technologies, i.e. SLM approaches. Thus, the objectives of this stage are:

1. to document and evaluate each identified locally applied technology and approach in a structured and standardised way,
2. to guarantee a certain level of data quality through a review and quality assurance process, and
3. to enter this information into the WOCAT database in order to share it with other actors involved in SLM around the globe.

Methodology

To evaluate identified SLM strategies, the WOCAT programme has developed comprehensive questionnaires and an online database. The use of questionnaires follows a structured and standardised process which helps to better understand the reasons behind successful sustainable land management technologies and approaches. The corresponding database serves as a basis for knowledge exchange between stakeholders in different sites and with other land managers around the world.

The WOCAT questionnaires

The WOCAT questionnaires allow teams of researchers and specialists to document and evaluate together with land users all relevant aspects of technical measures, as well as implementation approaches. Furthermore, all information is gathered, stored and assessed using a standardised format. As a result, using this widely accepted WOCAT methodology enables global sharing of best practices.

This standardised evaluation involves the use of two questionnaires[14], one on SLM technologies (QT) and the other on SLM approaches (QA). Together the corresponding technology and approach describe a sustainable land management strategy within a selected area. SLM technologies are the physical practices in the field, like mulching. An SLM approach includes the ways and means of support that help to introduce, implement, adapt, and promote SLM technologies on the ground.

For ***SLM technologies***, the questionnaire addresses the specifications of the technology (purpose, classification, design and costs) and the natural and human environment where it is used. It also includes an analysis of the benefits, advantages and disadvantages, economic impacts, and acceptance and adoption of the technology. Impacts are approximated through simple scoring, but supplemented by data where available. For ***SLM approaches***, questions focus on objectives, operations, participation by land users, financing, and direct and indirect subsidies. Analysis of the approach described involves monitoring and evaluation methods, as well as an impact analysis.

Morocco, Gudrun Schwilch

[13] For detailed information about these exercises, see http://www.desire-his.eu/en/potential-strategies/part-1-identifying-strategies-thematicmenu-177

[14] Both questionnaires can be found on the WOCAT website at http://www.wocat.net/en/methods/case-study-assessment-qtqa/questionnaires.html.

Table 2 provides a more detailed description of SLM technologies and approaches.

Table 2: A description of SLM technologies and SLM approaches

A SLM technology	A SLM approach
These are the physical practices in the field that control land degradation and enhance productivity in the field. They are: ▪ agronomic (e.g. intercropping, contour cultivation, mulching), ▪ vegetative (e.g. tree planting, hedge barriers, grass strips), ▪ structural (e.g. graded banks or bunds, level bench terrace), ▪ management measures (e.g. land use change, area closure, rotational grazing). Combinations of above measures which are complementary and thus enhance each other are part of a Technology.	The associated SLM approaches are the ways and means of support that help to introduce, implement, adapt, and promote those technologies on the ground. An SLM approach involves: ▪ All participants (policy-makers, administrators, experts, technicians, land users, i.e. actors at all levels); ▪ inputs and means (financial, material, legislative, etc.); and ▪ know-how (technical, scientific, practical). An approach may include different levels of intervention, from the individual farm, through the community level, the extension / advisory system, the regional or national administration, or the policy level, to the international framework. Besides conservation activities introduced through projects or programmes, indigenous conservation measures and spontaneous adoptions or adaptations of technologies are also included.

Selecting sustainable land management strategies; the decision support process

Aims and objectives

The aim of this third and final stage of the selection process is to select promising (existing and potential) SLM strategies for field testing in the study sites. Taking the options identified and selected in the previous two phases along with additional options from the global WOCAT database, this stage involves stakeholders working together to jointly select the best strategies that will then be tested in the field.

This stage uses a second stakeholder workshop, which builds on the analysis and discussions made in the first one. The main aim of this process is to jointly select one or two SLM options to be tested in the selected study site. The second workshop, therefore, has the following objectives:

1. Select possible implementation options from a basket of options, including those originating from the study area and those available in the online WOCAT databases on SLM technologies and approaches[15];
2. compare, score and rank these options;
3. negotiate the best option for implementation; and finally
4. decide upon one or two SLM strategies for implementation.

Methodology

The selection of the most promising SLM option for implementation is complex and requires the stakeholders to carefully consider both the costs and benefits for man and ecosystem. To guide the workshop participants through the decision-making process and allow them to negotiate the best option(s) in a structured way, the methodology applied in this stage consists of three main elements: (i) the WOCAT database is used to choose the options or strategies of land conservation; (ii) Decision Support System (DSS) software is used to support the single steps of the evaluation and decision-making process and, finally, (iii) a participatory approach guides and leads workshop participants through the process of evaluation and decision-making.

To demonstrate how a decision is reached using the participatory workshop approach, see the step-by-step guide (Table 3).

The WOCAT databases on SLM technologies and approaches

For each of the objectives identified at the beginning of the workshop, a number of options need to be selected and listed. These options are based on the locally applied and evaluated strategies as well as on worldwide documented experiences, all of them included in the WOCAT databases of SLM technologies and approaches. These databases contain a full range of different case studies documented from all over the world. The searching and retrieving of options from the WOCAT databases entails going through a series of key questions and using a predefined 'search-by-criteria' form to find the most suitable technologies and approaches. To ensure that the full variety of technologies and approaches are available for selection from the WOCAT databases, all


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Table 3: Step-by-step: Reaching a decision

Steps	Objectives
Step 1: Review and adjustment of objectives	▪ To recall and refresh main discussions and results from the first stakeholder workshop. ▪ To decide on which objectives to focus on for the selection of options that will be implemented later.
Step 2: Identification of options	• To identify with the help of the WOCAT database a range of options (technologies and approaches) that fit the selected objectives. • To visualise the potential options.
Step 3: Identification of relevant criteria for evaluation	• To identify and agree on a set of 9-12 criteria (ecological, economic, and socio-cultural) per objective, relevant for the local context, along which the different options can be evaluated.
Step 4: Scoring the options	• To assess for each option, to which extent it fulfils the different criteria identified in step 3, i.e. to assess the options by the criteria.
Step 5: Creating a hierarchy and ranking criteria	• To organise criteria in a hierarchical order.
Step 6: Analysis and interpretation	• To visualise the relative merits of the different options. • To interpret the results.
Step 7: Prioritising of options – negotiation and decision making	• To find a final agreement on which option should be selected for test-implementation in the study site.
Step 8: Embedding into the overall strategy and seeking a commitment	• To refine the overall strategy and to ensure that the options selected for test-implementation fit in and framework conditions are considered. • To get a certain commitment of participants to support the test-implementation process.
Workshop evaluation	• To evaluate contents, methodology, and results of the workshop.

local solutions put forward in the first stakeholder workshop should be documented and evaluated with the WOCAT questionnaires and entered into the WOCAT databases before this second stakeholder workshop.

The WOCAT databases act as a basket of diverse options and ideas, which can be used as a model for the development of a context specific version but should not be confused with a blueprint solution. Biophysical and socio-economic conditions vary so much between sites that the options from the WOCAT databases must be assessed and reflected, and where necessary adapted to local circumstances, such as to local plant species, slope conditions or market mechanisms.

The Decision Support Tool

A comparative selection and decision support tool is applied during the second stakeholder workshop to support the negotiation process. The tool allows a better appreciation and negotiation of the various SLM strategies, and objective evaluation through scoring of options with regard to a list of pre-defined criteria.

Facilitated by the workshop moderator, participants conduct a multi-criteria evaluation to rank existing and potential SLM technologies and/or approaches for field trials. This involves stakeholders identifying and weighing relevant criteria (e.g. technical requirements, costs and benefits of implementation, social acceptability, etc.) and taking into account the technical, bio-physical, socio-cultural, economic and institutional dimensions. The only purpose of the Decision Support Tool is to calculate what participants evaluate in the course of the different working steps, and to visualise it. The decision support software is used in the stakeholder workshop, but many steps are done on paper and without a computer. Within the DESIRE project, the open-source software 'Facilitator'[16] proved to be most suitable for the envisaged purpose, mainly because it is simple and adaptable to almost any situation requiring negotiation and decision by a group of stakeholders.

Summary

Overall, the step-by-step process for the identification, assessment and selection of SLM options described above is fairly easy to apply and, when done properly, helps to successfully facilitate joint decision-making processes among stakeholders. As described, this stage has, at its core, three key elements: the WOCAT databases on SLM technologies and approaches, the Decision Support Tool and participatory facilitation. What is most valuable about the combination of the three key elements is that it makes the stakeholders work together from the very beginning to understand and evaluate the SLM options. Each stakeholder group has an equal say in determining the criteria that they will use to assess each SLM option and in doing so, they not only learn about SLM options, but also learn from each other. They are forced to consider each other's positions and opinions, before entering into negotiations to come to an acceptable

Morocco, Gudrun Schwilch

[15] The WOCAT databases on SLM technologies and approaches can be accessed on http://www.wocat.net/en/knowledge-base/technologiesapproaches.html

[16] Heilman et al., 2002

decision. This leads to solutions being selected that are not only widely accepted, but also financially feasible. In addition, the process creates a sense of ownership of the implemented choices.

III Trialling and monitoring selected SLM strategies

Introduction

The question, "how well does a strategy work?" is at the heart of this stage because in spite of decades of research and experience, it is not an easy question to answer. Although there is a wealth of SLM knowledge and experience, the fact is that the world is changing rapidly and old technologies and approaches need to be adapted or new ones designed to keep up with the pressures of climate change, resource scarcity and population growth. Also, technologies selected from the WOCAT database that have not yet been implemented before in a specific area, should be tested in order to prove effectiveness in that specific setting. Simply described, this step of the methodology is where the effectiveness of the SLM strategies, selected by stakeholders during the workshops, is tested at a number of study sites round the world.

Aims and objectives

As described above, the main aims of this stage are to trial and monitor the SLM technologies and approaches selected by the stakeholders in the preceding workshop activities.

The effectiveness of a particular strategy needs to be tested against two goals:
1. The expectancy of the land users, in general farmers, pastoralists or foresters, who have to implement the SLM measures. The goal of this particular stakeholder group is generally a direct improvement of their yield and/or security, or reductions in the risk of crop/grazing failure, which they expect to happen within the lifecycle of the project.
2. The effects on the environment, and mitigation of desertification processes. This is often the primary goal of the environmental scientists involved, although many stakeholders recognise the negative impact of desertification processes and also wish to improve this in the long run.

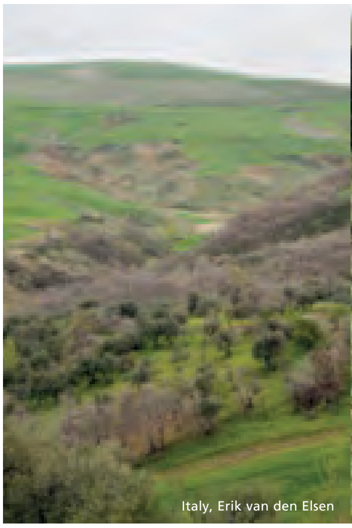
Methodology

This step of the methodology involves running a series of comparative field trials for several years. The step-by-step process to carry this out can be described in three stages:

i Design phase

In order to have a structure to a number of experiments on different study sites and to facilitate comparison between the sites, a Site Implementation Plan (SIP) was used within the DESIRE project. The SIP is a summary of the situation on the monitoring locations, followed by a practical implementation of the SLM technologies and/or approaches chosen by stakeholders and a detailed monitoring activity plan, divided into several categories. This plan should be comprehensible on its own, without many references to other project documents, so that it can be understood by 'outsiders' and provide a concise overview of activities.

Within DESIRE, each SIP had the following sections:
1. General: Location of the monitoring plots.
2. Summary: A brief overview of the problems at this particular location and the SLM technologies chosen. This is based on the site descriptions and information from the outcome of methodological step II.
3. Location description, including a brief outline of the environmental setting: A description of geomorphology, soil types, relief, climate, and photographs of the field location.
4. Information about the stakeholder(s) involved.
5. Land use and management, for example crops, rotation, tillage practices, irrigation, fertilizer use, grazing practices, forestry practices.
6. Conservation measures and experimental setup: A short description of SLM technologies, experimental setup, plot layout, situation map/sketch.
7. Monitoring activities:
   a. Climate/rainfall monitoring details
   b. One time measurements (of relatively slowly varying environmental properties, like topography)
   c. Repeated visual monitoring of environmental properties that vary of time, supported by digital photography (soil cover, structure, tillage activities, erosion traces)
   d. Repeated measurements of environmental properties that vary over time (e.g. instrumental monitoring and logging), and selected indicators.
   e. Stakeholder activities (e.g. tillage activities)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Spain, Erik van den Elsen

8. Yield assessment or assessment of other returns (quantity, quality) and a general stakeholder appraisal.

To assist the design of the experiments, the DESIRE project compiled a manual of field measuring and monitoring methods for on-site effects of SLM technologies. Provided in the manual is an overview of currently available methods, techniques and instruments[17].

ii Implementation and Monitoring phase

After collecting the background data, each study site can begin implementing the selected SLM strategies. During the implementation practical adaptations can be made to better fit the circumstances. However, this should always be done in discussion with the stakeholders. During this time, study sites are monitored closely and all information is recorded[18]. Within DESIRE, each site reported regularly based on the variables and situations described in the SIP.

iii Analysis

To ensure a standardised approach to comparing experiment results both within and between study sites, this stage of the DESIRE methodology uses part of the WOCAT Technologies Questionnaire (QT), described in detail in Step II of this chapter.

Firstly, the monitoring results are analysed and set in a climatic context. A scientific analysis of the experimental results is carried out, followed by an interpretation of the results that translates them into terms of performance of the SLM technology or approach. It is at this stage that the WOCAT QT questionnaire is used to evaluate all results in a standardised manner. Secondly, the information gathered from the scientific reports and WOCAT QT questionnaire is used to compare results both within and across study sites, enabling the identification of common denominators. Finally, the results are translated to define "good land management practices" and advise both land users and local government on how to integrate the SLM measures in their annual farming plans.

Furthermore, the information gathered at this stage can also be used to evaluate the use of indicators in monitoring. Applying technologies and/or approaches to a piece of land, such as happens as part of this methodological step, can result in changes to identified indicators. Many indicators remain unaffected by the strategies, but some will change (e.g. plant cover could change). Combining the knowledge gained at this stage with the information developed as part of the indicator work in Step I, we can calculate whether applying strategies results in a change of the risk for desertification.

Summary

These field trials take place over several years and so persistent and accurate recording is essential throughout this period to ensure effective and realistic outcomes. We hope that lessons learned and documents developed within the DESIRE project can go some way to help those readers planning to implement similar field trials. For more detailed information on trialling and monitoring SLM strategies, please visit the DESIRE Harmonised Information System (HIS)[19].

After concentrating with this step of the methodology at the plot scale, the next section considers testing SLM technologies and approaches at a larger scale.

IV Up-scaling SLM strategies

Introduction

Even when promising SLM strategies have been tested in field experiments, there remain many challenges to developing general recommendations for their use. Firstly, experimental conditions during field trials will always be limited and, as a result, cannot reflect the variable conditions within a region. For example, rains may have been so plentiful during the trial period that water conservation did not boost yields. Secondly, the time it takes for strategies to develop full effectiveness and deliver their full range of benefits is longer than they can be tested during the usual lifespan of a research project. For example, build up of soil organic matter after changing tillage methods or crop rotations is a slow process, and long-term yield increases will not have been observed. Finally, policy and decision makers would like to know whether a technology or approach performs across a range of conditions before supporting its implementation. Apart from differences in environmental conditions and the time it takes to develop full benefits, the investment costs and access to markets are important factors influencing the viability of an SLM strategy.

The challenge then is to evaluate the likely environmental effects of adopting different SLM strategies at a regional scale and assess their financial viability.

Morocco, Gudrun Schwilch

[17]"Field measuring and monitoring methods for on-site effects of soil and water conservation measures", by Jetten et al., 2008, available for download on the HIS at http://tinyurl.com/c6hqc8v

[18]For more information on the monitoring methods used within the DESIRE project, see deliverable 4.2.1, available for download at http://www.desire-his.eu/

[19]Details of the field trials in each study site can be found at www.desire-his.eu/en/implementing-field-trials/field-experiments

Aims and objectives

This penultimate step of the methodology has several main objectives:

1. Identify the likely environmental effects of the proposed SLM strategies.
2. Evaluate the financial viability of the selected SLM strategies.
3. Assess how different policy incentives might influence the uptake of strategies, and what the wider economic impacts of such policies might be.
4. Come to a conclusion as to what SLM strategies should be implemented where to achieve desertification policy targets at least cost.

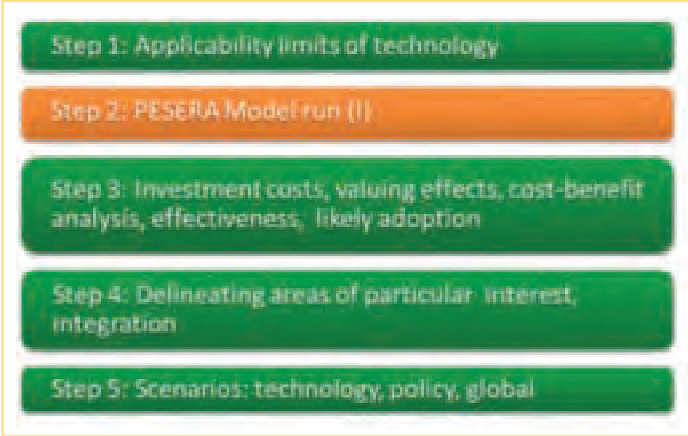

Figure 5: WB5 approach to modelling with PESERA/DESMICE.

Methodology

There are two phases to this methodological step. For the first stage, models are used as a tool to work with the environmental and socio-economic data. The information and outputs from this modelling is then presented, in the second stage, to stakeholders during a third and final workshop.

At the first stage, models are used to evaluate (i) the environmental and economic effects of the SLM strategies selected by stakeholders at both field and regional scales; (ii) potential policy scenarios; and (iii) global scenarios, for example about climate change and food security.

Within the DESIRE project, two interlinked modelling approaches were developed and applied[20]:

1. A **biophysical model**[21] was used to investigate the likely environmental effects of the selected SLM options. This model was an extension of the PESERA model, adapted to consider a wide range of SLM options and processes, for example forest fires and grazing. Adapted to each study site, the model was developed to closely reflect the indicators and land degradation drivers identified at earlier methodological steps. Model outputs were then used to look at the likely regional biophysical effects of different SLM options that had previously been trialled in study areas at a local (usually field) scale, to help formulate extension and policy recommendations.

2. The **DESMICE** (Desertification Mitigation Cost Effectiveness) model was used to evaluate the related socio-economic effects. This model was newly developed within the DESIRE project to scale up the economic assessment of SLM strategies from field to regional scale. To do this, it uses a spatially-explicit cost-benefit analysis. Taking the SLM strategies selected in stakeholder workshops in each study site as a starting point, DESMICE establishes how costs and value generated by those strategies change based on environmental conditions and things like distance to markets. Using the combination of biophysical and socio-economic modelling, it is possible to determine the field conditions in which different SLM strategies are likely to be most cost-effective and adoptable. Furthermore, DESMICE output can be tailored to stakeholder needs: from a land manager's perspective, it demonstrates spatially where each promising technology is likely to perform most efficiently; from a policy makers' perspective, analyses can be made to see how different policies might affect the viability of different strategies across a region, or help policy makers identify what environmental targets can be satisfied at what cost. Finally, DESMICE can be used to assess the cost-benefit effects of SLM strategies under global scenarios, e.g. to select the SLM technologies with the highest mitigating effect on land degradation, by comparing the costs and productivity the area would have for different SLM technologies.

At the second stage of this methodological step, a third and final stakeholder workshop is held to present and discuss the combined results from the models and field trials. Following a similar methodology as the preceding workshops (described in step II of this chapter), this participatory process enables stakeholders to make a final selection of what technologies they consider to be worthwhile for dissemination, based on a combination of environmental, social and economic considerations. The information and stakeholder feedback gathered at this stage can go some way to

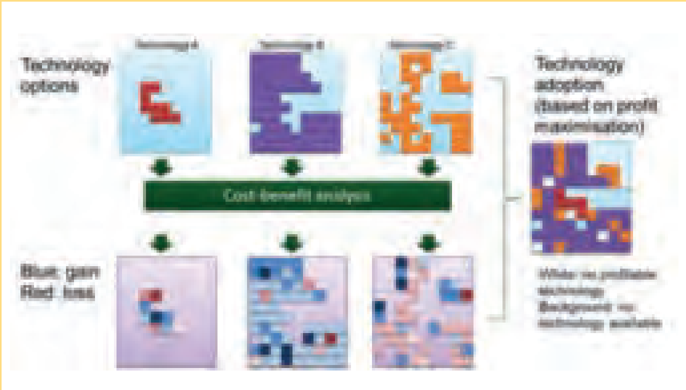

Figure 6: Cost benefit analysis in DESMICE.

formulating recommendations for extension and policy. If fed specifically to regional and/or national level policy makers, the hope is that they will create the boundary conditions (legislation, subsidies etc) that will enable stakeholders to actually implement the selected technologies.

V Dissemination

Introduction

In order for any research to be implemented, it needs to be communicated to the right people, in the right way, at the right time. Any effective research project, therefore, requires an effective communication strategy to ensure research outcomes lead to effective actions. From the very start of the DESIRE project, making sure the key messages were communicated to a wide range of stakeholders was an important part of the process. As a result, the project worked to address groups and individuals at many different levels, from land users and teachers, to policy makers at local to national and global levels.

Aims and objectives

The aim of the DESIRE project was to involve local people in choosing, trialling and evaluating technologies and approaches to combat desertification. As a result, communication and dissemination were at the heart of the research process. The main objectives of this dissemination stage for DESIRE, therefore, were;
1. to disseminate research outcomes to all relevant stakeholders, and
2. to develop a group of researchers who are well trained in research dissemination.

Methodology

In its simplest form, this step of the methodology involves four main stages;

i Identifying the range of audiences that communication and dissemination products must reach

Within DESIRE, a stakeholder was identified as anyone who would like to know more about sustainable land use in their local area or region. Lists of all relevant stakeholders were made for each of the project's study sites. These lists generally included land users, land owners, community-based organisations, government officials, local and national administrators, NGOs, UNCCD, researchers and scientists. The variety of stakeholders involved with DESIRE is demonstrated in lists for particular study sites that include firemen, tourist institutes, unions, local and national media, as well as local education institutions and youth committees, and including teachers and school children.

For many following SLM projects, the relevant stakeholders will be similar to those involved with the DESIRE project. However, carrying out a comprehensive stakeholder analysis process at the beginning of any research project ensures that all the relevant key players are identified. For further information about stakeholder analysis and management, see the articles in the Further Reading section at the end of this chapter.

ii Tailor the communication materials to the identified audiences

When we transfer knowledge, it will be translated by the recipient based on their experiences and opinions. So it is essential to consider how they will engage with the material. Although it is unrealistic to attempt to produce communication outputs for all stakeholder groups individually, material can be provided at different levels of complexity. For example, at the most complex level, a researcher would write a scientific paper using scientific language, whilst at the simplest level, an illustration or poster could be used to communicate with a less literate audience. Within SLM projects, there are many levels of complexity that need to be acknowledged and catered for.

iii Make the dissemination materials available for the relevant audiences in the most appropriate way

It is often the case that research projects do not have sufficient funding to print and distribute a comprehensive range

Morocco, Erik van den Elsen

[20] For more details on these models and their use, please see deliverable 5.4.2, available to download at http://www.desire-his.eu/, or the model descriptions on www.desire-his.eu/en/regional-remediation-strategies/model-descriptions

[21] This model is described in detail in Deliverable 5.1.2 "Improved Process Descriptions in the PESERA Model", available to download as above.

Figure 7: The DESIRE Project has focussed on promoting the value of participatory collaboration between researchers and stakeholders, and providing information for a wide range of audiences in appropriate languages.

of material widely, so using an online information hub is often an effective, and achievable, solution.

Within the DESIRE project, the whole story of research is presented within the Harmonised Information System (HIS, www.desire-his.eu). This system is easy to access and uses mainly non-scientific language. To make the HIS easy to dip in and out of, the project information is presented through each study site and/or the series of project research themes. Key messages and recommendations are highlighted so that they can be easily accessed by land users, land owners and policy makers, as appropriate. Information is often presented in simple, pictorial poster formats, and video clips. Where there is written information, it is mostly available in multiple languages, and if not, there is also a facility to use Google automatic translate.


Turkey, Gudrun Schwilch


Portugal, Gudrun Schwilch

For those who do not have access to the internet, non-scientific summaries and explanations related to the research have been compiled into booklets, leaflets and briefing notes. These are all stored on the HIS and can be printed off and distributed by the project team or users outside DESIRE, including Agricultural Extension Officers. Apart from these summaries, the HIS also stores all other dissemination products that deal with DESIRE, such as newspaper articles, television broadcasts and a film that was specifically made for DESIRE. For those who do have access to the internet, social media outlets, such as Twitter, provide an additional communication pathway to new and varied audiences. DESIRE announces new publications and items of interest regularly through email networks, email subscriber lists and international newsletters related to desertification.

DESIRE also paid specific attention to dissemination to policy makers. This included talks with local policy makers, as well as attending high level UNCCD and other political meetings. Spreading the DESIRE message at international policy level was assisted by two NGOs that were members of the DESIRE consortium.

iv Provide dissemination training to all members of the project team

This involves training a research team to (i) identify the range of stakeholder groups; (ii) identify the complexity of information required; and (iii) identify the ideal formats for the information that needs to be communicated, including planning timetables to put these methods into action. For example, team members learn when to distribute leaflets, show DVDs or put on a community event or exhibition[22] to ensure optimal impact. Timing can be especially important for dissemination at (international) policy levels, as for these levels there may be windows of opportunity during which specific messages about (global) political urgencies can be delivered.

Summary

The results of DESIRE demonstrate the multiple benefits of investing in an effective dissemination strategy and, hopefully, provide some of the materials and templates necessary to help other research projects do the same. A key output from the DESIRE dissemination work has been a comprehensive manual of communication and dissemination. Supported by further practical advice and a series of PowerPoint presentations, the manual aims to provide guidelines about how to continue sharing knowledge and building networks with stakeholders and to provide ideas about how to effectively communicate or "disseminate" project outputs (results, messages and products) to all kinds of stakeholders, inside and outside the research project. Originally assembled to address dissemination issues being encountered specifically within the DESIRE project, a version of this manual for more general use is now available for download.

Figure 8: The on-line Harmonised Information System (HIS) (www.desire-his.eu) provides information in non-scientific language. On this example page the aims and procedures of the WOCAT Workshop 2 to select SLM strategies are explained. The HIS menus are designed to follow both the succession of research themes, and information for each individual study site.

Conclusion

The methodological approach described in this chapter incorporates multiple knowledge sources and types (including land manager perspectives) from local to national and international scales. In doing so, it aims to provide outputs for policy-makers and land managers that have the potential to enhance the sustainability of land management in drylands, from the field scale to the region, and to national and international levels.

China, Erik van den Elsen

Morocco, Hanspeter Liniger

[22] For more information regarding team member dissemination training, see the Dissemination section of the HIS; http://www.desire-his.eu/

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Morocco, Gudrun Schwilch

China, Hanspeter Liniger

1.2 Analysis of degradation and SLM maps

Introduction

The mapping of land degradation phenomena and their control measures originates from the aim of WOCAT[1] to improve the Global Assessment of Soil Degradation (GLASOD)[2]. WOCAT was also the first to provide a spatial view of the effectiveness of Sustainable Land Management SLM in response to this land degradation. By collaborating with the LADA[3] and DESIRE[4] projects, WOCAT has been able to provide a scale-independent method to map land degradation and conservation for predefined spatial units based on land use, which is the basis for assessing land degradation and conservation.

In this chapter, the WOCAT mapping methodology and the outputs from the process will be described in detail.

The WOCAT-LADA-DESIRE Mapping Method

Maps of degradation and conservation properties provide a powerful tool to obtain a spatial overview of land degradation and conservation in a country, a region, or worldwide. The WOCAT mapping methodology employs a mapping questionnaire and database[5].

The WOCAT-LADA-DESIRE Mapping Questionnaire (QM) complements the information provided by the individual case studies on SLM Technologies (QT) and Approaches (QA), described in chapter 1.3. The Mapping Questionnaire evaluates what type of land degradation is happening where, as well as assessing the response to land degradation in terms of SLM. Within the DESIRE project, the information obtained through the mapping questionnaire for the DESIRE study sites was entered in the online Mapping Database. The accompanying map viewer allows the user to inspect various aspects of land degradation and conservation for each site.

The mapping method consists of a spatial assessment of individual map units on the predefined land use map (base map). This is carried out with the use of a questionnaire. The hierarchical system for defining Land Use Systems, originally developed by the LADA project, was used to construct the base maps for each study site[6]. The LUS system, originally developed to map regions and countries, was adapted to be also applicable to small DESIRE study sites. The steps to define the base map units are explained in chapter 1.1 (Box 1). The starting point for mapping degradation and conservation is land use and land management, since these are considered the major factors that influence land degradation and conservation.

Information on land degradation and conservation is collected for each unit on the base map according to the characteristics listed in Table 1. Following the principles of all WOCAT questionnaires, the collected data are largely qualitative, based on expert opinion and consultation of land users. This permits a rapid and general spatial assessment of land degradation and SLM, including information on the causes and impacts of degradation and SLM on ecosystem services.

Table 1: Characteristics of land degradation and SLM documented in the WOCAT-LADA-DESIRE Mapping Questionnaire and Database.

Degradation assessed for each Mapping unit	SLM assessed for each Mapping unit
Type	Name / Group / Measure
Extent (area)	Extent (area)
Degree	Effectiveness
Impact on ecosystem services (type and level)	Impact on ecosystem services (type and level)
Direct causes	
Indirect causes	Degradation type addressed
Recommendation	

Land use

Within the DESIRE study sites, the areas of cultivated land, grazing land and mixed land are approximately the same size covering 175.000 - 200.000 ha. Forestry covers about 100.000 ha, mainly in the two Portugese sites and Mexico. Grazing and mixed land are predominant in Botswana

Greece, Erik van den Elsen

[1] World Overview of Conservation Approaches and Technologies (http://www.wocat.net/)

[2] Oldeman et al., 1990

[3] Land Degradation Assessment in Drylands (http://www.fao.org./nr/lada)

[4] Desertification mitigation and remediation of land (http://www.desire-project.eu/)

[5] The mapping questionnaire and database can be accessed on http://www.wocat.net/en/knowledge-base/slm-mapping.html

[6] Nachtergaele and Petri, 2008

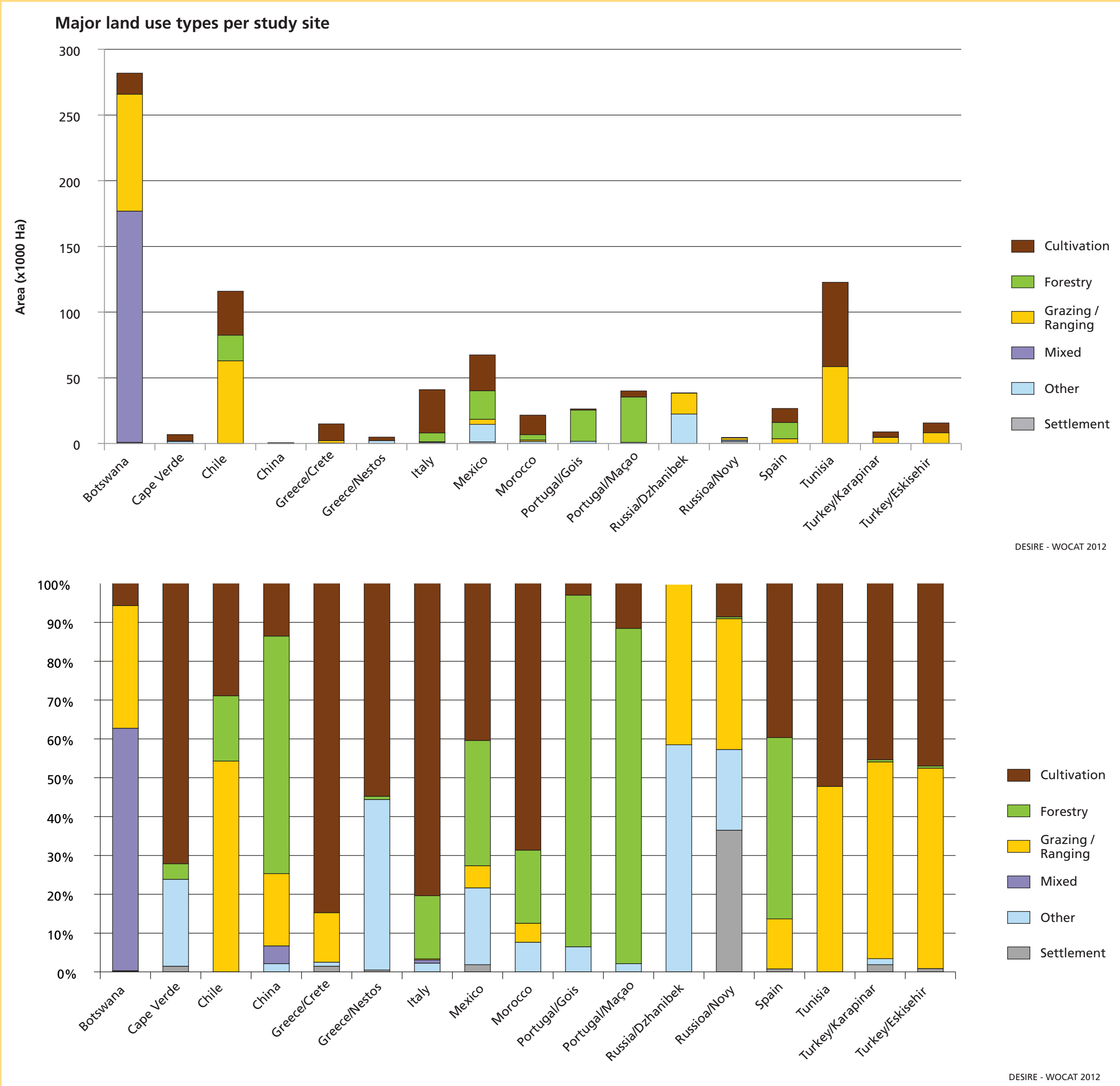

Figure1: Study site size and land use types (top) and distribution of major land use types per site (bottom).

(which covers by far the largest area in absolute terms), Russia, the two Turkish sites and Tunisia. Cultivated land and grazing/ranging are the dominant major land use types in relative terms (Figure 1).

Historical trends in the extent and intensity of land use can help us predict future land degradation and, as a result, may enable the implementation of relevant SLM strategies. The increase or decrease in area with the major land use types was assessed over the past 10 years (Figure 2). Box 1 shows the classifications used to describe the changes.

Box 1 Classification of trends in areal coverage of major land use type.

2: area coverage is rapidly increasing in size; i.e. with > 10% of the land use type area/10 years
1: area coverage is slowly increasing in size, i.e. with < 10% of the land use type area/10 years
0: area coverage remains stable
-1: area coverage is slowly decreasing in size, i.e. with < 10% of the land use type area/10 years
-2: area coverage is rapidly decreasing in size, i.e. > 10% of that specific land use type area/10 years

As can be seen in Figure 2, the area covered by the major land use types in the majority of the study sites has remained stable over the past 10 years. Cultivated land, forestry and grazing land have expanded, but decreases in areal coverage were also recorded for grazing and range land. At the same time, due to increased numbers of livestock in the study sites in Botswana, Crete and Tunisia over the last ten years, the land use intensity of grazing and ranging has increased in about 20% of the grazing land.

Mapping land degradation

Degradation types, extent and degree

A spatial design of SLM activities requires a spatial overview of the types, extent and causes of actual land degradation phenomena. The WOCAT-LADA-DESIRE mapping method distinguishes six major types of land degradation, each with several subtypes:

B: Biological degradation, e.g. reduction of vegetation cover (Bc), Quality and species composition / diversity decline (Bs), Detrimental effects of fires (Bf), Quantity / biomass decline (Bq)

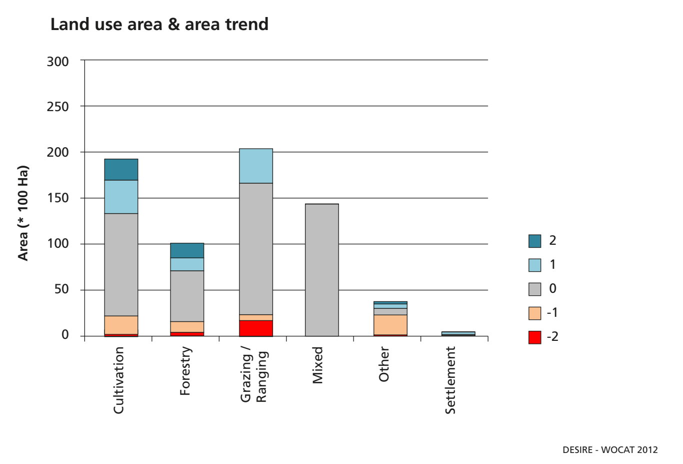

Figure 2: Trend in area of major land use types for all study sites, from rapidly decreasing in size (-2) to rapidly increasing in size (+2). See Box 1 for a detailed explanation of trend indices.

C: Chemical soil deterioration, e.g. soil fertility decline/loss of organic matter (Cn), Salinization (Cs)
E: Soil erosion by wind, mainly loss of topsoil (Et)
H: Water degradation, e.g. Aridification (Ha), Change in quantity of surface water (Hs), Change in groundwater / aquifer level (Hg)
P: Physical soil deterioration, e.g. compaction (Pc) and Sealing/Crusting (Pk)
W: Soil erosion by water, e.g. sheet erosion (Wt), gully erosion (Wg), mass movements (Wm) or off-site effects like flooding and siltation (Wo)

Figure 3 shows the distribution of major degradation types within the DESIRE study sites. Water erosion (W), in particular sheet erosion by water (Wt), is the most commonly reported type of degradation, occuring in all sites except Botswana, Greece (Nestos site), Russia (Novy site) and Turkey (Karapinar site). In about 70% of the degraded area various types of degradation occur, and therefore have a combined effect (e.g. erosion and soil nutrient decline) (only the major type is presented in Figure 3 and 4).

Figure 4 shows that the largest surfaces of degraded land occur in cultivated land and land under mixed use, covering 89% and 100% of these areas respectively.

Soil erosion by water (W) or wind (E) are important forms of land degradation in all land use types, and is most important in cultivated land. In cultivated land, grazing land and mixed

Cape Verde, Hanspeter Liniger

Mexico, Christian Prat

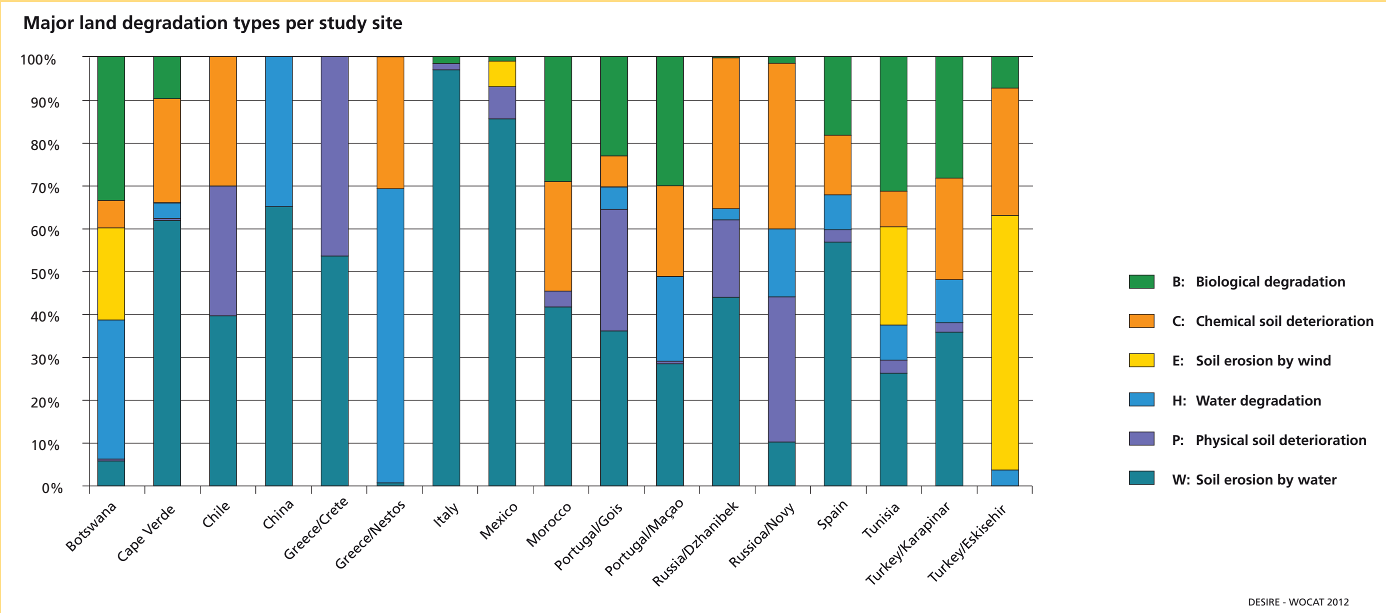

Figure 3: Major land degradation types per study site.

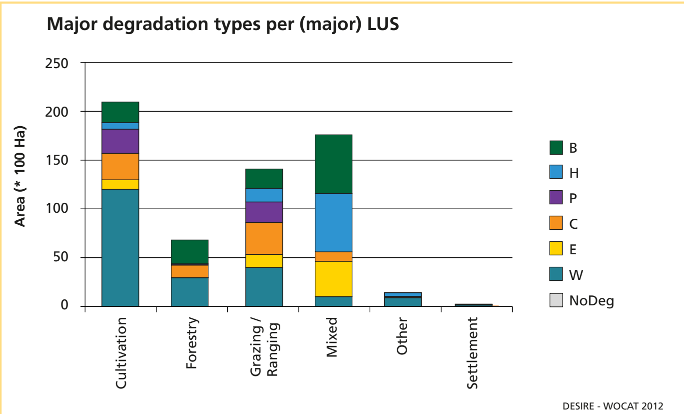

Figure 4: Major land degradation types per land use type. See Figure 3 for explanation of symbols.

land all types of land degradation occur. In forest mainly water erosion, chemical and biological degradation were recorded. Due to its vegetation cover and the absence of mechanical agricultural operations wind erosion and physical soil deterioration are less likely to occur here.

The degree of degradation refers to the intensity of the land degradation process. For example, in the case of soil erosion it is the amount of soil washed or blown away. The larger part of degraded land in the DESIRE study sites was recorded as being degraded at moderate to strong degrees (Figure 5, Figure 6). Extreme forms, i.e. land degradation beyond restoration were only recorded for the study sites in Spain and Turkey. For the Turkish site the degradation refers to wind erosion and soil fertility decline in the Karapinar site, and to several degradation types in the Eskişehir site (soil fertility decline, water erosion, biological degradation, water degradation).

Rate of land degradation

While the degree of land degradation indicates the state of degradation at the moment of observation, the degradation rate indicates the trend of degradation over a recent period of time (about 10 years). A severely degraded area may be stable at present (i.e. low rate, no trend towards further degradation), whereas an area that is currently only slightly degraded may be characterised by a high degradation rate, or a trend towards rapid further deterioration. Identifying the rate of degradation is not only useful to prioritise areas for SLM interventions, but also to reveal areas where land health is improving due to SLM.

Land degradation appeared to have increased moderately to rapidly in most of the DESIRE study sites, in particular in the Italian and Portugese (Góis) sites, Tunisia, Botswana, Turkey

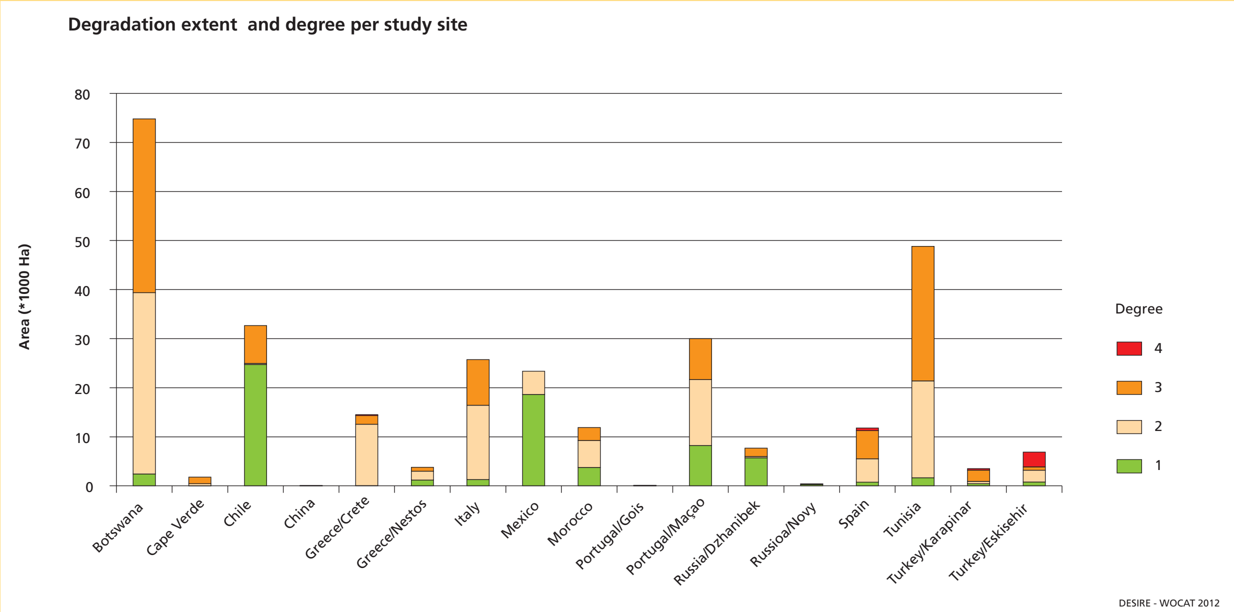

Figure 5: Total areal extent of degradation types for all study sites, and degree of degradation. 1: light (some indications, repaired with minor efforts), 2: moderate (apparent, full rehabilitation possible with considerable efforts), 3: strong (evident signs, very difficult to restore within reasonable time) and 4: extreme (degradation beyond restoration) degree of degradation.

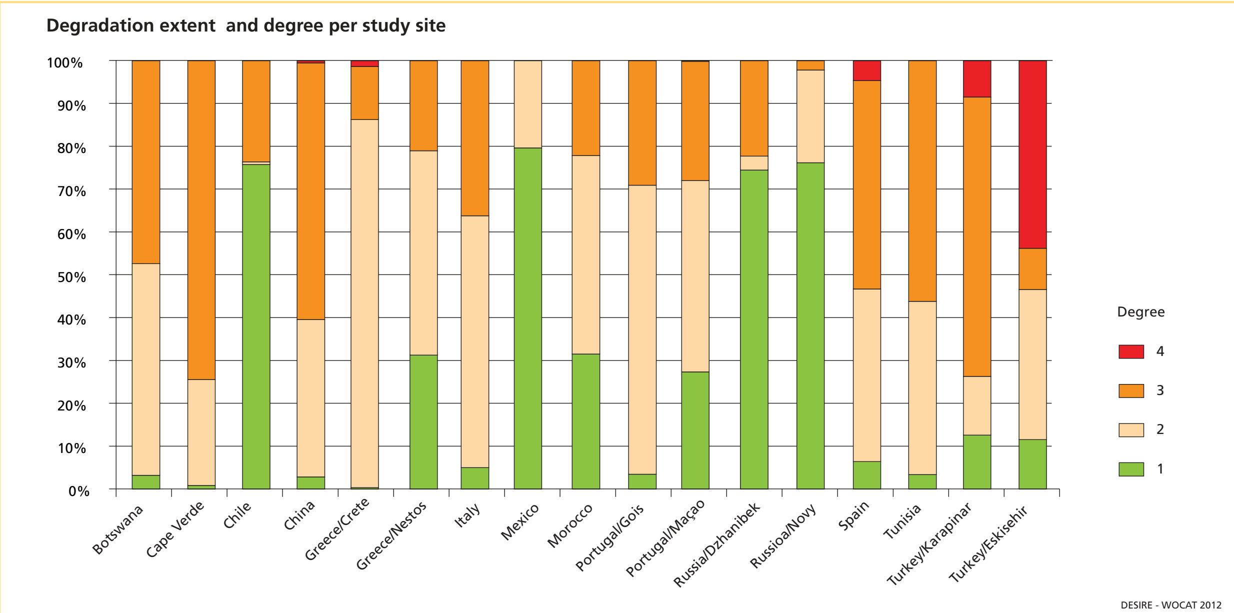

Figure 6: Relative extent of degradation degree per total degredation area of each study site. 1: light, 2: moderate, 3: strong and 4: extreme degree of degradation.

Cape Verde, Hanspeter Liniger

Greece, Hanspeter Liniger

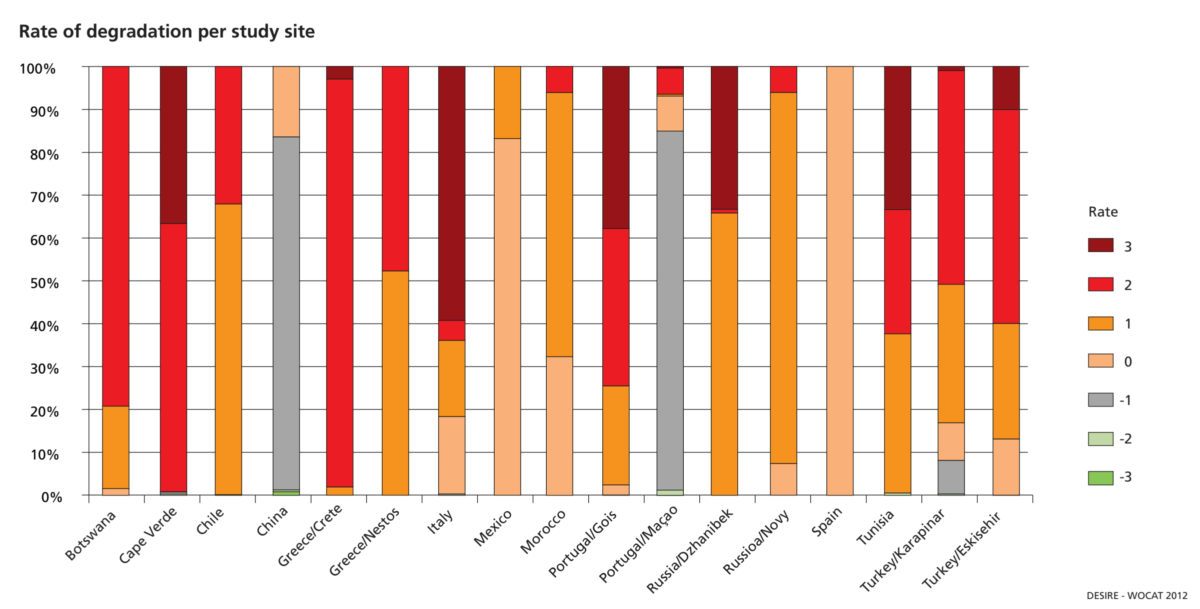

Figure 7: Relative (areal) extent of the rate of degradation per study site. 3: rapidly increasing degradation, 2: moderately increasing degradation, 1: slowly increasing degradation, 0: no change in degradation, 1: slowly decreasing degradation, 2: moderately decreasing degradation, -3: rapidly decreasing degradation.

(both sites) and Greece (Crete site) (Figure 7). These sites exhibit moderate to strong land degradation. Degradation is increasing predominantly in mixed land use (45% of the land with increasing degradation), followed by cultivated land (31%) and grazing land (24%). For some sites slowly decreasing degradation was reported (China and Portugal (Mação)) as a result of SLM efforts already in place. This is confirmed by the mean effectiveness of conservation measures reported for these sites.

Direct causes of degradation

Various human activities and natural causes may lead to land degradation. The emphasis in the degradation assessment is on human-induced degradation, but sometimes degradation due to natural causes also requires measures to be taken. Natural causes include, for example, droughts, topography or flash floods, although these in turn may be influenced by human activities, as explained for the indirect causes in chapter 1.4.4.

Figure 8 shows that inappropriate soil management is by far the most common cause of land degradation. It is responsible for about half of the degraded area in the DESIRE study sites. Inappropriate soil management includes, for example,

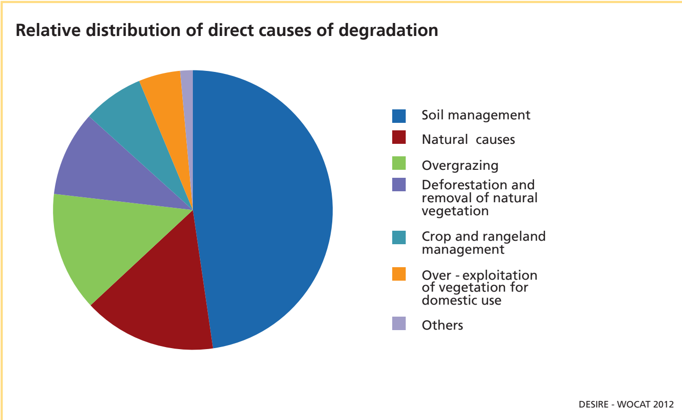

Figure 8: Relative distribution of direct causes of land degradation in the DESIRE study sites, expressed in the share of the degraded area.

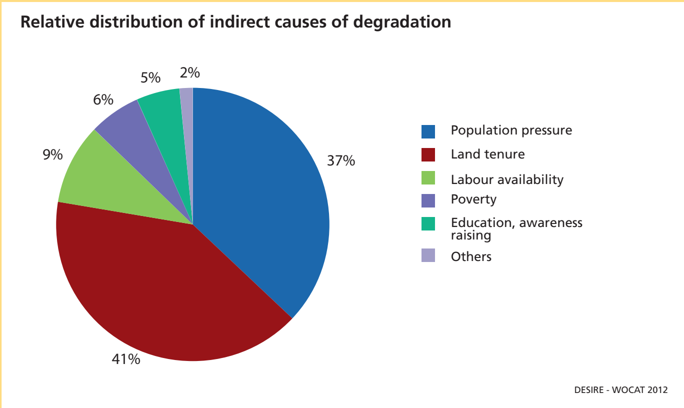

Figure 9: Relative distribution of indirect causes of land degradation in the DESIRE study sites, expressed as the share of the degraded area.

cultivation of highly unsuitable or vulnerable soils, the missing or insufficient soil conservation or erosion control measures, or the use of heavy machinery. In contrast, crop or rangeland management refers to the improper management of annual, perennial (e.g. grass) shrub and tree crops, like the reduction of plant cover and residues for burning[7].

In more than 50% of the mapping units (covering almost 70% of the degraded area in the total area of DESIRE study sites), more than one causative factor is responsible for land degradation. In 20% of the degraded area five or more direct causes of land degradation apply. This illustrates the complexity of land degradation, and highlights the need for SLM technologies to address multiple forms of land degradation.

Indirect causes of land degradation

Indirect causes of land degradation include socio-economic factors. Population pressure and land tenure were reported as the two most important indirect drivers of land degradation in the DESIRE study sites (Figure 9). This is confirmed in the literature[8]. In most study sites a combination of indirect causes of land degradation was reported; with three or more causes accounting for 28% of the degraded area. The most frequent combination of indirect causes included population pressure, land tenure and poverty, combined with governance, institutions and politics (14% of the degraded area).

Impact of land degradation on ecosystem services

Ecosystem services are defined as the benefits people derive from ecosystems[9]. These include the production of food and biomass, water and energy (provisioning services), regulating services like the prevention of soil erosion and the regulation of water flows, cultural services like information for education, and habitat services (e.g. the maintenance of genetic diversity).

The same degree of land degradation can have different impacts on ecosystem services in different places. For example, the removal of a 5 cm layer of soil may have a greater impact on the crop or fodder production on a poor shallow soil than on a deep, fertile soil. In WOCAT-LADA-DESIRE Mapping, the impact of land degradation on ecosystem services is compared to situations without land degradation at present (e.g. areas that are already well conserved).

The WOCAT-LADA-DESIRE Mapping Method regroups the ecosystem services into the following categories[10]:
P Productive services (provisioning services)
E Ecological services (regulating and habitat services)
S Socio-cultural services (cultural services)

Land degradation was reported to have negative impacts on all categories of ecosystem services in the DESIRE study sites (Figure 10). Negative impacts on ecosystem services were reported for 94% of the degraded area, of mostly moderate degree, and referring to more than one category of ecosystem services in 35% of the degraded area. Negative impacts on ecosystem services were most widespread in cultivated land (36% of the degraded area), followed by grazing land and mixed land use (20 and 19%).

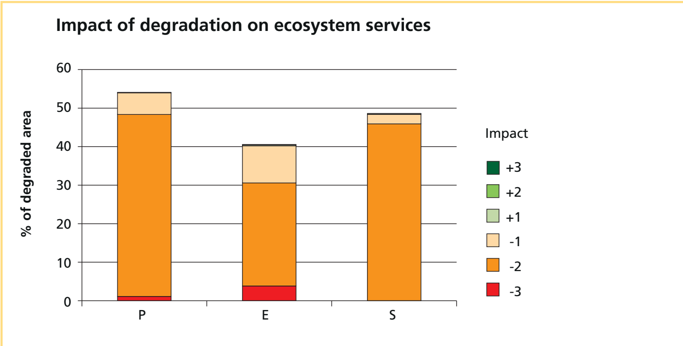

Figure 10: Extent of impact of land degradation on ecosystem services (ES) in all DESIRE study sites. P: production services, E: ecological services, S: socio-cultural services. Negative numbers: negative contributions to changes in ES (-3: >50%, -2: 10-50%; -1: 0-10%); positive numbers: positive contributions to changes in ES (3: >50%, 2: 10-50%; 1: 0-10%).

Greece, Hanspeter Liniger

[7] Liniger et al., 2008

[8] e.g. Cotula, 2011; Flintan, 2011; Liniger et al., 2011

[9] www.maweb.org; TEEB, 2010

[10] TEEB (2010) groups in between brackets

Production services were affected over the largest part of the degraded area (Figure 10). Degraded land with negative impacts on uniquely production services (not on ecological or socio-cultural services) covers 20% of the total degraded area in the study sites. Of this land, mixed land use was most affected (49%), followed by cultivated land (24%) and grazing land (19%). In forest the largest part of the degraded area experiences negative impacts from land degradation on all categories of ecosystem services.

The largest part of the area under high negative impact on ecosystem services (-3) was observed for regulating ecosystem services, indicating that these require specific attention in the process of developing and implementing remediation strategies against land degradation. Negative impacts on regulating ecosystem services were reported for equally large areas in cultivated land, grazing land and forest.

Sustainable Land Management: dominant measures and groups, extent, effectiveness and trend

Mapping conservation and SLM

As shown in Table 1, the land conservation mapping is analogous to the land degradation mapping. The mapping of conservation measures includes the identification of the SLM

Box 2 Conservation groups in the WOCAT-LADA-DESIRE Mapping Method.

Conservation technologies are clustered into groups which have names familiar to most SLM specialists and rural development specialists. The technology groups cover the main types of existing soil and water conservation systems.

CA: Conservation agriculture / mulching
NM: Manuring / composting / nutrient management
RO: Rotational system / shifting cultivation / fallow / slash and burn
VS: Vegetative strips / cover
AF: Agroforestry
AP: Afforestation and forest protection
RH: Gully control / rehabilitation
TR: Terraces
GR: Grazing land management
WH: Water harvesting
SA: Groundwater / salinity regulation / water use efficiency
WQ: Water quality improvements
SD: Sand dune stabilization
CB: Coastal bank protection
PR: Protection against natural hazards
SC: Storm water control, road runoff
WM: Waste management
CO: Conservation of natural biodiversity
OT: Other

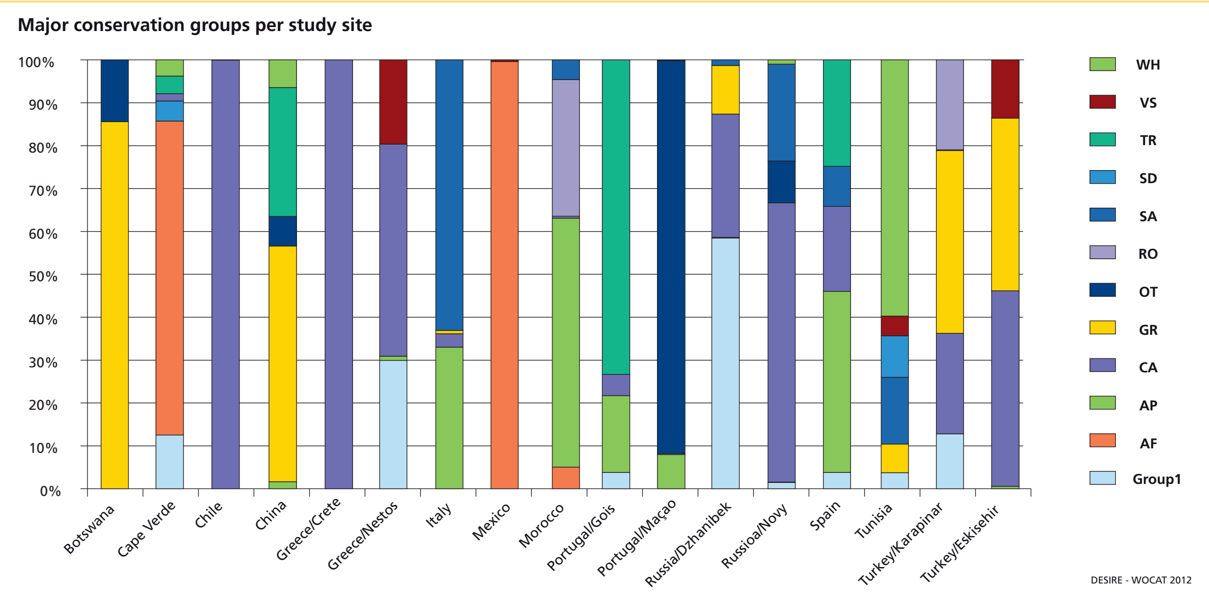

Figure 11: Relative distribution of major Conservation Groups per study site. Legend: see Box 2. Group 1 includes all groups not specified in the legend.

technologies applied in the field, including their combinations. Technologies are grouped into broader 'conservation groups' (Box 2). The extent of the technologies is assessed, along with their (trend of) effectiveness, and the impact on ecosystem services.

SLM technologies in the groups of 'Grazing land management' and 'Conservation agriculture and mulching' are the most widely applied in the DESIRE study sites (GR and CA in Figure 11). Grazing land management is dominant in grazing land and mixed land use (Figure 13). The largest variety in conservation groups is found in cultivated land (Figure 13). The variety in conservation groups recorded for the different study sites appeared to correspond to the variety in types of land degradation. For example, in the Moroccan study site, rotational systems and conservation agriculture and mulching were applied in response to soil erosion by water (loss of topsoil/surface erosion) on cropland, while afforestation and forest protection were practiced in areas with biological degradation (reduction of the vegetation cover and/or biomass decline) (Figure 12).

Effectiveness of implemented SLM measures

The effectiveness of SLM measures is defined in the WOCAT-LADA-DESIRE Mapping Method in terms of how much the

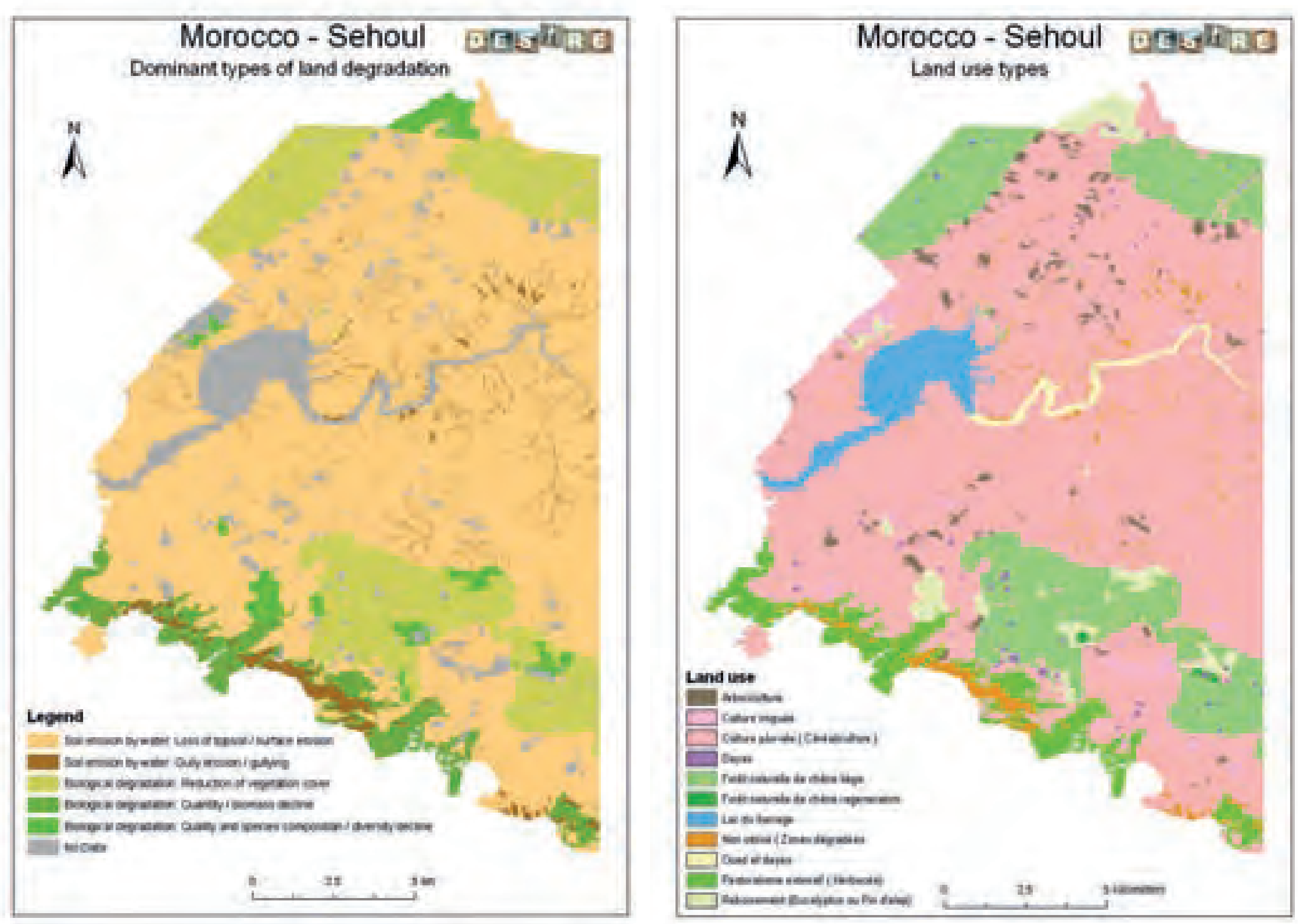

Figure 12: Types of dominant land degradation and conservation groups in the Moroccan study site. Source: research team of the Sehoul study site in Morocco from University Mohammed V, Chaire UNESCO-GN, Morocco.

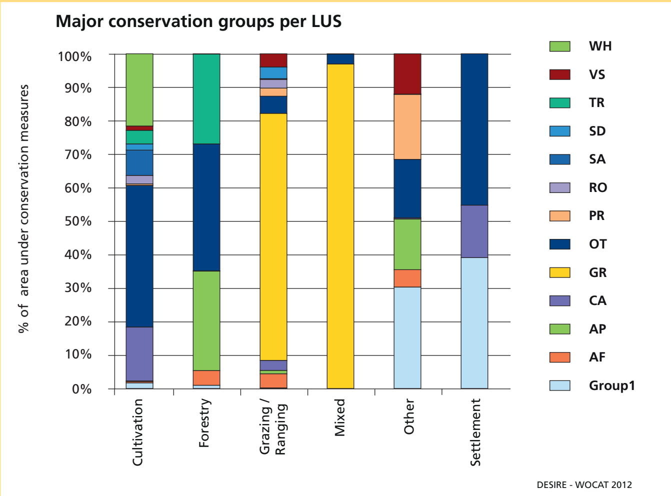

Figure 13: Relative distribution of major Conservation Groups per land use type. Legend: see Box 2. Group 1 includes all groups not specified in the legend.

Box 3 Classification of effectiveness of conservation measures in the WOCAT-LADA-DESIRE Mapping Method.

4: **Very high:** the measures not only control the land degradation problems appropriately, but even improve the situation compared to the situation before degradation occurred. For example, soil loss is less than the natural rate of soil formation, while infiltration rate and/or water retention capacity of the soil are increased, as well as soil fertility; only maintenance of the measures is needed. Either the measures have strongly improved water availability and quality (addressing water degradation), or vegetation cover and habitats have been highly improved (addressing biological degradation).

3: **High:** the measures control the land degradation problems appropriately. For example, soil loss does not greatly exceed the natural rate of soil formation, while infiltration rate and water retention capacity of the soil are sustained, as well as soil fertility; only maintenance of the measures is needed. Concerning water and vegetation degradation, the measures are able to stop further deterioration, but improvements are slow.

2: **Moderate:** the measures are acceptable for the given situations. However, loss of soil, nutrients, and water retention capacity exceeds the natural or optimal (as with "high") situation. Besides maintenance, additional inputs are required to reach a "high" standard. Regarding water and vegetation degradation, the measures only slow down the degradation process, but are not sufficient.

1: **Low:** the measures need local adaptation and improvement in order to reduce land degradation to acceptable limits. Much additional effort is needed to reach a "high" standard.

measures reduce the degree of degradation, or how well they prevent degradation (Box 3). SLM measures appeared to be most effective in cultivated land: high to very high effectiveness was reported in cultivated land over 20% of the land under SLM measures, compared to only 2 and 4% of the land under respectively forest and grazing. For most conservation groups applied in the DESIRE study sites the effectiveness is moderate to high (Figure 14). Water harvesting and groundwater salinity regulation appear to be highly effective technologies for the areas concerned.

The conservation efforts reported do not necessarily correspond directly with the degradation occurrences in the same mapping unit: areas with no degradation may have this status because of effective conservation, or conversely strong degradation occurs because of lacking conservation. For example, in the Goís study site in Portugal, land degradation in the form of soil erosion and degradation of the forest was found in 80-100% of map units where no conservation measures had been implemented (Figure 16).

The effectiveness of conservation technologies differs considerably between the study sites (Figure 15). Highly effective conservation technologies over the entire area of application were reported for Tunisia, but far less effective technologies for Italy and Mexico. The techniques applied in Tunisia are ancient and have a long record of development and experimentation. The sites in Italy and Mexico experience severe soil erosion by water, which is aggravated by land levelling (Italy), and inadequately managed by the conservation measures applied (agroforestry in Mexico and sod seeding, no tillage, fallow and cover crops in Italy).

Conservation measures

The WOCAT framework distinguishes four categories of conservation measures:

1. Agronomic (.g. mulching)
2. Vegetative (e.g. contour grass strips)
3. Structural (e.g. check dams)
4. Management (e.g. resting of land).

A conservation measure is a component of an SLM technology, which may consist of a combination of several conservation measures. For instance, a terracing system is a SLM technology which typically comprises structural measures – the terrace riser, bed and a drainage ditch – often combined

Spain, Erik van den Elsen

Cape Verde, Hanspeter Liniger

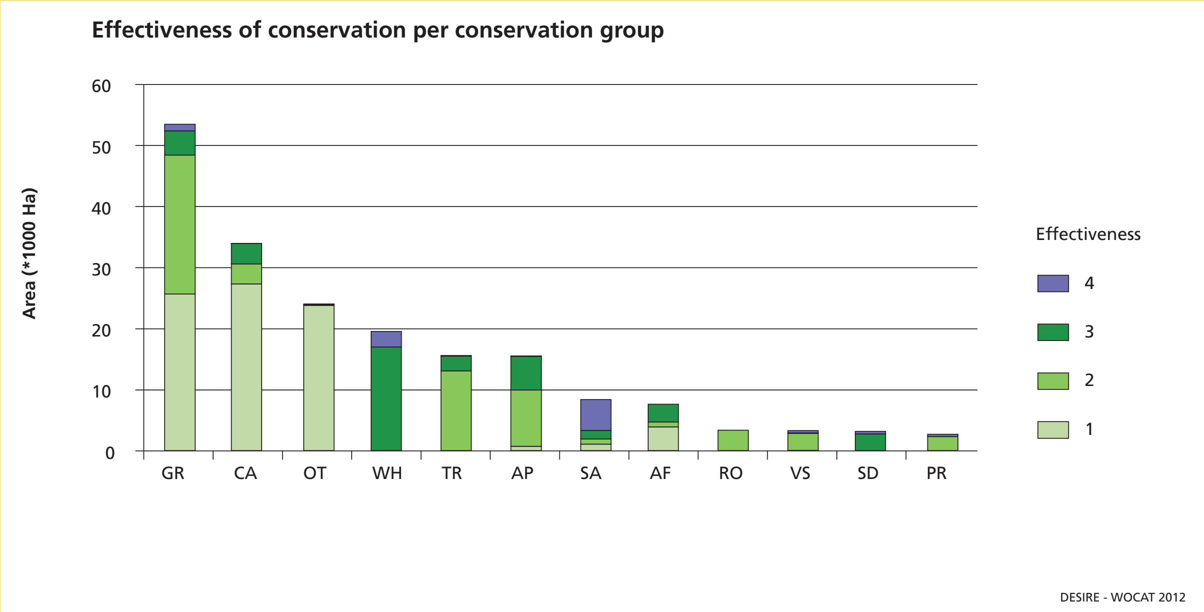

Figure 14: Extent and effectiveness of major conservation groups in the DESIRE study sites. Legend for conservation groups in Box 2; for effectiveness in Box 3.

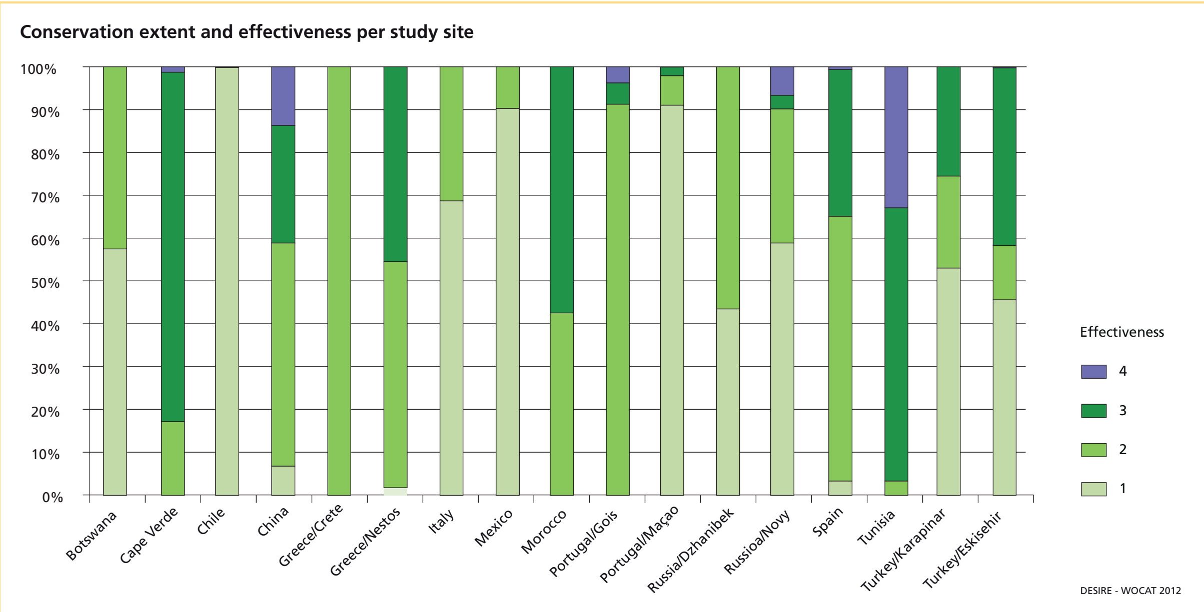

Figure 15: Relative effectiveness of conservation technologies per study site in terms of areal coverage.

China, Hanspeter Liniger

Greece, Hanspeter Liniger

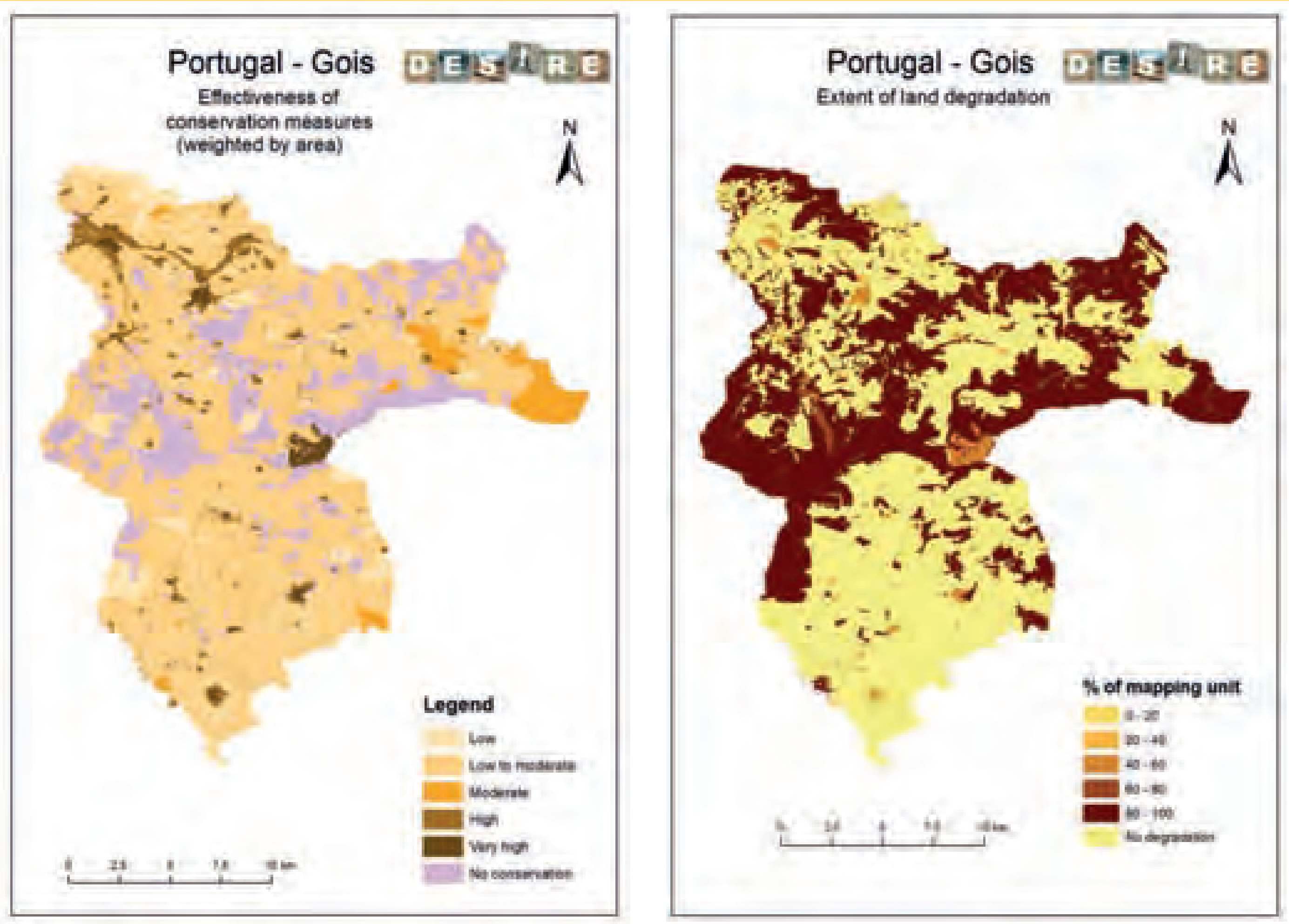

Figure 16: Effectiveness of conservation measures and extent of land degradation in the Goís study site, Portugal. Source: research teams of the Goís study site from ESAC and the University of Aveiro.

with other conservation measures, such as grass on the risers for stabilisation and fodder (a vegetative measure), or contour ploughing (an agronomic measure).

The categories of conservation measures applied vary between the major land use types (Figure 17). In cultivated land, all categories are found, but in forest, agronomic and vegetative measures dominate. Management measures are most applied in mixed land use and grazing land. Combinations of conservation measures occur in all land use types, and take up the largest absolute area in cultivated land. Structural measures are relatively most applied in settlements, since this type of measure is most suitable to control the large runoff volumes generated in built-up area. Figure 18 shows that in the DESIRE study sites, agronomic measures are the most widespread. However, combinations of two or more measures were reported for about 40% of the mapping units or approximately 20% of the area under conservation. Sites with single conservation measures appeared to have a relatively low effectiveness of conservation. This confirms that combinations of conservation measures are more effective than single measures, as is often reported in the literature[11].

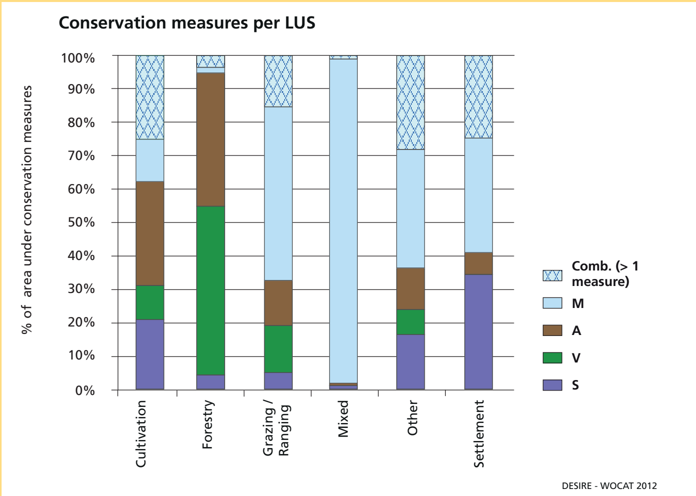

Figure 17: Relative distribution of categories of conservation measures in major land use types (LUS). M: management, A: agronomic, V: vegetative, S: structural measures.

Impact on ecosystem services

Conservation measures in the DESIRE study sites have positive impacts on ecosystem services over the largest part of the area under conservation (Figure 19). Impacts are relatively most positive on regulating ecosystem services, which may help to balance the relatively high level of negative impacts from land degradation observed before.

Negative impacts of conservation measures were also reported for production services and socio-cultural services for respectively 20% and 5% of the area under conservation. Negative impacts on production services can be explained by loss of land due to area occupied by conservation measures, like structures or vegetative strips. For socio-cultural ecosystem services, negative impacts of conservation may originate from conflicts due to the implementation of measures, for example due to closure of rangeland or forest for the regeneration of the vegetation.

Considering positive impacts on all three categories of ecosystem services in the total area under conservation measures in the study sites (largely 195.000 ha, or 23% of the total area), positive impacts of conservation measures were mostly observed in forest and grazing land (resp. 19% and 15% of the area under conservation measures). Only 8% of the

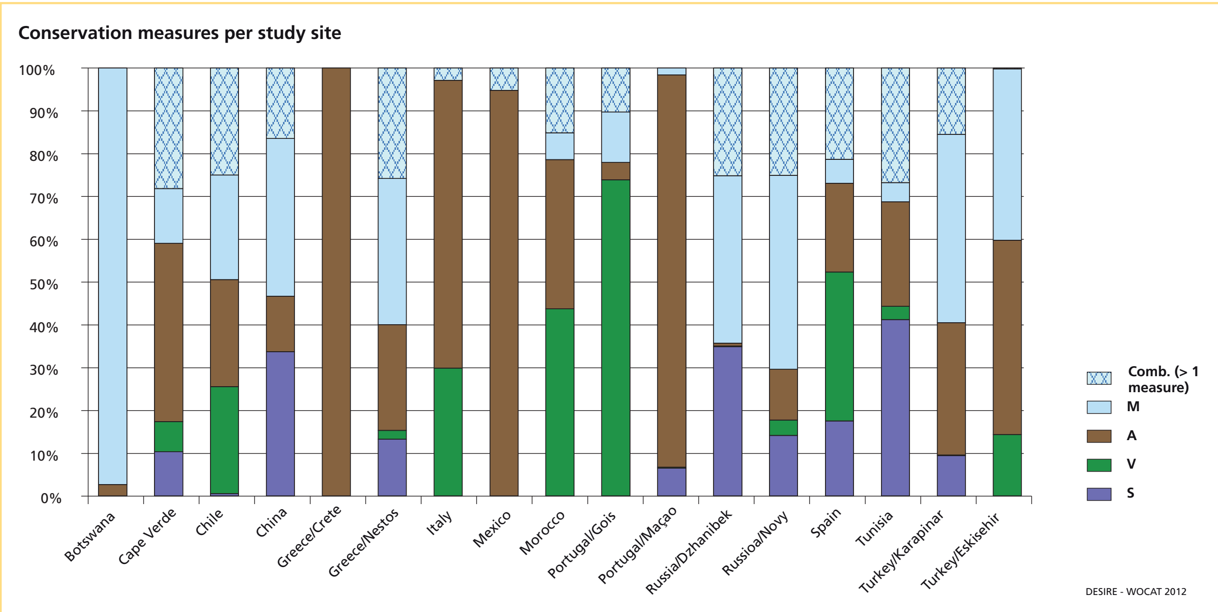

Figure 18: Relative distribution of conservation measures per study site, expressed in % coverage of the treated area. M: management, A: agronomic, V: vegetative, S: structural measures.

[11] e.g. WOCAT, 2007; FAO, 2011; Liniger et al., 2011

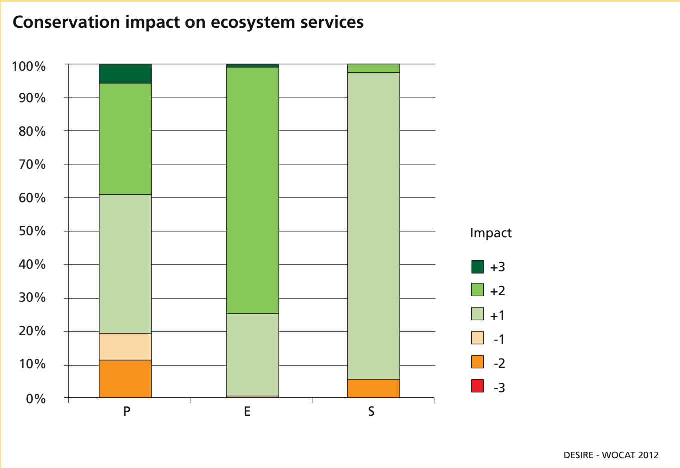

Figure 19: Impact of conservation on ecosystem services (ES) in all study sites. P: production services, E: ecological services, S: socio-cultural services. Negative numbers: negative contributions to changes in ES (-3: >50%, -2: 10-50%; -1: 0-10%); positive numbers: positive contributions to changes in ES (3: >50%, 2: 10-50%; 1: 0-10%).

area under conservation measures with positive impacts on ecosystem services was found in cultivated land. At the same time, the effectiveness of conservation measures in cultivated land was reported to be high (in 20% of the cultivated area under conservation) (section 1.5.2). This implies that if conservation measures are effective in remediating land degradation processes, this does not necessarily entail positive changes in the level of ecosystem services provided by the land. Obviously there is scope for improving contributions from SLM to ecosystem services in cultivated land.

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China, Erik van den Elsen

1.3 Analysis of assessed SLM technologies and approaches across DESIRE sites

Compilation of case studies

In this chapter, the selection of SLM strategies presented in Part II will be analysed and evaluated. The compilation of these case studies, consisting of 30 technologies and 8 approaches, was based on various criteria. Essentially, the selection comprises of what was identified and documented through the participative procedure described in chapter 1.1 (step II). Most of these SLM technologies were also trialled in step III and their documentation was updated based on the monitoring of this experience. Some new technologies were documented only after the field trials carried out as part of the DESIRE project. It is important to note that in principle WOCAT is documenting only real field experience, which is why the technologies and approaches are presented in a case study format. The selection of cases is based on the completeness of the description and their relevance in the DESIRE process. A primary aim of the project was to achieve a wide variety of SLM strategies, study sites, land use types, degradation types, etc. and yet still keep a manageable number of cases in order to achieve a high quality output. The information compiled through the WOCAT questionnaires was put into an attractive four-page summary format. All documentation was reviewed and quality assured through an interactive process with the authors from the study sites. To support the following discussion of the analysis, the DESIRE project experiences as well as the overall WOCAT database have been used, but the figures are based on the DESIRE case studies only. It is important to note that the case studies analysed do not represent a 'random sample' from which statistical significance can be drawn. What the analysis does provide is an insight into common denominators of what are, in most cases, successful examples.

Table 1: SLM technology groups

SLM group	Country	SLM technology name	WOCAT code
Cropping management	Chile	No tillage preceded by subsoiling	CHL01
	Greece	Olive groves under no tillage	GRE01
	Spain	Reduced contour tillage of cereals	SPA01
	Spain	Reduced tillage of almonds and olives	SPA06
	Chile	Crop rotation with legumes	CHL02
	Morocco	Crop rotation: cereals / fodder legumes (lupin)	MOR12
	Spain	Ecological production of almonds and olives using green manure	SPA05
	Turkey	Fodder crop production	TUR04
Water management	Tunisia	Jessour	TUN09
	Tunisia	Tabia	TUN12
	Spain	Water harvesting from concentrated runoff for irrigation purposes	SPA04
	Greece	Transport of freshwater from local streams	GRE05
	Tunisia	Recharge well	TUN14
	Turkey	Drip irrigation	TUR03
	Russia	Drip irrigation	RUS01
	Botswana	Roof rainwater harvesting system	BOT04
Cross-slope barriers	China	Progressive bench terrace	CHN53
	Turkey	Woven wood fences	TUR05
	Spain	Vegetated earth-banked terraces	SPA02
	Morocco	Olive tree plantations with intercropping	MOR14
	Cape Verde	Aloe Vera living barriers	CPV06
	Mexico	Land reclamation by agave forestry with native species	MEX02
	Morocco	Gully control by plantation of Atriplex	MOR15
Grazing land management	Tunisia	Rangeland resting	TUN11
	Italy	Controlled grazing in deciduous woods	ITA01
Forest management	Cape Verde	Afforestation	CPV03
	Morocco	Assisted cork oak regeneration	MOR13
	Portugal	Primary strip network system for fuel management	POR01
	Portugal	Prescribed fire	POR02
	Botswana	Biogas	BOT05

Analysis of SLM technologies

Introduction

For the purpose of this analysis the 30 case studies are clustered into five groups, which are presented in Table 1.

The five groups are characterised as follows:

1. Cropping management: includes soil fertility management (benefits of use of organic and inorganic plant nutrients, minimum disturbance of the soil, crop rotation and permanent soil cover, including agroforestry systems). They are applied on cropland and mixed land use systems (crop-tree and crop-grazing).
2. Water management: includes rain water harvesting, improved irrigation efficiency and provision of drinking water for domestic and livestock use. It involves different land uses, mostly related to crop production through irrigation and water harvesting but also water supply systems. There can be combinations of uses for the same technology, such as provision of irrigation and drinking water.
3. Cross slope barriers: measures on sloping lands in the form of soil bunds, stone lines, barriers in gullies, vegetative strips and all forms of terraces. They are applied on various land uses systems but often related to cropland or control of gullies.
4. Grazing land management: includes controlled grazing, resting periods and is only applied on grazing land use systems
5. Forest management: includes afforestation, assisted regeneration of forests and fire control. The biogas technology from Botswana is also assigned to this group, as its major land degradation related role is to reduce pressure on forest and wood resources.

The following analysis is often carried out in relation to the five conservation groups, enabling similarities and differences to be identified.

Land use

Most technologies are rather specific for a certain land use type. No tillage, for example, can only relate to cropland. The introduction of a technology sometimes induces a shift from one land use (e.g. cropland) to another (e.g. agroforestry). After the implementation of the SLM practice, 40% of the technologies are applied only on cropland, 7% on grazing land and only one out of 30 (3%) is applied in forested land. The other half is applied in mixed systems, such as cropland and forests (agroforestry) or cropland and grazing land. After the introduction of the technology the agroforestry systems increased at the expense of the grazing land systems.

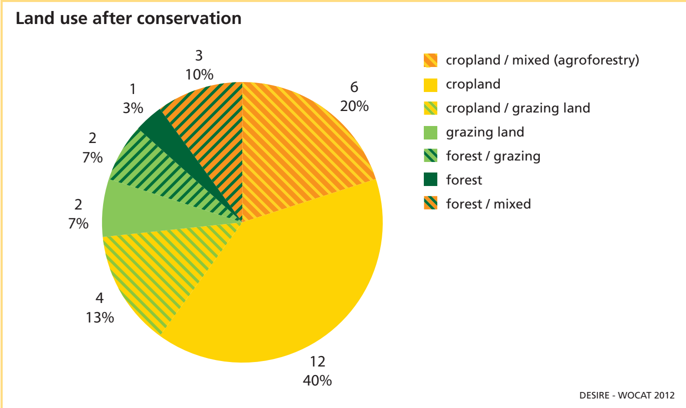


Figure1: Study site size and land use types.

The area where the technology is applied is in most cases rather small, often between 10 and 100 km², but in a number of cases also below 10 ha. WOCAT aims to document the experience of unique SLM Technologies, which should cover a homogeneous set of natural (bio-physical) and human (socio-economic) conditions. Larger areas tend to include variations in climatic or altitudinal zones, differences in slope categories or diverse conditions of land tenure.

Degradation

Degraded land is defined as land that, due to natural processes or human activity, is no longer able to properly sustain an economic function and / or the original ecological function[1]. WOCAT differentiates between six major degradation types, namely soil erosion by water, soil erosion by wind, chemical soil deterioration (incl. soil fertility decline), physical soil deterioration (e.g. compaction), biological degradation (e.g. reduction of vegetation) and water degradation (e.g. aridification).

Cropping management technologies are used against all types of degradation and often address combinations of these. The other technology groups are more targeted at fewer degradation types, i.e. water management technologies mainly address water degradation, cross-slope barriers are established against soil erosion by water, and grazing land and forest management technologies mainly address biological degradation. Surprisingly, soil crusting and sealing (physical soil deterioration), a phenomena often observed in

Morocco, Abdellah Laouina

Turkey, Sanem Açıkalın

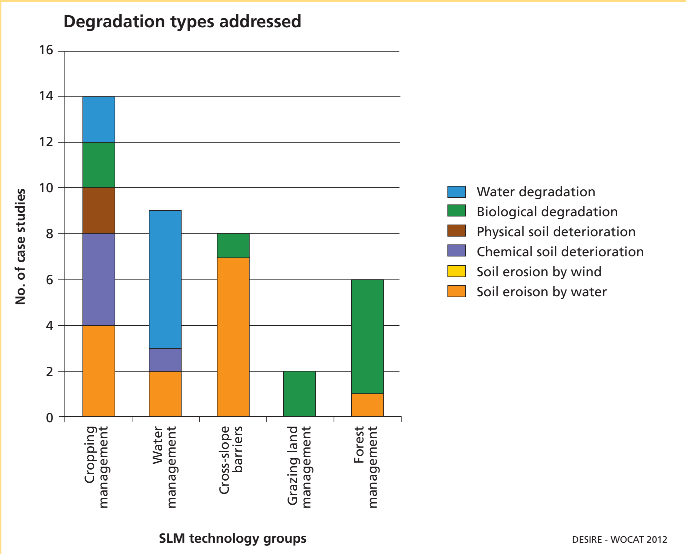


Figure 2: Degradation types addressed by the DESIRE technologies. A technology may address several types of degradation and the total sum of items displayed is therefore more than the total of 30 technologies.

drylands, is only mentioned in one technology description of Spain (reduced contour tillage). Another surprising result is that soil fertility is mentioned as a problem only for four case studies (Chile, Spain and both Turkish sites).

The only study site to be majorly affected by salinization is Nestos in Greece, which suffers from seawater intrusion. However, salinization is also mentioned as a minor degradation type in the Russian drip irrigation case study.

Stage of SLM intervention

Depending on what stage of land degradation has been reached, there are three types of SLM intervention that can be made: (i) prevention of expected land degradation; (ii) mitigation of on-going land degradation; or (iii) rehabilitation of already degraded land.

Prevention implies employment of SLM measures that maintain natural resources and their environmental and productive function on land, which may be at risk of degradation. The implication is that good land management practice is already in place.

Mitigation is intervention intended to reduce ongoing degradation. This comes in at a stage when degradation has

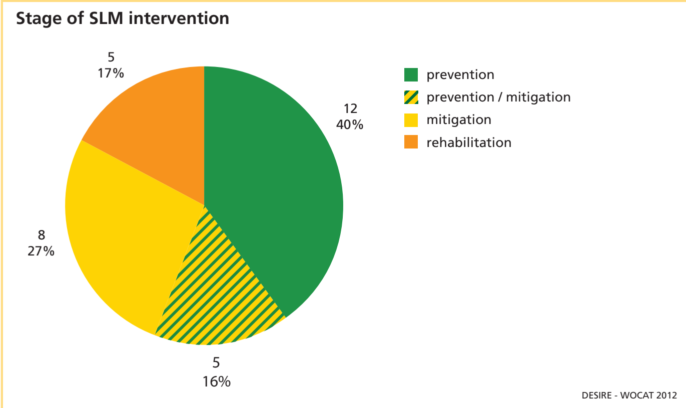


Figure 3: Prevention, mitigation or rehabilitation of land degradation by the 30 case studies.

already begun. The main aim here is to halt further degradation and to start improving resources and their ecosystem functions. Mitigation impacts tend to be noticeable in the short to medium term; the observed impact then provides a strong incentive for further efforts.

Rehabilitation is required when the land is already degraded to such an extent that the original use is no longer possible. In this situation, the land has become practically unproductive and the ecosystem seriously disturbed. Rehabilitation usually implies high investment costs with medium- to long-term benefits.

Inputs and achievements depend very much on the stage of degradation at which SLM interventions are made. The best input-benefit ratio will normally be achieved through measures for prevention, followed by mitigation, and then rehabilitation[2]. This is confirmed by the DESIRE case studies, where the technologies for rehabilitation indeed have a lower cost-benefit ratio than those for prevention and mitigation. It implies that while the impacts of rehabilitation efforts can be highly visible, the related achievements need to be critically considered in terms of the cost and associated benefits.

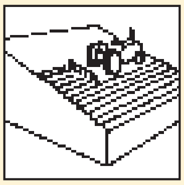
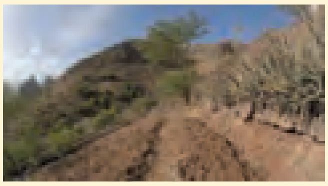
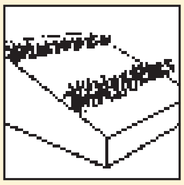
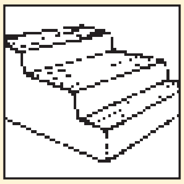
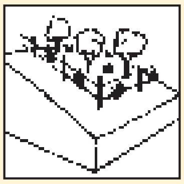
Of the 30 technologies analysed here, 12 were classified as prevention, eight as mitigation and five as combining mitigation with prevention. Only five were described as rehabilitation, mostly trying to put highly degraded forest or grazing land back into production. These include biogas in Botswana, which allows the forest to regenerate and four vegetative measures in Cape Verde, Mexico and Morocco, which use high-value trees and shrubs to rehabilitate gullies

Spain, Felicitas Bachmann

[1] ISO, 1996

[2] WOCAT, 2007

Table 2: WOCAT categories of SLM measures

		**Agronomic measures:** measures that improve soil cover (e.g. green cover, mulch); measures that enhance organic matter / soil fertility (e.g. manuring); soil surface treatment (e.g. conservation tillage); subsurface treatment (e.g. deep ripping).
		**Vegetative measures:** plantation / reseeding of tree and shrub species (e.g. live fences; tree crows), grasses and perennial herbaceous plants (e.g. grass strips).
		**Structural measures:** terraces (bench, forward / backward sloping); bunds banks / level, graded); dams, pans; ditches (level, graded); walls, barriers, palisades.
		**Management measures:** change of land use type (e.g. area enclosure); change of management / intensity level (e.g. from grazing to cut-and-carry); major change in timing of activities; control / change of species composition.

or degraded slopes. It is good to see that the major efforts of SLM in these dryland sites go into prevention and mitigation. Examples for prevention include crop rotation systems (Chile, Morocco), fire prevention in forests, controlled grazing in forests (Italy), water harvesting systems (Tabia from Tunisia), and drip irrigation in Turkey.

Conservation measures

WOCAT categorises technologies into specific measures in order to help understand how they function (see Table 2). A technology group, as presented in Table 1, may consist of several such measures. Not surprisingly, the technologies within a particular group all have similar compositions in terms of their component measures (see Figure 5).

Structural and agronomic are the most frequent measures of the 30 cases presented in this chapter. In contrast to the experiences in other case studies[3], there are very few combinations mentioned. A typical combination is the bench terrace from Spain, which is combined with a vegetative measure – drought-resistant shrubs with a good surface cover – to stabilize the structure.

The analysis for the five groups (Figure 5) shows that for the cropping management purely agronomic measures were used, whereas for the grazing land purely management measures were used, i.e. without additional planting of trees or grasses and without implementing structures. In the water management group structural measures were applied in all except one of the case studies. Cross-slope barriers and forest management consist of various measures.

Technical function

Figure 6 shows through which technical functions the SLM technology is combatting land degradation. Combinations of different functions are very common. One of the most impor-


Morocco, Gudrun Schwilch


Portugal, Gudrun Schwilch

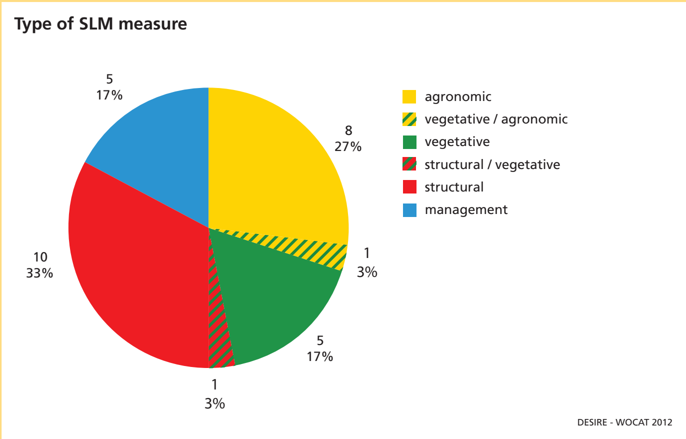


Figure 4: Type of SLM measures.

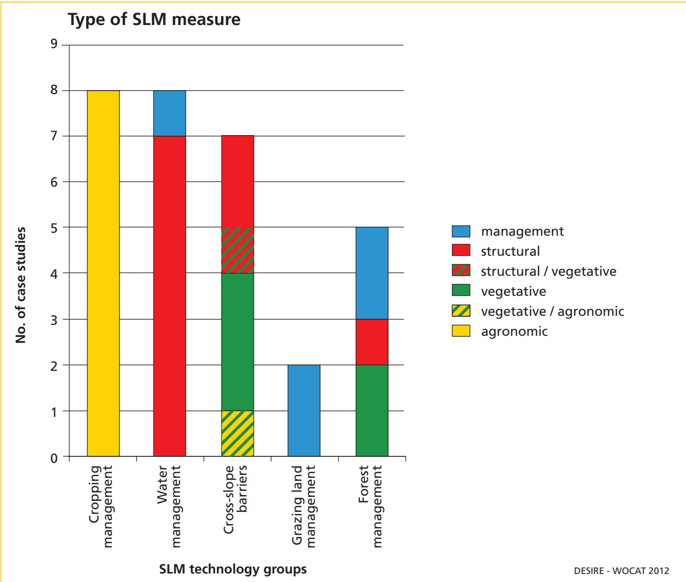


Figure 5: Type of SLM measures in relation to the SLM technology groups.

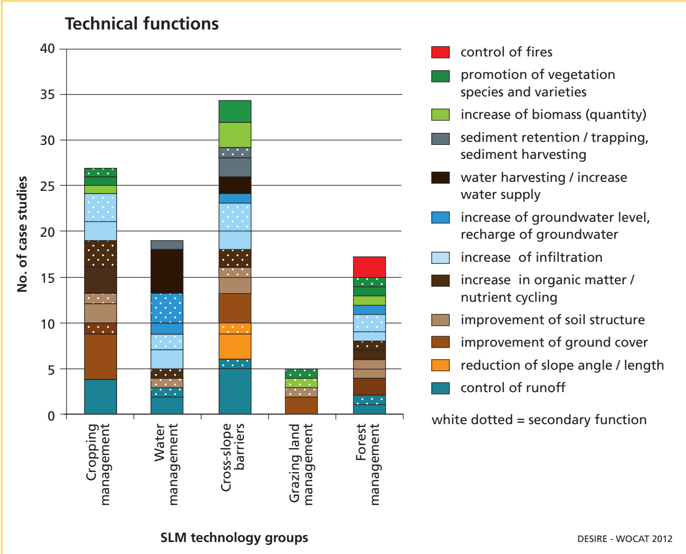


Figure 6: Technical functions in relation to the SLM technology groups. A technology may fulfil several types of functions and the total sum of items displayed is therefore more than the total of 30 technologies.

tant functions of the DESIRE SLM technologies is an increase of infiltration. This is found in all technology groups. Only the grazing land management technologies group does not include this function. Often an increased infiltration is envisaged together with an increase or maintenance of water stored in soil (see Figure 20 on increased soil moisture). Remarkably this does not apply to the water management group, where infiltration of water is rather a secondary aim after control of concentrated runoff (Spain, Tunisia) or replenishment of saline groundwater with surface freshwater (Greece).

Out of the many functions the technologies have, the following need to be highlighted:

- Improvement of ground cover is a key function in all SLM groups, except for water management. Several other functions are related to improvement of soil cover, such as increase of infiltration and, as a consequence, reduction of surface runoff and erosion.
- Increase of infiltration is important, except in the grazing land management group. Due to the envisaged improvement in ground cover for both grazing land examples, infiltration is most probably also improving, but not considered specifically.
- Control of runoff appears everywhere, except in the grazing land management group. For these two technologies it is not a primary issue of concern.
- Improvement of soil structure can be found in all groups as an aim of some, but rather few technologies.
- Increase in soil organic matter is mainly mentioned for the cropping management technologies, where it plays an important role as an input factor for agricultural productivity.
- Water harvesting appears mainly in water management and partly for cross-slope barriers.
- Sediment retention is only attributed to cross-slope barriers.
- Increase of biomass / vegetation species is mainly related to cross-slope barriers, but appears everywhere to some extent.

[3] WOCAT, 2007

Origin of technology

SLM technologies can be of local or external origin. They can also be recently introduced or originate from a long time ago. These combinations of origin and age for the DESIRE technologies are presented in Figure 7. In total, eight technologies are older than 50 years, nine are between 10 and 50 years old and thirteen are younger than 10 years. Ten technologies are from land users' initiatives, either traditional or innovative, six are from experiments / research and fourteen are from projects. Almost all combinations are represented in each technology group, except the two grazing management technologies, which are both from land user's initiative. It is remarkable that three quarters of the technologies documented were implemented within the last 50 years. This coincides with the boost of investments in agricultural research and extension by the Food and Agriculture Organization of the United Nations (FAO) and governments since the 1960s, which is especially known in Asia as having led to the Green Revolution. This fact is also reflected by the high percentage of externally introduced technologies (e.g. through projects, but not necessarily from another country), under which two thirds of all technologies fall.

Natural environment

Due to the focus of the DESIRE project on drylands and desertification, most of the technologies are applied in semi-arid agro-climatic zones. Some are even applied in arid zones, and a few in sub-humid zones. Rainfall is below 750 mm / year in almost all sites, mostly falling between 250-500 mm annually. Most of the technologies are applied at altitudes between 100 and 500 m a.s.l.

In order to accurately understand the conditions under which each technology is applied, many parameters of the natural environment are documented within the WOCAT questionnaire. In this analysis, we only focus on a few issues that are most relevant to the dryland and desertification context found in the DESIRE sites.

Figure 8 presents the **slope** categories where the technologies are applied. As expected, cross-slope barriers and forest management technologies are mostly found on sloping land. In total, half of all technologies are applied on slopes above 8%, which demonstrates the focus of and need for SLM on sloping (marginal) land. It is erosion and water loss that are the main

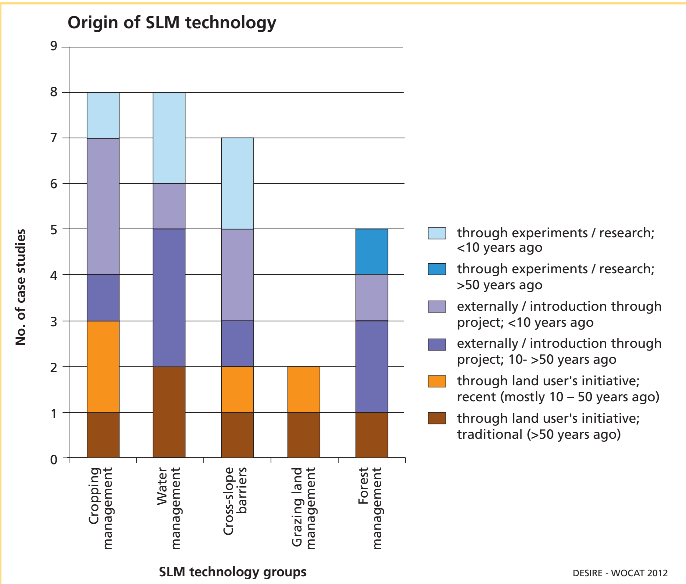


Figure 7: Origin and age of SLM technologies in relation to the SLM technologies group.

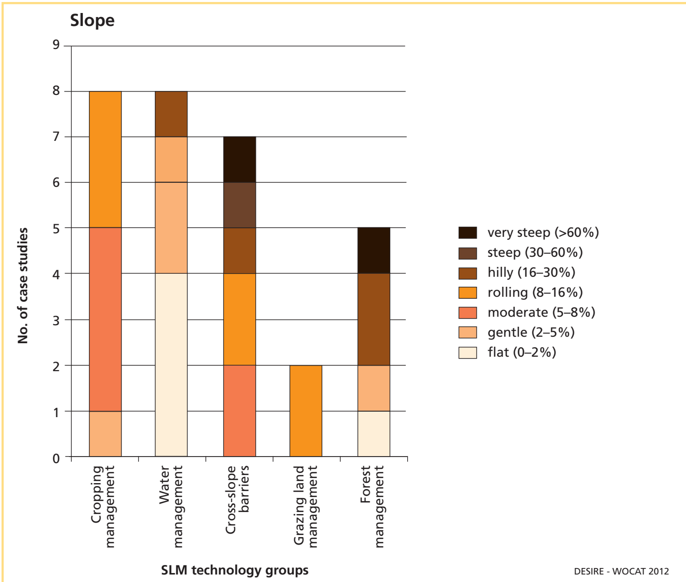


Figure 8: Slope categories in relation to the SLM technology groups. (Note that for each technology only the major category was selected).


Mexico, Christian Prat


Morocco, Gudrun Schwilch

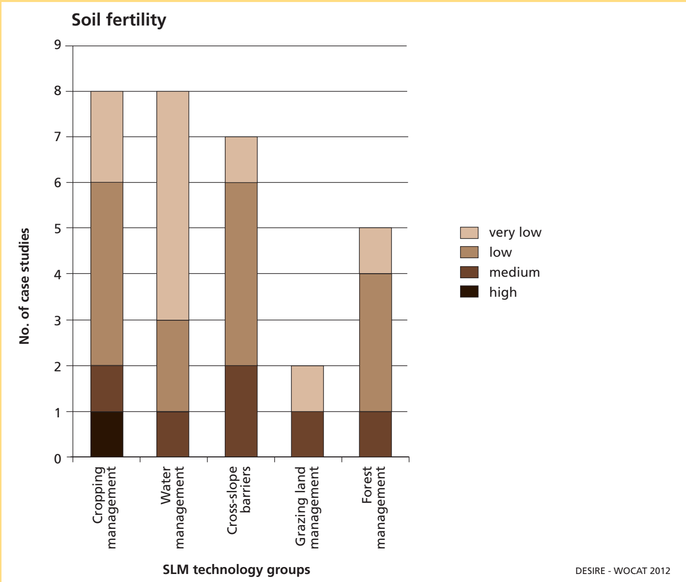


Figure 9: Level of soil fertility in relation to the SLM technology groups before intervention. (Note that for each technology only the major category was selected).

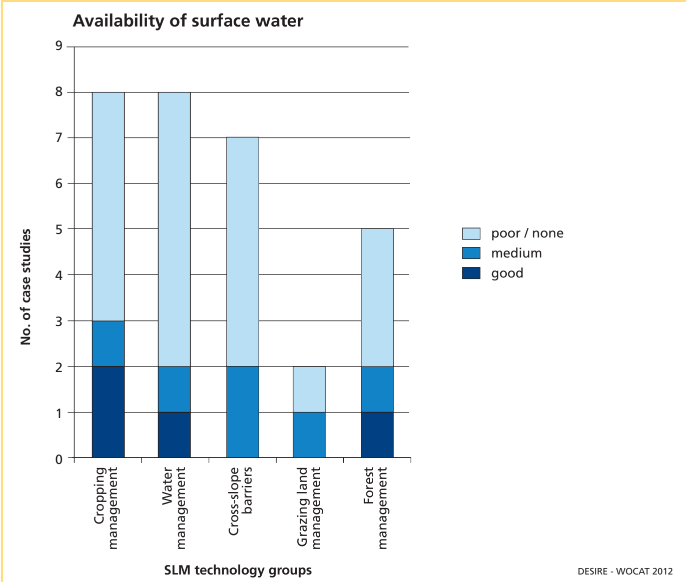


Figure 10: Availability of surface water in relation to the SLM technology groups. (Note that for each technology only the major category was selected).

degradation problems requiring mitigation action in these areas. Cropping management and water management technologies are mainly applied on flat to gentle slopes, where other degradation problems are prevalent, such as fertility depletion, vegetation degradation or salinization.

23 of the 30 technologies (77%) are practiced on soils with low or very low **soil fertility**. None of the case studies are applied on soils which initially had a very high fertility and only one technology is on a soil with high initial fertility. Compared to earlier assessments, including all climatic zones[4], more focus is given to improve the management of low fertility soils in the drylands of this study. This reflects the reality of drylands, where soils are generally less fertile due to less weathering and the prevalence of unfavourable substrates. It has not been assessed how far degradation and nutrient mining have contributed to a reduced soil fertility.

Topsoil organic matter is closely related to soil fertility and has an impact on physical, chemical and biological properties. Similar to soil fertility, the majority of cases have low topsoil organic matter. Naturally, topsoil organic matter is rather low in drylands due to the reduced biological activities under arid and semi-arid climatic conditions. Because most soils where SLM has been applied contain a low level of soil organic matter, they have potential to increase organic matter and nutrient holding capacity and simultaneously sequester carbon in the degraded soil. This is an important functionality of reduced tillage, crop rotation with legumes and agroforestry systems.

Figure 23, which is presented later in this chapter, shows an interesting comparison of the initial soil organic matter and the impacts of the SLM technology.

As expected, the **availability of surface water** (proximity of streams or lakes) is very poor in most cases (see Figure 10). More on the impacts of this issue can be found below.

Sensitivity of, and tolerance to, climate change

The technologies were documented for the current climatic situation of the study sites. If climate is changing, then the positive-functioning of a technology could be negatively affected. Equally, under certain situations the effect could be positive. If the species used are not drought tolerant, a reduction of seasonal rainfall may cause hedge rows to become ineffective. The WOCAT questionnaire therefore assesses the perceived tolerance and sensitivity of an applied technology during extreme conditions, be it seasons with exceptionally low or high rainfall, temperatures or heavy storm (wind or rain).

[4] WOCAT, 2007

Table 3: Sensitivity of and tolerance to climate change

		temperature increase	seasonal rainfall increase	seasonal rainfall decrease	heavy rainfall events	windstorms / dust-storms	floods	droughts / dry spells	decreasing length of growing period
Cropping management	CHL01	tolerant	tolerant	tolerant	tolerant			sensitive	
	GRE01			sensitive	tolerant			sensitive	
	SPA01	sensitive	tolerant	sensitive	tolerant	tolerant	tolerant	sensitive	tolerant
	SPA06	tolerant	tolerant	tolerant	tolerant	tolerant	tolerant	sensitive	tolerant
	CHL02	tolerant		tolerant				sensitive	
	MOR12	tolerant	tolerant	sensitive	sensitive	sensitive	sensitive	sensitive	
	SPA05	tolerant	tolerant	tolerant	tolerant	tolerant		sensitive	tolerant
	TUR04	sensitive	tolerant	sensitive	tolerant	tolerant	tolerant	sensitive	sensitive
Water management	TUN09	tolerant	tolerant	tolerant	tolerant	tolerant	sensitive	tolerant	tolerant
	TUN12	tolerant	tolerant	tolerant	tolerant	tolerant	sensitive	sensitive	tolerant
	SPA04	tolerant	tolerant	sensitive	sensitive	tolerant	sensitive	tolerant	tolerant
	GRE05		sensitive	sensitive	sensitive		sensitive	sensitive	
	TUN14	tolerant	tolerant	tolerant	tolerant	tolerant	sensitive	tolerant	tolerant
	TUR03	tolerant		tolerant					
	RUS01	tolerant	tolerant	tolerant	tolerant	tolerant	sensitive	sensitive	tolerant
	BOT04	tolerant	tolerant	sensitive	tolerant		tolerant	sensitive	tolerant
Cross-slope barriers	CHN53	tolerant	tolerant	tolerant	tolerant	sensitive		tolerant	
	TUR05				sensitive				
	SPA02	sensitive	tolerant	sensitive					
	MOR14	tolerant	tolerant	tolerant	tolerant	tolerant	tolerant	sensitive	sensitive
	CPV06		sensitive	tolerant		tolerant	tolerant	sensitive	tolerant
	MEX02	tolerant	tolerant	tolerant	tolerant	tolerant	tolerant	tolerant	tolerant
	MOR15	tolerant	tolerant	sensitive	tolerant	tolerant	tolerant	sensitive	
Grazing land management	TUN11		sensitive	sensitive		tolerant	tolerant	tolerant	
	ITA01	tolerant		sensitive					sensitive
Forest management	CPV03	tolerant		tolerant		sensitive		sensitive	tolerant
	MOR13	tolerant	sensitive	tolerant	tolerant			tolerant	
	POR01	tolerant	tolerant	tolerant	sensitive	sensitive	sensitive	sensitive	tolerant
	POR02	tolerant	tolerant	tolerant	tolerant	sensitive	tolerant	tolerant	tolerant
	BOT05	tolerant	tolerant	tolerant	tolerant	tolerant	tolerant	tolerant	tolerant

tolerant sensitive not known / not applicable


Morocco, Hanspeter Liniger


Cape Verde, Erik van den Elsen


Turkey, Erik van den Elsen

It is notable that all cropping management technologies are sensitive to droughts and dry spells. However, this can be explained because of their sole dependence on annual crops. In dryland areas, crops usually receive close to the minimum amount of water that they need to give yield; hence any decrease of water availability might induce crop failure. Temporal variability, such as periods of drought, also affects crop growth. Besides, these systems do not provide an alternative source of income, such as with agroforestry systems or other technologies. On the other hand, the sensitivity to droughts might be reduced due to the applied SLM technology, as water is better stored in the soil with the help of improved infiltration and better soil cover. This could lead to an increase in the amount of water made available to the plant, especially during dry periods.

Water management technologies are also sensitive to droughts, but even more so to floods, which is indicated as a problem by six out of the eight water management technologies. It is a special challenge to have water harvesting structures which are strong enough to withstand the power of floods.

Apart from droughts, coping with heavy storms and a decrease of seasonal rainfall are two additional concerns for dryland regions. It must be highlighted that except for five technologies (17%) all of the others are tolerant to such extreme events. Some of them, especially the cross slope barriers, have been designed to cope with extreme storm events. With regards to the seasonal decrease of rainfall, approximately one third is sensitive (11 out of 30), which is spread over all groups, except the forest management. The two grazing land management examples are both sensitive to seasonal rainfall decrease, which diminishes the availability of fodder. Again this illustrates that good practices today are already designed to cope with climatic extremes and possible shifts.

In general, most of the technologies are tolerant to the expected climatic variations. In a few areas there might even be an opportunity for increased rainwater availability. However, especially for the Mediterranean region, in which most of the selected case studies are located, most of the climate prediction scenarios forecast declining rainfalls[5].

Human environment

To identify the type of **land users applying the SLM technology**, the WOCAT questionnaire assesses if the land user is working (i) individually and at household level or (ii) in groups / communities, (iii) in cooperatives or (iv) as employee of a company or the government. Almost all DESIRE SLM technologies are applied at the individual or household level, except those of the forest management group.

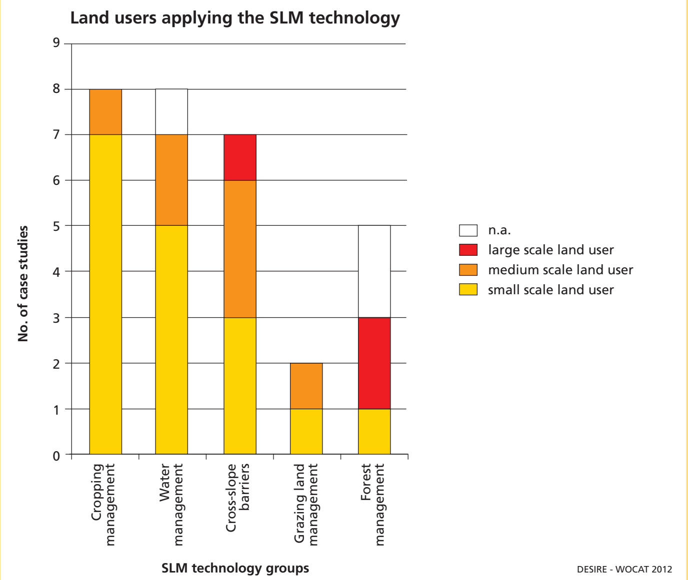


Figure 11: Land users applying the SLM technology in relation to the SLM technologies groups.

Another issue used to characterise the land users is their size of scale, i.e. from small scale land users to large scale land users. Here, the picture of the DESIRE case studies is more diversified, although the majority (57%) is small-scale land users (see Figure 11). This helps to support the theory that within the smallholder farming sector there is significant and underestimated worldwide investment and innovation in conservation[6].

Land ownership and land use rights are important issues that can hinder or facilitate the uptake of SLM technologies. The majority of results from previous studies demonstrate that individual ownership of the land facilitates the implementation of SLM[7]. Figure 12 confirms this picture. Land use rights might be even more important than land ownership because security of tenure can provide the same degree of confidence to carry out SLM as titled ownership. For the DESIRE case studies, the data on land use rights shows an almost identical pattern as the data on land ownership. Cropping land management technologies are all individually owned and titled. Thus, SLM successes on cropland are all on private land. This statement also counts for cross-slope

[4] WOCAT, 2007

[5] EEA, 2008

[6] WOCAT, 2007; Wegner and Zwart, 2011

[7] WOCAT, 2007

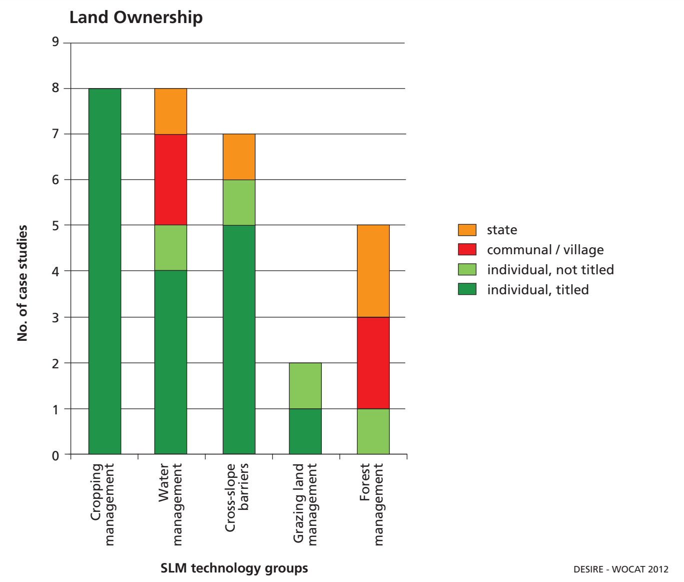


Figure 12: Land ownership in relation to the SLM technology groups.

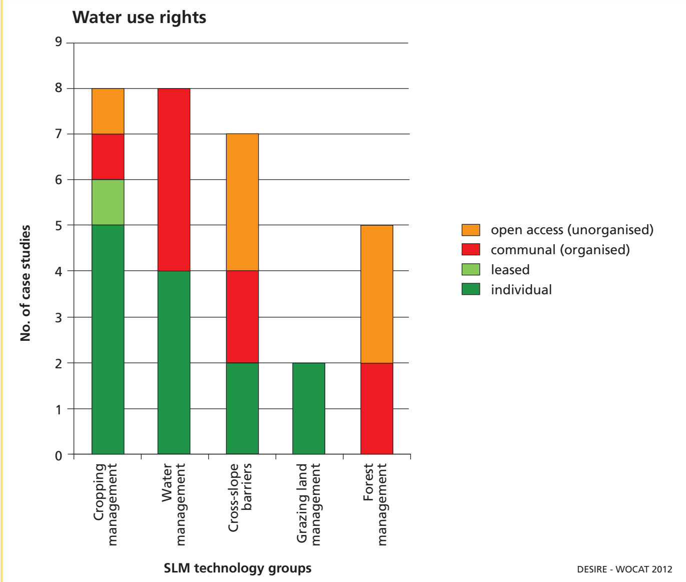


Figure 13: Water use rights in relation to the SLM technology groups.

barriers, where all except one SLM technologies have individual and, for the most part, titled ownership. The expensive water management group has more than one third of the SLM practices in communal and state ownership. Water management technologies, such as dams and water supply systems, might be large-scale projects carried out by state or communal bodies on public land. An example of this is the case study in Tunisia where the well technology used to recharge the deep groundwater aquifers is mainly exploited by the government agencies. Private irrigated farms are also benefiting indirectly by increased groundwater availability. Grazing land degradation is often attributed to the 'tragedy of the common', i.e. state or common ownership and the open access rights lead to irresponsible overuse. Both grazing land examples in this study, however, have individual ownership and rights. As a result, these two examples are special. This supports the assumption that it is difficult to find good examples of SLM on communal and state land without private rights. There is a stark contrast between the ownership of cropping land and forest land; whereas cropping land is all individually owned, forest land is almost all communally or state owned. On forests that are not privatized, there also seem to be good management options.

Water use rights are generally regulated to a lesser extent than land use rights. However, almost half of the case studies within DESIRE are based on individual or leased water use rights, as illustrated in Figure 13. The most difficult situations are open access regimes, both for land and water use. This is the case for seven of the DESIRE case studies, none of which are in the water management group, which would probably cause conflicts over water use. It should however be noted that most technologies concern rainfed agriculture, where water use is less of an issue than with irrigation systems.

The **relative level of wealth** is classified according to local rather than international standards. Poverty and well-being can be causes as well as impacts of land degradation. Looking at Figure 14 shows that 60% of the land users applying the SLM technologies are of average wealth; only a few are either very poor or very rich. The technology group of cross-slope barriers has mainly rich and average land users, which makes sense because of the higher costs associated to this technology.

Figure 15 illustrates the high importance of **off-farm income** for most of the land users applying the documented technologies. Almost half of the land users (43%) depend on an income of more than 50% from additional activities outside farming. This is especially the case for rainfed systems, for example; for the Cape Verde Aloe Vera Living Barrier technology the dependence on off-farm income is reduced from over 50% to 30-40% if irrigation water is used. Access to employment is generally considered low and it can therefore be assumed that the rate of off-farm employment would


Italy, Erik van den Elsen


Morocco, Erik van den Elsen

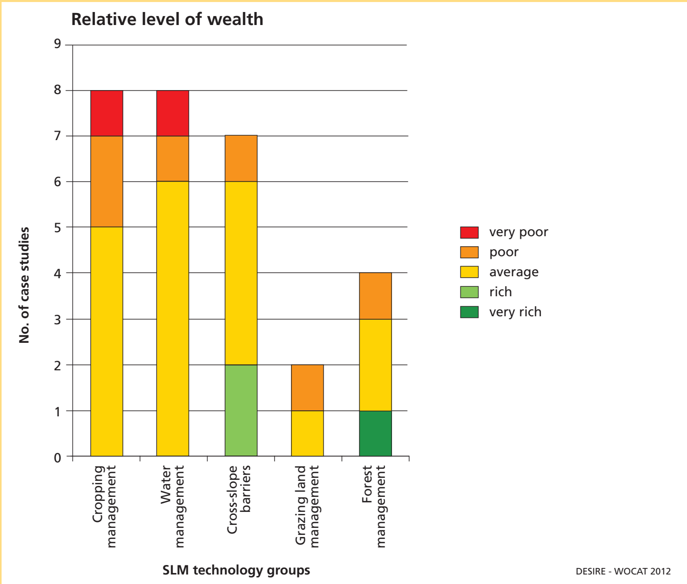


Figure 14: Relative level of wealth of the land users applying the SLM technology.

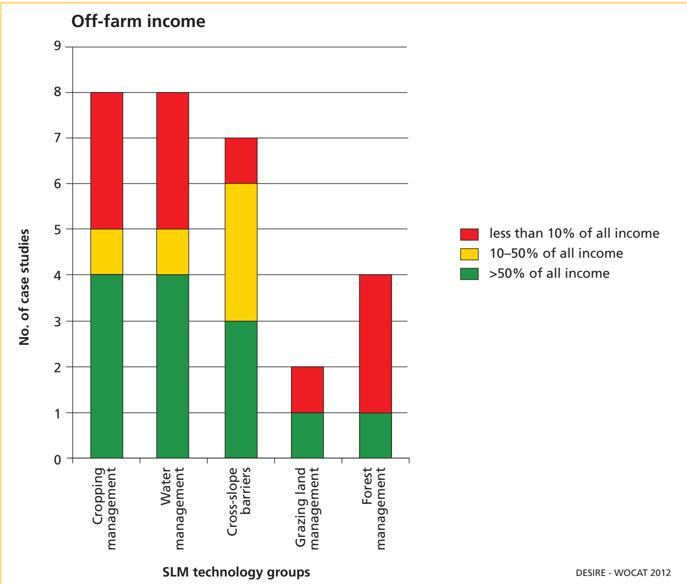


Figure 15: Off-farm income of the land users applying the SLM technology.

be even higher if access to it was facilitated. Out-migration might be one answer and is an issue observed in some of the sites (e.g. Portugal).

Production and socio-economic impacts

Improved **production** can be observed for almost all of the technologies. This is important as it indicates that SLM technologies in general are successful in increasing production, and are, therefore, suitable to support increasing demands for food, fodder and other products. Depending on the land use type, the result is more crop yield increase, more fodder or animal production or more wood production. Cross-slope barriers seem to have the highest benefit in terms of production. Still, in each technology group there are one or two technologies with no increase in production, such as the two no tillage of olive (and almond) orchards in Spain and Greece. Their benefit is related to lower costs, rather than improved production, and a net increase in farm income is still achieved. Other technologies are not assessed regarding agricultural production increase (such as the biogas example). A third of all technologies reduce the risk of production failure, and these are mainly found in the water management group.

Farm income is related, on the one hand, to the inputs (expenditures) needed to apply the technology and, on the other, to the increased production (see previous Figure 16). Increased farm income, generated from improved land management through the technology, was recorded in three-quarters of the cases (excluding forest management technologies, for which this analysis is not applicable). Both cross slope barri-

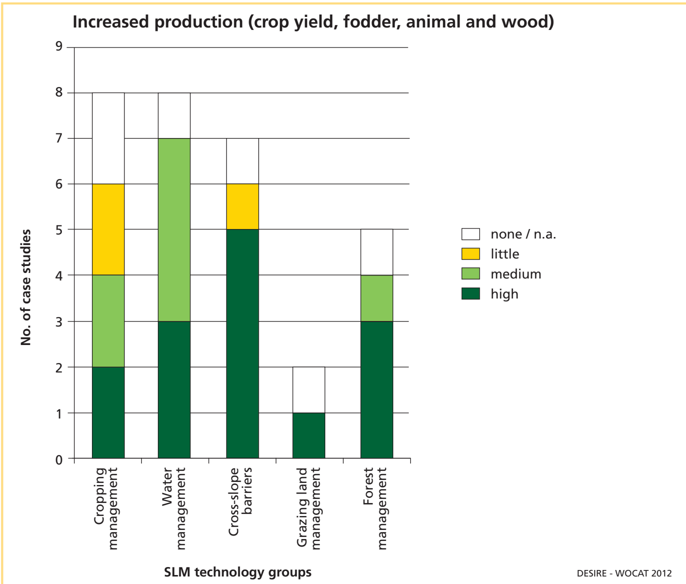


Figure 16: Increased production across the SLM technology groups.

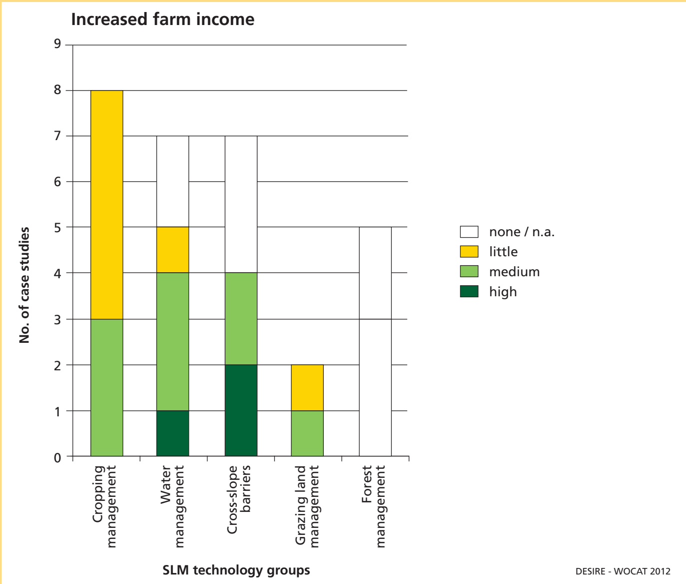


Figure 17: Increased farm income across the SLM technology groups.

ers and water management are rather costly. However, they show the whole range from "high" (meaning the investment resulted in much higher benefits), to "no", where there was no additional gain (meaning that the investment did neither reduce nor increase the overall farm income). This indicates that if investments can be made, the benefits can be increased. External inputs and subsidies might be justified in such cases, especially where establishment costs go beyond the means of the local land users. Such issues are covered by the approach questionnaire.

In general, **socio-economic disadvantages** were not often mentioned. Nine technologies increase the land user's expenses on agricultural inputs, mainly in the cropping management group due to investments in special machinery (e.g. no tillage) or in seeds (e.g. leguminous). Still, these all report about a net farm income increase. The highest increased expenses are reported from the two Botswana case studies (biogas and roof rainwater harvesting) as both of them require high investments. These two technologies can therefore only be implemented with subsidies, especially for poor land users.

Socio-cultural impacts

The socio-cultural benefits most often mentioned are 'improved conservation / erosion knowledge'; see Figure 18. Other socio-cultural benefits were only mentioned for specific cases, such as increased recreational opportunities for the two ecological production examples in Spain. Community or national institution strengthening is a benefit primarily reported by forest management technologies, for which this seems to be an important issue. Conflict mitigation was reported for seven technologies from all groups except cropping management. This is probably due to the fact that the technologies in this group are usually applied on individual land where the potential for conflicts is reduced, except where neighbours are suffering e.g. by too much withdrawals of irrigation water from rivers.

On the other hand, four of the five forest management technologies seem to increase socio-cultural conflicts, albeit only a small amount. For the land reclamation with agave forestry, a significant increase in conflicts is expected due to the high economic benefits and the alcohol problem, although these disadvantages have not yet been witnessed.

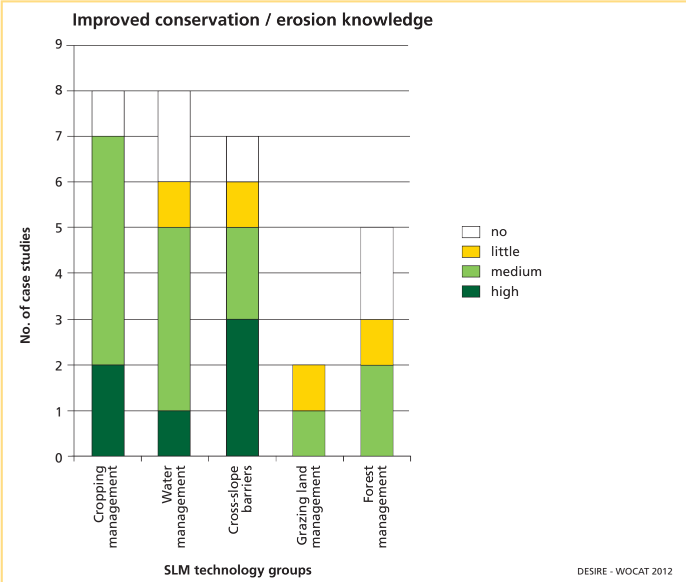


Figure 18: Improved conservation / erosion knowledge across the SLM technology groups.

Ecological impacts

Water issues

Reduction of uncontrolled **runoff** is a benefit particularly related to erosion control and downstream flooding. Furthermore, in drylands, surface runoff is a great loss of precious rainwater, especially during the short periods of heavy rain storms. Where storm water cannot be retained

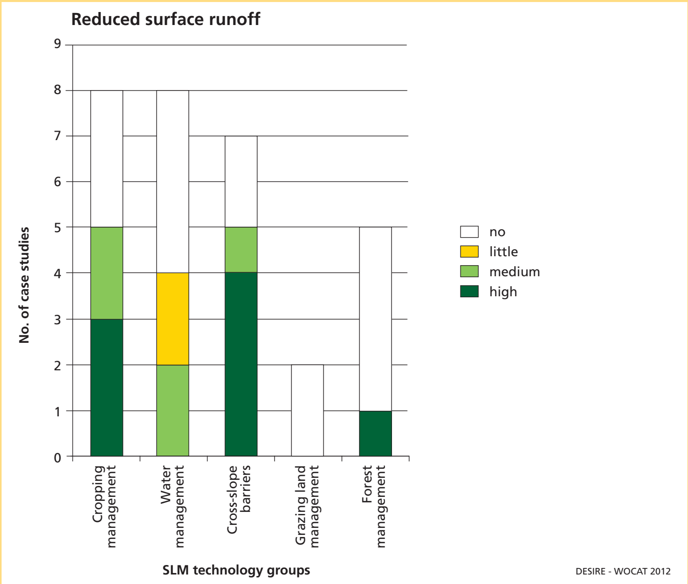


Figure 19: Reduced surface runoff across the SLM technology groups.

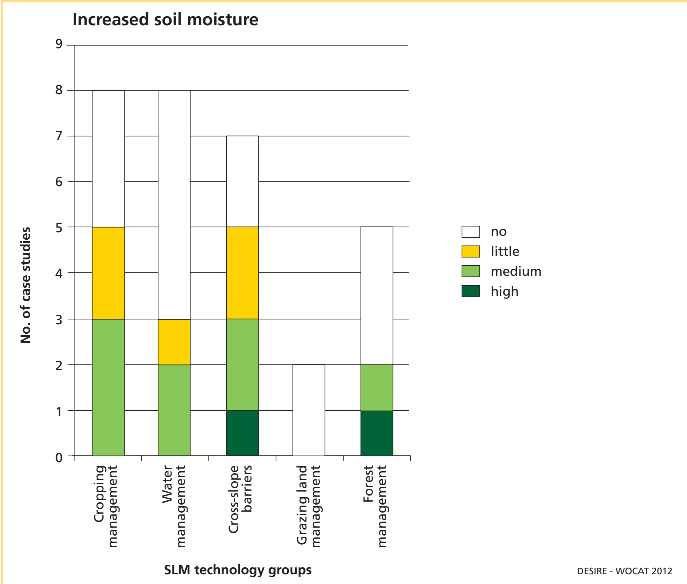


Figure 20: Increased soil moisture across the SLM technology groups.

and stored it will not be available for later use during the dry seasons. Reducing surface runoff is thus a major concern in drylands. As indicated by the authors of the case studies, the most effective technologies are improved cropping management and cross-slope barriers. For both, they indicated that runoff and erosion is a major problem to be addressed on cropland. For the two grazing land experiences they did not indicate an impact on runoff, which, as noted earlier, does not seem to be an issue for these cases. Experiences from other WOCAT cases show that especially overused grazing areas have the highest runoff and that improved grazing land management leads to significant reductions of runoff and erosion.

Improving **soil moisture** through in-situ conservation of rainwater or irrigation water is effective water conservation. This is another key function that is most important to drylands. Cropping management and cross-slope barriers show the greatest potential to increase the water availability to crops in that way. Under dryland conditions, this often results in increased yields.

Reduced **evaporation** was only reported in three case studies (Afforestation Cape Verde, Roof Rainwater Harvesting Botswana and Drip Irrigation Turkey). Drylands usually suffer from extreme evaporation losses on the bare soil surface, which accounts for 40-70% of the already scarce rainfall[8]. Yet, evaporation loss is often not perceived and therefore not seen as a problem. The role and importance of these technologies to reduce water losses through unproductive evaporation of the soil surface needs to be recognized. Improved soil cover management (see impact on reduced surface runoff, Figure 19) can heavily reduce such losses. The potential of improved soil water availability has been highlighted in previous WOCAT analyses, especially in the guidelines for Sub-Saharan Africa, where water scarcity is the main challenge[9]. Increase of soil moisture can also be combined with improved water harvesting techniques.

Improved **harvesting and collection of water** (Figure 21) is achieved by improved water management, e.g. collecting excess water from the fields or from episodic streams, storing it in intermediate storage facilities such as dams, ponds and tanks and guiding it to areas where the water is most productive. It is mainly the technologies aiming at improving available water, such as the water management technologies and the cross-slope barriers, which do show highly positive results, especially where availability of surface water was poor before the technology implementation. No impact was mentioned for all grazing and forest management technologies and for most of the cropping management technologies.

Looking at the impact of those technologies for which water decrease was indicated as a degradation problem before

Morocco, Erik van den Elsen

[8] Liniger et al., 2011

[9] WOCAT, 2007, Liniger et al., 2011

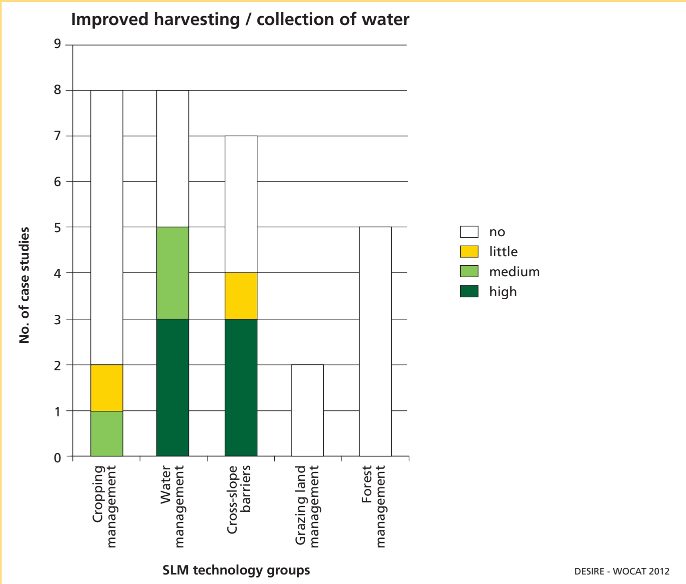


Figure 21: Improved harvesting / collection of water across the SLM technology groups.

(aridification, decline in surface water), reveals that this problem was best tackled with the Jessour technology of Tunisia. However, the other water management technologies also seem to adequately mitigate this major problem. It is also remarkable that many of the technologies have a positive impact on water availability in one way or another (water harvesting, soil moisture increase, reduced runoff, etc.). This confirms that even in cases where water decrease was not specifically reported as a degradation problem, increased water availability on the surface or in the soil is a desired and achieved impact.

Increased **water quality** and reduced salinity, rather than improved water quantity, was an impact of the water management technology in Nestos, Greece (transport of freshwater from local streams), as the major problem at this study site was the salinization of irrigation water. The Nestos example is also one of the seven technologies that report an impact on groundwater availability. The recharge of groundwater table / aquifer was mainly an issue for the water management technologies, where a small to medium increase was assessed for four technologies in Greece, Spain and Tunisia, and a high increase for the Recharge Well of Tunisia due to its specific target on this. Two forest management technologies also found a recharge of groundwater, namely afforestation in Cape Verde (medium) and the assisted cork oak regeneration in Morocco (little).

Soil issues

Soil erosion by water or wind is one of the most common degradation problems mentioned within the DESIRE project. Figure 22 shows that most technologies do indeed manage to decrease **soil loss**. And even those for which it was not identified as a problem report reduced soil loss, especially in the groups of grazing and cropping management technologies. Once again, these mainly concern the crop rotation examples and less the no / minimum tillage technologies. This means, that crop rotation is preventing soil loss even where it was not considered a problem. On the other hand, there are three technologies for which soil erosion was mentioned as a degradation problem, but for which no reduction in soil loss was measured after the application of the technology. This concerns Gully Treatment with Fodder Shrubs in Morocco and Woven Wood Fences in Turkey. These technologies were installed only very recently and a soil loss reduction will probably only be measurable after some time.

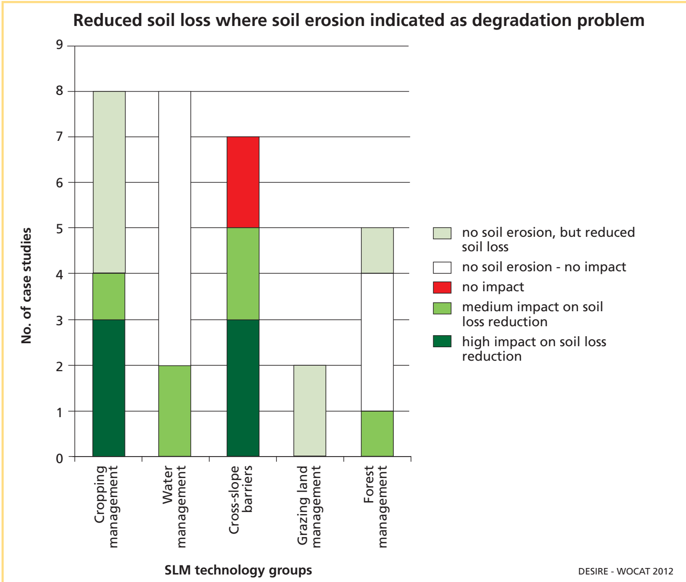


Figure 22: Reduced soil loss where soil erosion was indicated as a degradation problem.

Organic matter and soil fertility decrease was only indicated as a degradation problem in those sites where a cropping management technology was applied. None of the other sites seem to suffer from this problem. This could be because it is not deemed as relevant in these locations. Looking at the impact assessed after implementation, increased soil


Portugal, Gudrun Schwilch


Turkey, Felicitas Bachmann

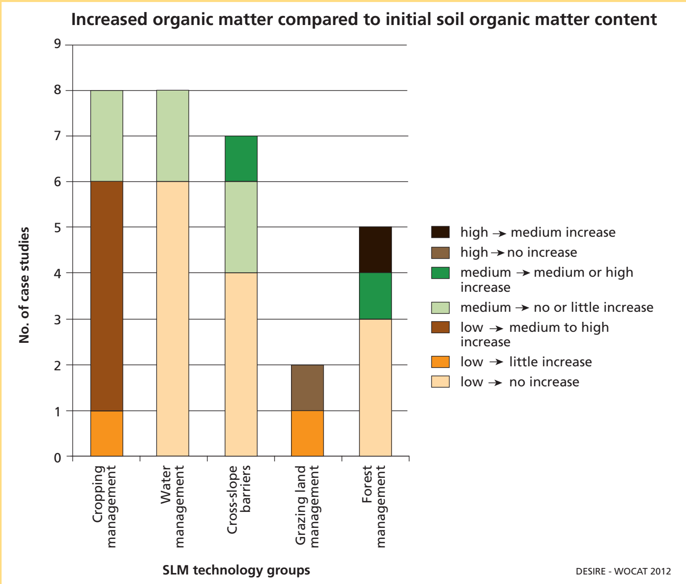


Figure 23: Increased organic matter compared to initial soil organic matter content.

organic matter was between medium and high for most of the cropping management technologies. Some increase in organic matter was also identified in five other technologies in all groups (except water management).

As stated earlier, most cases indicated a low topsoil organic matter before implementation. Comparing this with the impact now does not show high increases.

Surprisingly, most technologies which are applied on soils with low organic matter content do not improve the problem at all. This could be because it takes a long time for such an increase to be seen. Equally, it could be due to the difficulty of increasing organic matter under dry conditions. Exceptions are those cropping management technologies, which aim directly at improving soil organic matter. The reduced tillage examples from Spain and Greece already have a medium level of soil organic matter and therefore only improve it slightly. For all the other case studies, organic matter improvement is only one amongst several major impacts. Most of the water management, the cross-slope barriers and the forest management technologies do not impact on soil organic matter. However the reason for this could be that, due to its insignificance for these technologies, increasing organic matter was not assessed. This is despite the fact that the build-up of soil organic matter is much larger in grassland and forest under sustainable land management. This is probably because soil organic matter plays a more important role as an input factor for agricultural productivity on cropland.

Reduced **soil crusting and sealing** was not only observed for the reduced contour tillage example of Spain, where it was indicated as an observed degradation type, but also for some other technologies.

These are almost all within the cropping management group, where the Greece example of olive groves under no tillage showed the highest impact with over 50% of crusting reduction. The same level was also achieved by the other Greece example, the transport of freshwater from local streams, as salinization and, as a result, crusting is also reduced tremendously.

Vegetation issues

As **improved soil cover** (by crops, fodder, weeds, shrubs or dead material) is usually linked to more vegetation cover, it is for these same technologies that an increase in biomass (and related above ground carbon) was reported. An increase in soil cover or biomass was not indicated for any of the water management technologies. Although there were reports about increased production, it did not improve the level or time of soil being covered.

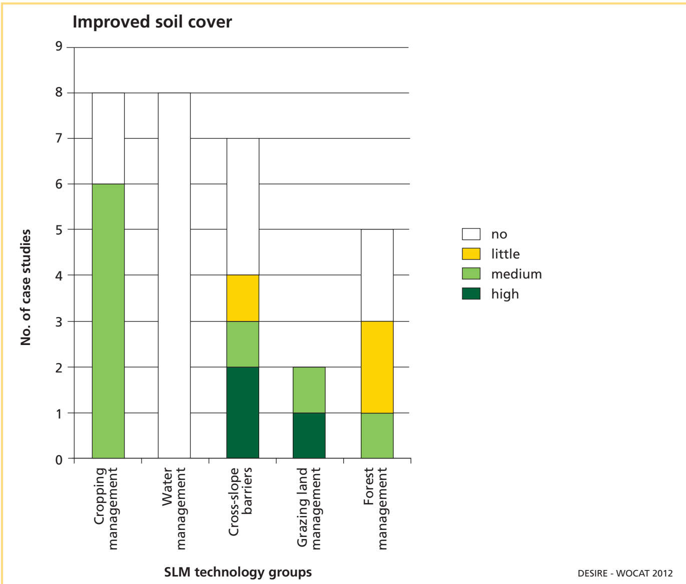


Figure 24: Improved soil cover across the SLM technology groups.

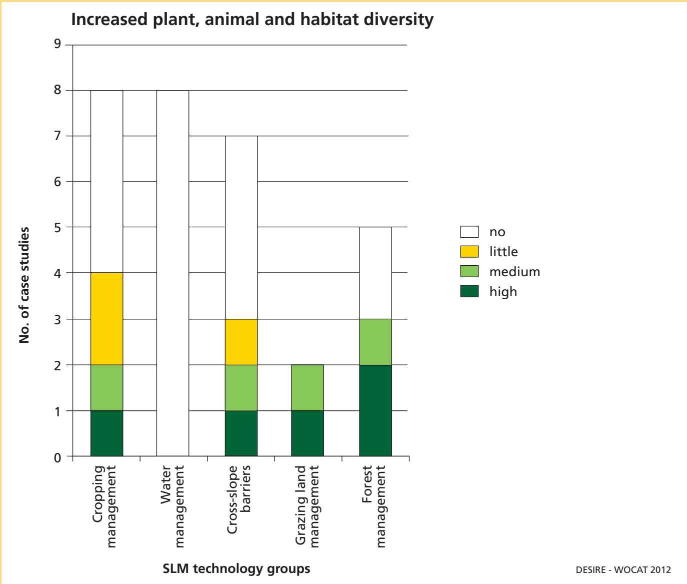


Figure 25: Increased plant, animal and habitat diversity across the SLM technology groups.

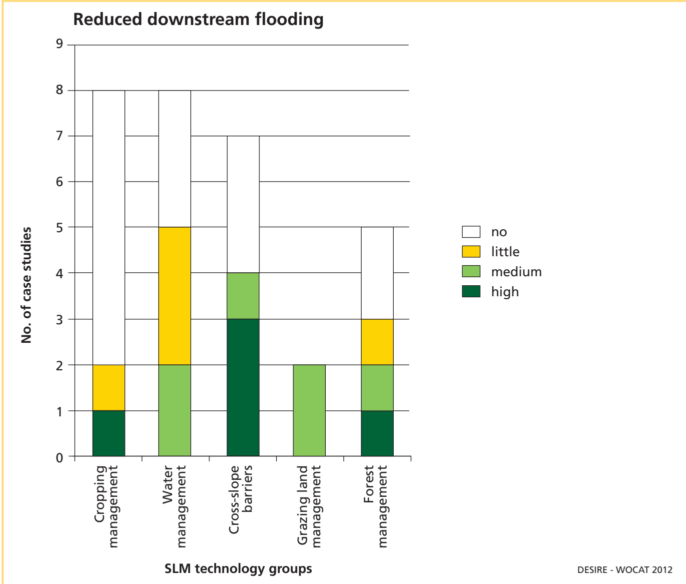


Figure 26: Reduced downstream flooding across the SLM technology groups.

Figure 25 presents a combination of plant, animal and habitat **diversity**, which was assessed separately. All reported impacts, however, refer mainly to increased plant diversity; only in six technologies do the impacts also refer to increased animal diversity and / or maintained habitat diversity. Considering that cropland usually has a low biodiversity compared to grazing land and forests[10], it is interesting that the cropping management technologies have a considerable impact here. From the documentation it becomes clear, that this relates mainly to the new plant species used in rotational systems.

An improved **biological pest and diseases control** was only reported from three case studies, namely (i) the 'ecological production of almonds and olives using green manure' from Spain; (ii) the 'land reclamation with agave forestry' from Mexico (both with high improvement); and (iii) the 'prescribed fire' from Portugal with little improvement.

Off-site benefits and disadvantages

Apart from the on-site benefits, such as increased productivity and better water availability, the off-site impacts of SLM practices, such as reduced flooding and damage on neighbouring fields, need to be evaluated. Reduced downstream flooding (see Figure 26), as a result of better management of intensive and extreme storms, can greatly benefit people some distance away from where the land has been improved. Although not easy to prove, all groups of technologies make some contribution to reducing floods; four out of seven cross-slope barriers have been assessed to have

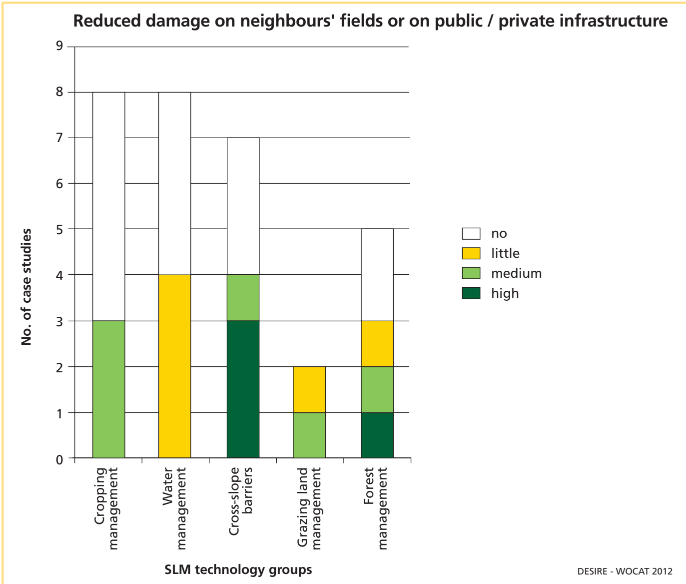


Figure 27: Reduced damage on neighbours' fields or on public / private infrastructure.

medium to high impacts, both grazing land practices have medium impacts, and three of the five forest management practices have been attributed with little to high impacts.

Benefits on neighbours' fields and public or private infrastructure (see Figure 27) have been particularly attributed to cross-slope barriers and forest and cropping management, and less to the direct water management. Still, all groups showed some reduction of damage off-site, demonstrating that damage caused by excessive water is a land management, rather than a purely water engineering, issue.

Costs

In compiling the cost of a technology it is often difficult to separate normal agricultural inputs from additional expenses. In some cases, e.g. reduced or no tillage, the costs are actually less than for the normal or conventional practice. Thus it is relatively difficult to determine the incremental (or alternative) costs (and benefits) for SLM[11].

Establishment costs are defined as those specific one-off, initial costs which are incurred during the setting up of a SLM technology[12]. These investments are made over a period of time that can last anything from a few weeks to two or three years. These costs typically include extra labour, purchase or hire of machinery and equipment, and seedlings. In general, there is no establishment phase involved in agronomic measures, but investments into specialised machinery like direct-seeding tractors can be considerable.

The "cheapest" SLM practices are within the cropping management group, where the majority of technologies require no extra costs compared to the more conventional land management practices. Grazing land practices are not expensive either but with these practices, the potential of production increase is smaller. Cross slope barriers range from cheap to expensive. The most expensive group is the water management. Compared with the potential benefits (see e.g. Figure 16), this group also has the highest potential of increasing the benefits / profits, thus making the investments worthwhile.

Maintenance costs are those that relate to maintaining a functioning system. They are regularly incurred and are accounted for on an annual basis[13]. In general, these are made up of labour, equipment, and agricultural inputs.

Compared to the establishment cost, the maintenance of the cropping management group can be quite high (over 300 $/ha). The reason for this is that this group of practices require annual inputs, such as renting machines and purchasing seeds, herbicides and fertilizer. As with the establishment costs, the water management group also has high

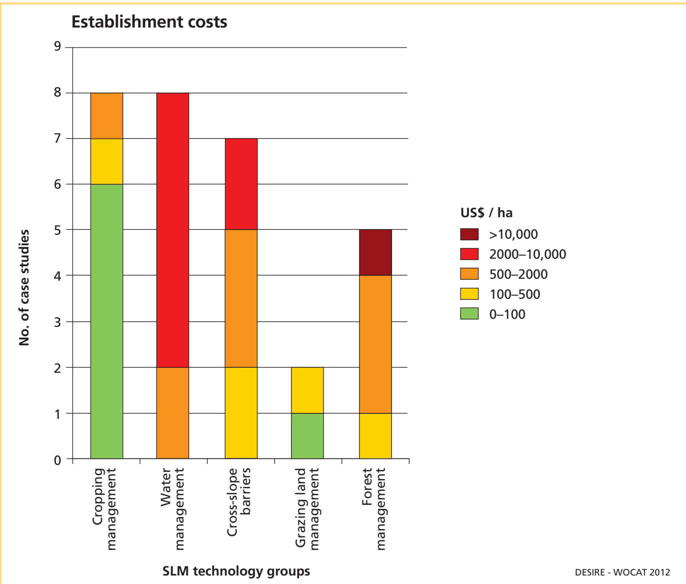


Figure 28: Establishment costs in relation to the SLM technology groups.

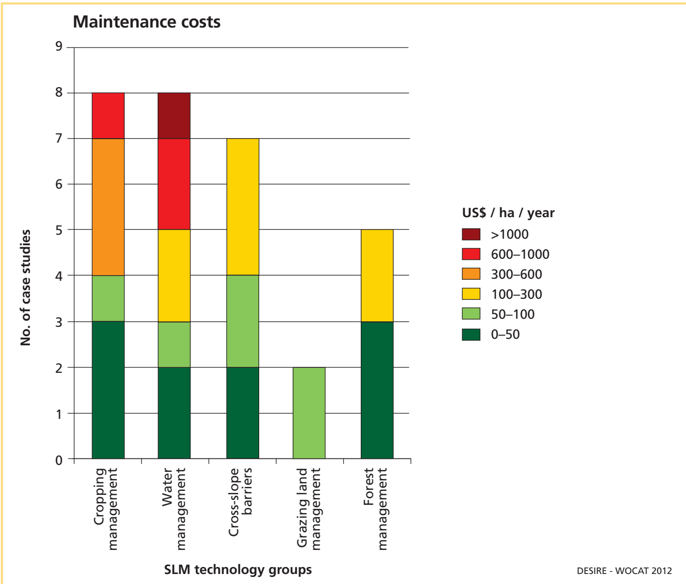


Figure 29: Maintenance costs in relation to the SLM technology groups.

[10] Alkemade et al., 2009

[11] WOCAT, 2007

[12] WOCAT, 2007

[13] WOCAT, 2007

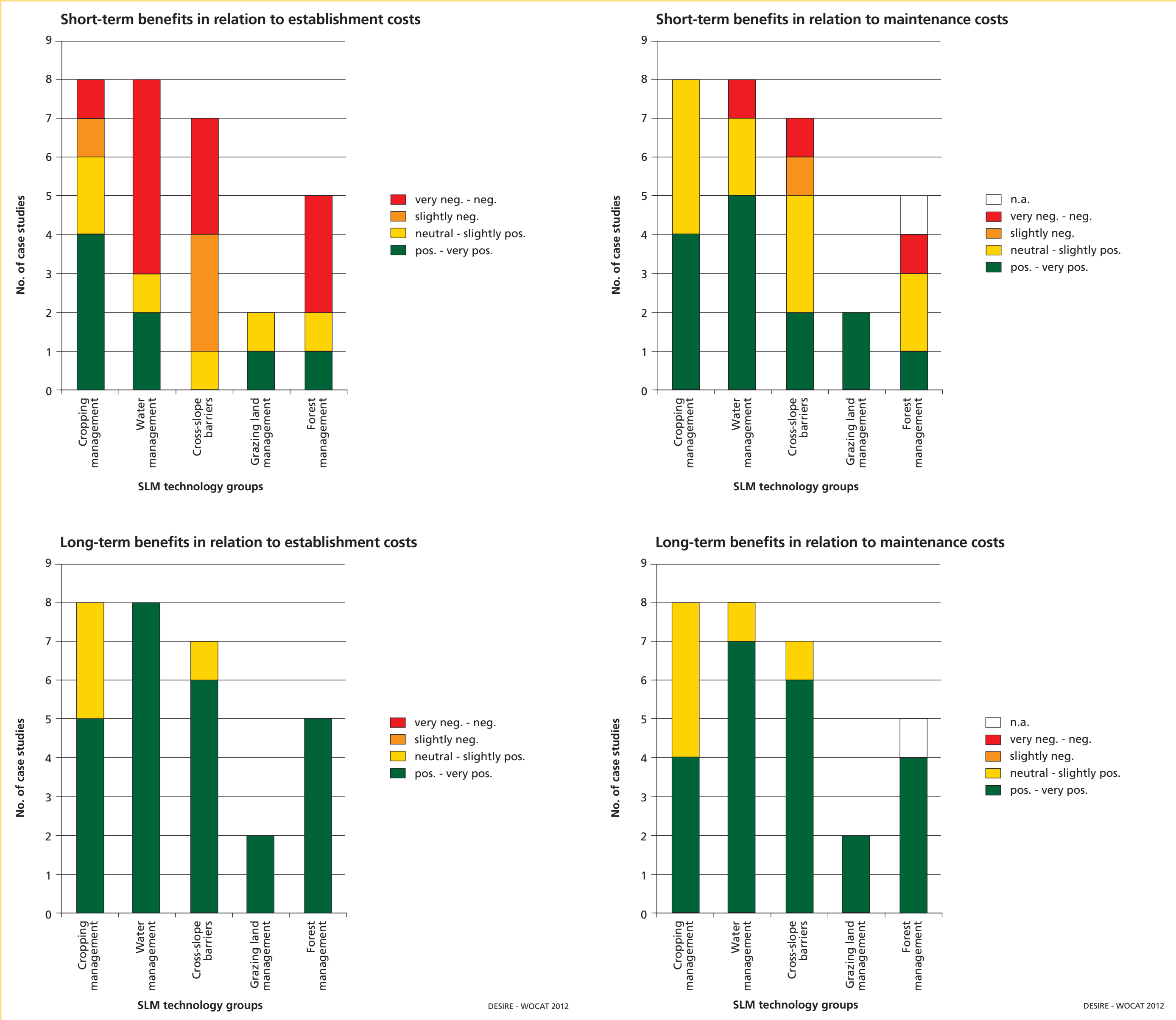


Figure 30: Perceived benefits of SLM technologies in the short and long term and related to establishment and maintenance costs.

maintenance costs. In contrast to this, cross-slope barriers are obviously rather cheap to maintain, even after heavy investments for their establishment, unless they happen to become damaged in extreme events. In the current analysis, grazing land and forest land management practices seem to incur low maintenance costs.

Land users do not always have to pay the full establishment and maintenance costs. In the studied cases, land users either paid almost all establishment costs (11 cases with contributions of 90-100%) or almost nothing (9 cases with contributions of 0-10%). Five case studies were somewhere between these two extremes and another five did not have


Morocco, Gudrun Schwilch


Cape Verde, Gudrun Schwilch

any establishment costs. Overall, land users paid 36% of the overall establishment costs (median value), the rest being subsidized by projects or the government. However, more than half of the technologies are fully maintained on land users' expenses. Experiences from other evaluations show that support for the land users for the establishment can be very helpful and lift the production to much higher levels. As long as the maintenance costs are fully covered by the land users, there are good chances of the system continuing without dependencies on external inputs. As such, costs can be a barrier for poor land users, even if their investment would pay off in the end. Having said this, it is necessary for any investment to also evaluate the benefits; the costs are only a valuable criteria when compared to the associated benefits.

Cost-benefit ratio

Cost and benefits are extremely difficult to assess, but are obviously a crucial factor in justifying SLM interventions. The basic problem is the lack of hard and reliable data[14]. Furthermore, non-economic costs and benefits are not perceived in the same way by different people and WOCAT is therefore interested in a subjective assessment by the authors. Many authors had difficulties in deciding what to include and what monetary value to attribute to inputs and benefits, which made a comparison rather difficult. Regardless of these difficulties, the bottom line is that without a positive perception of benefits, land users or donors are unlikely to invest in SLM.

Figure 31 shows that for most technologies, the long-term benefits in relation to costs (of any type) are positive to very positive. However, the picture for the short-term benefits is somewhat different. The short-term benefits are negative in relation to establishment costs for a significant number of technologies, especially in the water management, cross-slope barrier and forest management groups. This implies that most implementations of SLM technologies can be expected to give negative returns on investment in the first 1-3 years, and in order to generate economic value from the SLM technologies in the long term (5-10 years), land users will need support from revolving funds, PES, or other financial mechanisms.

Figure 30 confirms the observation made earlier that the Water Management technologies are the most expensive ones. Their cost-benefit ratio in the short term is therefore mostly negative or even very negative. Exceptions to this pattern include the recharge well in Tunisia and the transport of freshwater in Greece, although they are both very expensive. For the cross-slope barriers, only one of the technologies (terraces China) has a slightly positive cost-benefit ratio. More than half of the forest management group also have negative or even very negative cost-benefit ratios. An exception here is the prescribed fire from Portugal, due to its immediate benefit in preventing more damaging wildfire.

In the long term, all investments made for the establishment are giving a positive return. Regarding maintenance, 83% of the cases perceived positive, or at least neutral, benefits within the first five years. In the long term, the maintenance inputs gave positive returns in all cases. It is only some of the cropping management technologies that remain at a neutral to slightly positive level.

Adoption

In 62% of the cases, the land users have implemented the technology with external material support (eg payment, subsidised machinery) and in 38% of cases, they have done it wholly voluntarily. From the figures available, there are over 4000 families who are engaged in sustainable land management within the DESIRE study sites.

More than half of the technologies report a growing spontaneous adoption trend, see Figure 31. For others it is too early to know. Of course, not all technologies are suited to spontaneous adoption by land users. Some technologies require high initial investments, which need to be provided by a project or through subsidies.

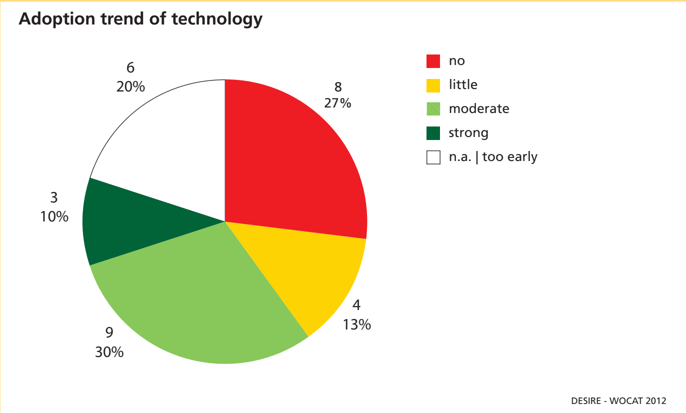


Figure 31: Adoption trend towards (growing) spontaneous adoption of the Technology.

[14] WOCAT, 2007

Analysis of SLM approaches

Introduction

According to WOCAT, a SLM approach constitutes 'the ways and means of support that help introduce, implement, adapt and apply SLM technologies on the ground'. An overall concept that best describes the two basic ways in which adoption can spread, namely through promotion (incentives) and spontaneously, is an 'enabling environment' within which conservation thrives[15]. Compared to the 30 technologies, analysed above, only 8 corresponding approaches were documented to illustrate how these technologies were implemented in the field.

The approaches documented in this book range from examples of testing and disseminating new technologies to training and awareness raising campaigns, rural development programmes and government programmes in forest regulations.

Approach type and focus

WOCAT differentiates between three types of approaches; (i) traditional / indigenous; (ii) recent local initiative / innovative and (iii) project / programme based. Six out of the eight approaches are project or programme based and only the Tunisian case is based on a recent innovation. The Mexican approach is a combination of all three types.

The focus of the approach is not always on SLM, but can also be on other activities. Having said this, half of the DESIRE approaches do indeed focus on the conservation aspect; two include other aspects and another two focus mainly on other activities, such as registered alcohol production in Mexico and forest activities' productivity and profitability. Often, SLM is just one element of a wider rural development programme.

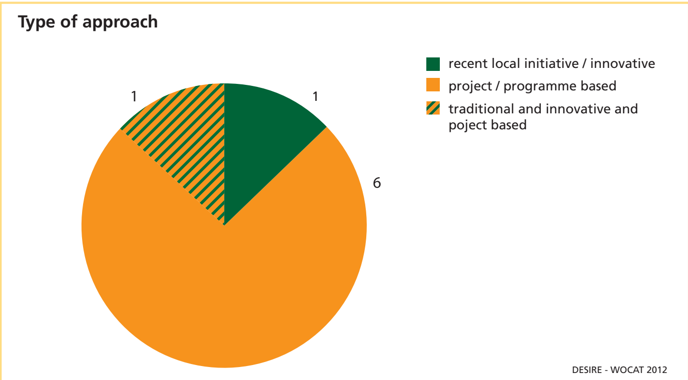


Figure 32: Type of approaches.

Objectives

It was often the case that the authors of the approaches paid more attention to environmental impacts than to institutional strengthening or training. As a result, most case studies primarily mention the control of degradation and desertification as the first objective. A second objective is the enhancement of productivity and the intensification of production. Another important objective mentioned by the majority of authors is the improvement of farmers' livelihoods, primarily through more income. More specific objectives include the implementation of national and regional forest management policy at the local level in Portugal and removing marginality and socio-economic opening up the region in Morocco.

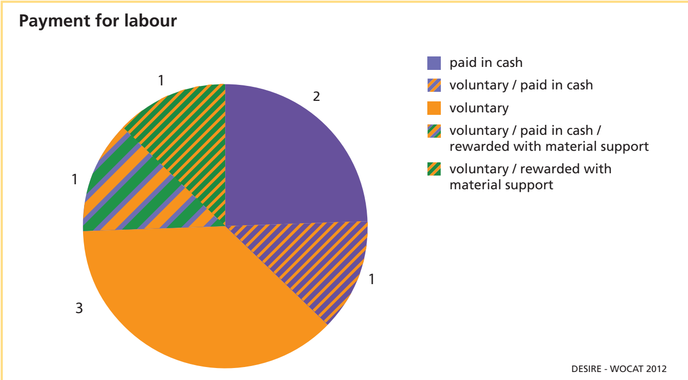


Figure 33: Rewarding labour under the reported approaches.

Support for labour

Labour provided by land users is only fully paid in two of the documented approaches. All others rely, at least partially, on voluntary contribution by land users; three of the cases rely fully on these voluntary contributions. In Cape Verde, labour is fully paid because of widespread poverty.

Funding sources

Roughly one third of funding comes from international sources, such as international institutions (e.g. FAO) or research programmes (e.g. EU). This varies from 0% in two cases to 100% in one case (Russia). The national government is the most important donor, supplying over 50% of

Turkey, Sanem Açıkalın

Greece, Hanspeter Liniger

funding, mainly in the government programmes of Chile, Mexico, Morocco and Tunisia. The local government is only important as a funding source in Spain. The local community and the land users themselves contribute in only three case studies, namely in Portugal (40%), in Mexico (10%) and in Tunisia (10%). This seems to contradict what was said earlier in the technology analysis section, but here we refer to eight approaches only and combine the technology implementation costs with the approach costs (e.g. training).

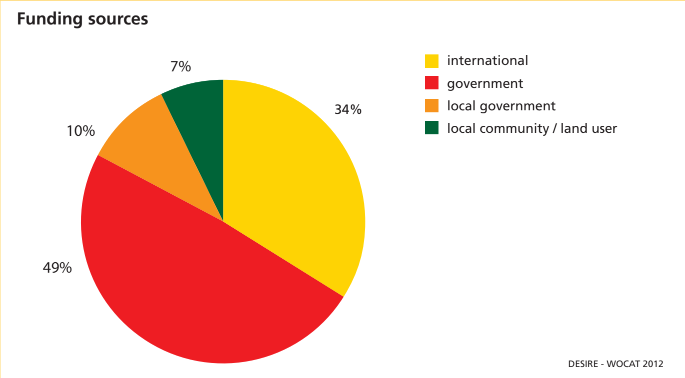


Figure 34: Average proportions of funding sources in reported approaches.

Community involvement

In more than half of the case studies, the local community is actively involved in all stages of the approach. This is a clear plea for participatory development, already recognised in earlier approach analyses[16]. However, it is also remarkable that especially in monitoring & evaluation and research, almost half of the approaches don't involve the local stakeholders at all (although, it should be noted that some have not started this phase yet).

This analysis shows that most of the case studies are clearly driven by experts. This is supported by the fact that in six of the eight approaches, the decision on the choice of the SLM technology was made by SLM specialists in consultation with land users. Only in Mexico was it a joint decision of various stakeholders, and in Tunisia it was a decision made by the land users supported by SLM specialists.

Most case studies noted a moderate to great difference between participation of men and women. Usually, men perform the hard manual work in the field or in the implementation of SLM measures, while women are more responsible for the work in and around the house. Only Portugal and Russia did not identify a gender difference. It is remarkable that in Cape Verde, 40% of the households are headed by women due to migration of their husbands to other areas or countries.

Disadvantaged groups are often specifically involved, except in the Moroccan approach. In particular, there is a special focus on poor or unemployed people.

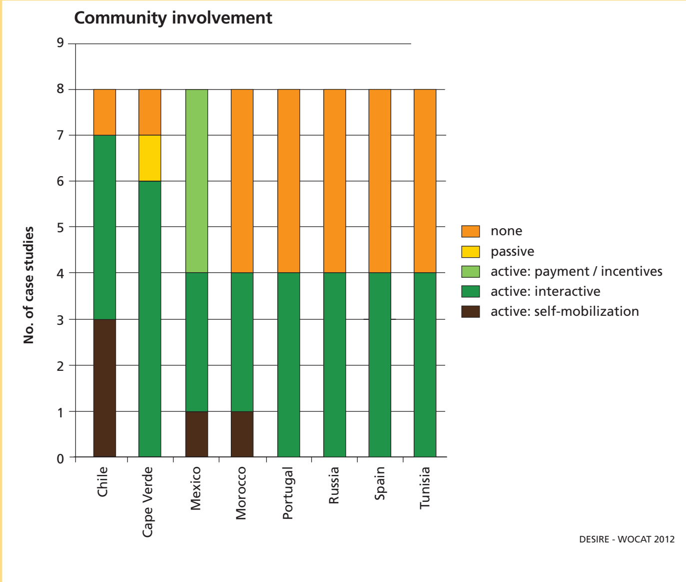


Figure 35: Community involvement in different stages of the approach.

Training, advisory service and research

These elements often form a key element of an approach. Training was provided in all eight approaches, mostly to land users and field staff / agricultural advisors. The training was provided in the form of public meetings, information sessions, site visits, demonstration areas, on-the-job and farmer to farmer sessions. All approaches work with an existing advisory service system, which is in most cases entirely adequate to ensure the continuation of the started SLM approach activities. This is a strong argument for further support of extension services.

The effectiveness of training and extension was mostly considered good to excellent, except in Spain.

Apparently, there is a serious lack of training for land users in Spain. The authors write that currently the extension

[16] WOCAT, 2007

system is focused on control rather than advice and training activities. There is more information and awareness building required for land users, as information is often only available at political or research level.

Research was part of the approach in all cases, which is not surprising as all these approaches were documented through the DESIRE research project which is based on local research institutions. All indicated a moderate or great level of research inclusion, except for Cape Verde, where only little research was used. Almost all research is based both on on-station, as well as on-farm experiments.

Impacts and adoption

All approaches perceive a moderate (3 cases) to great (5 cases) impact on improved SLM.

Adoption of the approach by other land users, other projects or in other areas is reported to be widespread. Almost all authors answer the respective question with 'yes, many', except for Russia ('some') and Mexico, for which it is too early to answer this.

Whether the approach has led to improved livelihoods / human well-being, improved the situation of socially and economically disadvantaged groups or helped to alleviate poverty was answered as shown in Figure 36.

Five out of the eight approaches have an impact on all three socio-economic issues. For Mexico, it is too early to assess these impacts. In Morocco, poverty alleviation is not achieved, because the small farmers and landless peasants were not sufficiently involved and have therefore not really benefited from the approach.

The use of subsidies and their long-term impact on the implementation of SLM was not considered to be a problem in any of the study sites. On the contrary, in six approaches the impact of subsidies was valued greatly positive and in one still slightly positive (Morocco). Only in Tunisia has the willingness to invest in SLM technologies without receiving financial support decreased due to the land users relying on being paid for the area treated. However, it is not only in Tunisia that there is uncertainty around whether land users can continue the approach activities without support, but also in Chile and Spain. In Portugal, it is impossible, as the forest owners do not have the financial capacity to apply and support the activities by themselves. This demonstrates that in these eight studied dryland areas, SLM approaches

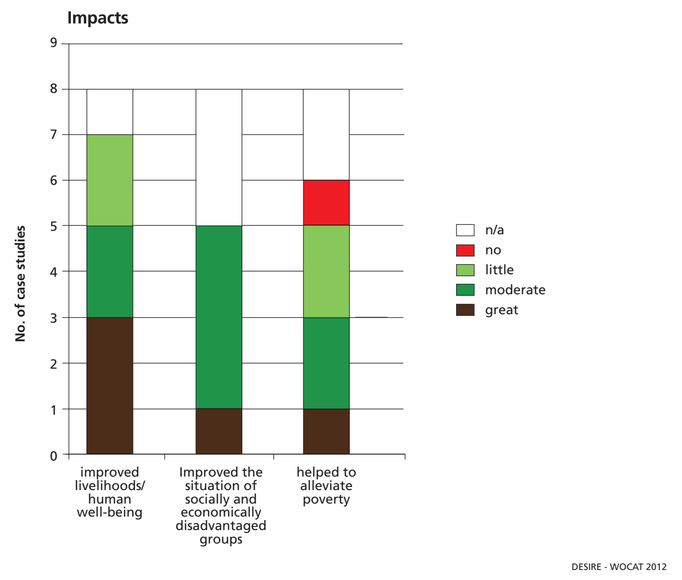


Figure 36: Socio-economic impact of approaches.

are not capable of generating a self-supporting, market driven mechanism in which the continuation of the approach is guaranteed. This implies that financial mechanisms are required to support the starting phase of SLM approaches. Such mechanisms could include revolving funds, contracts or payment for environmental services schemes.

Motivation of land users

In most SLM approaches, land users are driven by benefits from increased production, profitability, and/or payments and subsidies. It is remarkable that in the two Western European examples, from Spain and Portugal, the land users are mainly motivated by rules and regulations (fines) or enforcement. This is not the case anywhere else. As already discussed above, payments and subsidies play a key role in most of the approaches (exceptions here are Russia and Portugal). In five approaches, production and / or increased profit(ability) and / or improved well-being / livelihood are very important. Aesthetic and environmental consciousness seem to play a minor role.

Turkey, Felicitas Bachmann

Morocco, Gudrun Schwilch

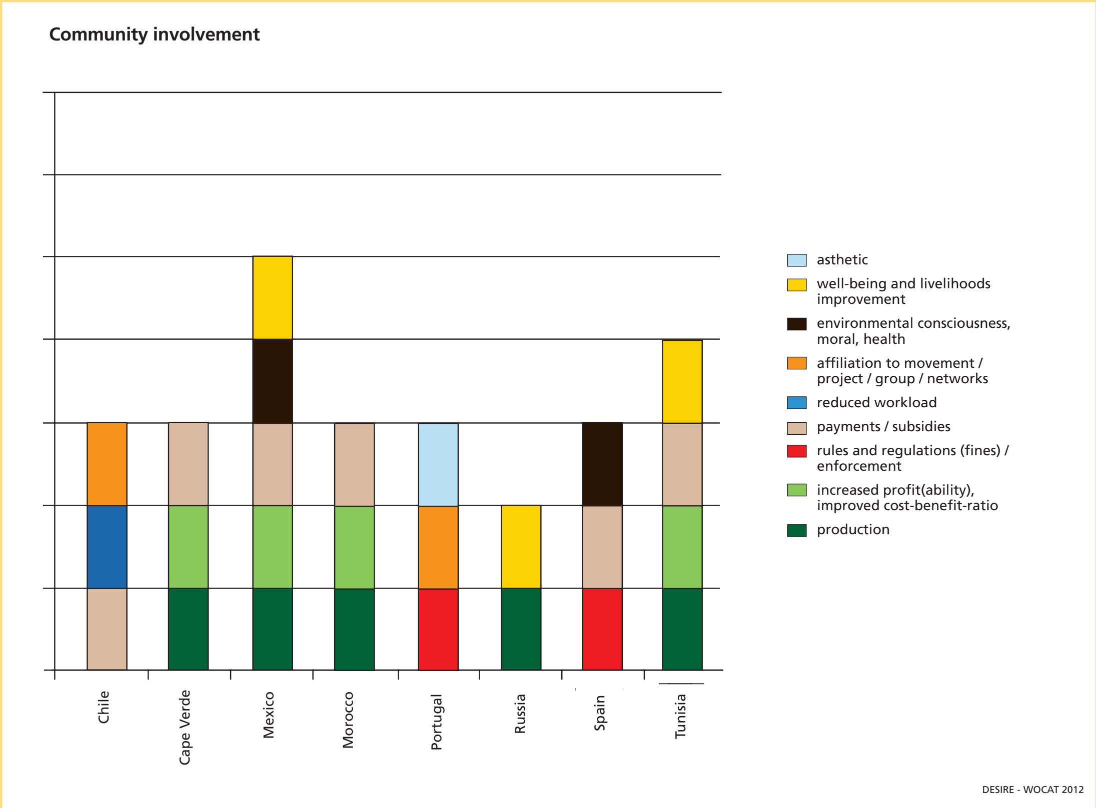


Figure 37: Main motivation of the land user to implement SLM.

Morocco, Gudrun Schwilch

Spain, Erik van den Elsen

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Spain, Erik van den Elsen

1.4 Conclusions and policy points

This book has discussed and evaluated strategies for Sustainable Land Management (SLM) that were developed and tested, with the aim to combat degradation and desertification, in 17 dryland areas in different parts of the world. The work and associated outcomes have been taken from a large research project involving scientists, land users, local communities and NGOs. The project developed a new approach (the DESIRE approach) for stakeholder – science collaboration in SLM projects and programmes. The DESIRE approach is founded on WOCAT methodology and tools, which have been under continuous development since their initiation in the 1990s, and have shown to foster successful implementations of SLM strategies in many places in the world[1].

The embedding of WOCAT methods and tools in the DESIRE approach was demonstrated to be of particular value for the identification, assessment and negotiation of SLM technologies and approaches in the DESIRE study sites, despite the large differences in their biophysical and socio-economic contexts.

Through the DESIRE project, 38 case studies were investigated; 30 for SLM technologies and 8 for SLM approaches. These case studies spanned a wide range of countries and covered a wide variety of bio-physical and socio-economic conditions. As a result, they provided valuable practical data that can be used to extract a wealth of generic recommendations and policy points. Some of these points are new, while others provide a confirmation of earlier case studies, such as those presented in previous WOCAT book 'where the land is greener' (WOCAT, 2007) and 'Sustainable Land Management in Practice: Guidelines and Best Practices for Sub-Saharan Africa'[2].

This chapter provides a summary of the DESIRE approach (chapter 1.1) and the project results (chapters 1.2 and 1.3). It aims to describe important issues and practicalities that have to be considered for a successful implementation of SLM projects. In conclusion, it summarises a number of important policy points.

The DESIRE approach to remediation

In a nutshell the DESIRE approach consists of 5 steps:

1. Establishing land degradation and SLM context and sustainability goals. This includes the description and mapping of the site, outlining the particular desertification problems, using indicator sets and the tool developed in DESIRE to make an ex-ante assessment of desertification risk, and finally stakeholder analysis, along with formulating the sustainability goals of all stakeholders involved.
2. Identifying, evaluating and selecting SLM strategies. This involves the identification, assessment and selection of SLM options in a participatory process, which brings together researchers and other stakeholders.
3. Trialling and monitoring SLM strategies, which entails implementing and monitoring SLM technologies in field trials.
4. Up-scaling SLM strategies. This involves the regional modelling of biophysical and socio-economic effects of SLM strategies.
5. Disseminating the information, which refers to the communication and dissemination to stakeholders and relevant policy arena.

The DESIRE approach can be effectively implemented by any project or programme that aims to combat land degradation. However, for the DESIRE process to be successfully applied, there are four key requirements:

1. An integrated multi-disciplinary approach,
2. Close collaboration between scientists and stakeholders,
3. A sound scientific basis, for example through field experimentation and state of the art modelling, and finally,
4. A continuous dissemination and communication process aimed at stakeholders and policy makers that is initiated right from the start.

These four key factors are discussed in detail below:

1. **Integrated multi-disciplinary approach**
   Desertification, being a complex problem, requires an integrated approach, in which various disciplines are involved. This integration is necessary so that a full site specific understanding of bio-physical, as well as socio-economic, issues can be obtained before measures are

Morocco, Gudrun Schwilch

[1] WOCAT. 2007. Where the land is greener – case studies and analysis of soil and water conservation initiatives worldwide. Eds: Hanspeter Liniger and William Critchley. CTA, FAO, UNEP and CDE, Berne, Switzerland.

[2] Liniger H.P., Mekdaschi Studer R., Hauert C. and Gurtner M. 2011. Sustainable Land Management in Practice – Guidelines and Best Practices for Sub-Saharan Africa. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO).

actually implemented in the field. In the DESIRE project, the involvement of different disciplines (environmental sciences, social sciences, development specialists, agronomists) allowed a greater depth of understanding regarding the biophysical and socio-economic issues in the specific dryland sites.

2. **Stakeholder – science collaboration**
   It is also vital to involve local stakeholders from the very start of a project, as this ensures that their site specific knowledge and experience can be taken into account, and that their views and practical experience are integrated into the project. The close collaboration in such a transdisciplinary approach creates a greater sense of ownership, and increases the chance that selected strategies will actually be implemented and adopted more widely. Most important aspects of involving local stakeholders are motivation and ownership, and these should never be underestimated. When local people are not motivated to cooperate and do not feel part of the project, because, for example, they do not see the value of the research, or perhaps do not see what they stand to gain from it, it can seriously jeopardise the success and effectiveness of project outcomes. Getting people involved as partners and keeping them motivated requires a continuous effort of stimulating them and informing them about what is happening within the project. Stakeholder participation can be further advanced by also involving (local) NGOs from the start of a project. Facilitation of the whole stakeholder process itself, embedded within the 'DESIRE approach', needs to be done by people trained for this purpose, such as skilled moderators.

   Without such an integrated, site specific understanding of the desertification issues at hand, and without the involvement of stakeholders, it is almost impossible to come to a selection of strategies against desertification that is a) suitable for the specific area in question, b) physically effective, as well as c) socially and economically acceptable.

3. **A sound scientific basis**
   Local knowledge needs to be backed-up by scientific knowledge. Participative approaches should not be misused to justify inaction due to scientific uncertainty, but need to be supplemented by rigorous scientific research for several reasons.

   Firstly, scientists generally have better access to remediation technologies that have been developed elsewhere. It is easier for them to find the right information sources and, as a result, they are well placed to pass relevant information on to local stakeholders. Scientists also have access to software tools that enable objective evaluation of technologies, such as the use of evaluator software in step 2 of the DESIRE approach. These tools enable local stakeholders to make a well-informed decision as to what SLM strategy is most suitable and effective for them, incorporating both physical and socio-economic criteria. Scientists can, through their understanding of the principles on which measures are based, also assist in adapting measures to local conditions, thus optimising the chance of implementation success.

   Secondly, scientists are needed to support the land user in testing and monitoring the selected SLM technologies and approaches in the field. Scientists have access to technical tools, which can effectively evaluate the impacts of different land management options in the field (eg. yields, soil moisture values, nutrient concentrations, etc.), as described in step 3 of the DESIRE methodology (chapter 1.1).

   Finally, scientists have access to state-of-the-art mapping and modelling methods, which can be used to up-scale the findings. This will ensure that expectations to increase productivity and reduce land degradation, whilst protecting important ecosystem services, can be met when they are applied in different contexts.

4. **Dissemination and communication from the start**
   Continuously providing the right information, to the right people, in the right form is vital, not only to keep stakeholders involved, but also to optimise the chance that project results will actually be used. DESIRE recognises that information and knowledge held by researchers and non-scientist stakeholders must be shared much more effectively to ensure the research outcomes can achieve the maximum possible impact in desertification-affected countries.

   Therefore, a dissemination strategy should be developed at the start of a research project and should clearly outline who the relevant stakeholders are and what information they should be given at what stage of the project. The communication strategy should not only include stakeholders that are directly involved with the project, like farmers, local and regional policy makers, contributing NGOs and scientists, but also relevant and influential politicians, as well as local, national and international, media. Each type of stakeholder needs to be addressed in ways that are suitable for them. DESIRE

China, Hanspeter Liniger

Morocco, Gudrun Schwilch

is, therefore, using a wide range of dissemination products, from the written word to videos and podcasts, to explain the science and recommendations from the start of the project. To achieve this, the DESIRE project makes research outcomes and recommendations available in a web-based Harmonised Information System, presented in non-scientific language. This is a direct information service for those who have internet access, but also provides printable material to be circulated in traditional ways to those who do not.

The role of WOCAT instruments in the DESIRE project

The WOCAT/LADA/DESIRE mapping questionnaire (QM) and the associated database provide vital data on which type of degradation processes are occurring, where, why, and in which degree, enabling researchers to obtain relevant site specific expert knowledge quickly and efficiently. The questionnaire especially facilitates mapping of current SLM technologies in the area, including their effectiveness and impacts on the threatened ecosystem services. The WOCAT/LADA/DESIRE mapping questionnaire is best employed in the first step of SLM projects (setting the context).

The use of the WOCAT questionnaires for Technologies (QT) and Approaches (QA), along with the associated databases, played a vital role in the participatory approach, in which the SLM technologies that will be implemented in the field are identified, assessed and selected, in collaboration with stakeholders (step 2 of the DESIRE approach).

Both the WOCAT/LADA/DESIRE mapping method and the WOCAT questionnaires and associated databases are available on-line, and are thus available world-wide for anyone to use. As a result, information on SLM options, that was previously scattered and inaccessible, is now being standardised and collated, facilitating the sharing of land management strategies to combat desertification. Through its search facilities, the WOCAT database can be used to find strategies that could be suitable in a certain location, based on its similarity in human-environmental characteristics to other locations described in the WOCAT database. Although in many cases, any potentially suitable strategies would have to be adapted to local circumstances, this database does allow the introduction of new strategies, based on tried and tested experiences in other places.

Finally, WOCAT methods provide a way to compare information between different sites because the same standardised methods are used across all sites.

WOCAT/LADA/DESIRE mapping of land degradation and current SLM

The main conclusions from the application of the WOCAT/LADA/DESIRE mapping in the DESIRE study sites are as follows.

Within the DESIRE study sites, the areas of cultivated land, grazing land and mixed land are approximately the same size (between 175.000 and 200.000 ha in total). Forestry covers about 100.000 ha. Cropland and grazing are the dominant major land use types in relative terms. The area covered by the major land use types has remained stable over the past 10 years, but the land use intensity has increased in about 20% of the grazing land.

The main degradation type in the DESIRE study sites was found to be erosion by water; however, in 70% of the degraded areas, more than one degradation type is found. The largest surfaces of degraded land occur in cultivated land and land under mixed use, covering 89% and 100% of these areas respectively. The degree of degradation was found to be moderate or strong in most cases, with only small areas showing extreme degradation. However, in most sites, degradation was found to be increasing, mainly under mixed land use, followed by cultivated land and grazing land.

Inappropriate soil management was identified as the most important direct cause for degradation, but in more than half of the mapping units, multiple causes were identified; for 20% of the degraded area five or more causes were found. This illustrates the complexity of the desertification problem, and highlights the need for SLM technologies to address multiple forms of land degradation. Population pressure and land tenure were found to be the two most important indirect causes; again often in combination with other indirect causes. The most frequent combination of indirect causes included population pressure, land tenure and poverty, combined with governance, institutions and politics (14% of the degraded area).

Land degradation was reported to have moderately negative impacts on ecosystem services in the DESIRE study sites over 94% of the degraded area. Production services were most affected in mixed land use (49% of the area with impacts on production services only), followed by cultivated land (24%) and grazing land (19%). The largest part of the area under high negative impact on ecosystem services was observed for regulating ecosystem services, indicating that these require specific attention in the process of developing and implementing remediation strategies.


China, Erik van den Elsen


Morocco, Gudrun Schwilch

Concerning SLM, the most widely applied technologies were SLM technologies in the groups of 'Grazing land management' and 'Conservation agriculture and mulching'. The technologies for cultivated land cover a larger total area, but are categorised in more different conservation groups. SLM measures appeared to be most effective on cultivated land where over 20% of the land under SLM measures had high to very high effectiveness, compared to less than 4% of the land under forest and grazing. For most conservation groups applied in the DESIRE study sites the effectiveness is moderate to high. Combinations of two or more conservation measures were reported for about 40% of the mapping units or approximately 20% of the area under conservation. Sites with single conservation measures appeared to have a relatively low effectiveness of conservation. This confirms that combinations of conservation measures are more effective than single measures.

Conservation measures in the DESIRE study sites have positive impacts on ecosystem services over the largest part of the area under conservation. Impacts are most positive on regulating ecosystem services and were mostly observed in forest and grazing land. Only 8% of the area under conservation measures with positive impacts on ecosystem services was found in cultivated land. Negative impacts of conservation measures were reported for production services and socio-cultural services for respectively 20% and 5% of the area under conservation (but only at a few sites). Obviously there is scope for improving contributions from SLM to ecosystem services, especially in cultivated land.

WOCAT questionnaires on SLM technologies and approaches

SLM technologies

The 30 case studies of technologies discussed in this book covered five groups of SLM technologies, namely cropping management, water management, cross-slope barriers, grazing land management and forest management. Most of them are applied on cropland, although grazing land is playing a key role in drylands, at least regarding its spatial dimension (see mapping results above). They also addressed all six types of degradation: water degradation, biological degradation, physical soil deterioration, chemical soil deterioration, wind erosion and water erosion. Depending on the kind of degradation addressed, agronomic, vegetative, structural and management measures were used, or a combination thereof. Most of the technologies aimed to prevent or mitigate degradation, and only few were described as rehabilitation technologies, mostly putting highly degraded forest or grazing land back into production. This reflected the state of land degradation in the various study sites, which had not passed thresholds of extreme loss of productivity or ecosystem service provisioning and, as such, did not yet require rehabilitation. Technically, the SLM technologies assessed are mainly functioning through increasing the infiltration, controlling runoff and improving ground cover. These actions support each other and can be considered key functions of SLM technologies in drylands. Most technologies are applied by small-scale land users, a group that is often underestimated regarding their investment and innovation, as well as their role in worldwide agricultural production[3]. As confirmed by previous studies, individual, as well as regulated communal land ownership and land use rights, facilitated the implementation of SLM.

The results show that, for the most part, the SLM technologies had positive effects on bio-physical processes, relevant to agricultural production, and on ecological services of the land, although in varying degrees. For example, organic matter content did not increase very much, but water availability did increase and land and water degradation were reduced. An obvious issue for drylands is the importance of improved water management. One of the main aims of SLM in rainfed systems is reducing water losses through runoff, and direct evaporation loss from unprotected soil surface. On irrigated land water use efficiency of the irrigation system and water harvesting technologies show the greatest potential and benefits.

Cropping management technologies and cross-slope barriers are the ones being most effective in reducing surface runoff and increasing soil moisture, which are major concerns in drylands. At the same time this confirms that the desired technical functions of the SLM technologies (see above) are achieved. Cropping management measures were found to be especially sensitive to increased droughts and dry spells, which is a particular concern in view of current climate change. However, most of the technologies are tolerant to the expected climatic variations, and, in some cases, the technologies are even able to reduce vulnerability to climatic threats, e.g. due to improved soil water availability.

Half of the technologies also provide off-site benefits, such as reduced damages on neighbours' fields, public / private infrastructure or reduced downstream flooding. This might be an argument to provide reward schemes to farming communities for providing ecosystem services. In view of disaster risk reduction, technologies with additional off-site benefits need more attention.


Italy, Erik van den Elsen


Morocco, Gudrun Schwilch

The costs of a technology are difficult to assess, especially in cases where the costs are actually less than for the normal or conventional practice (e.g. with no tillage). Low-cost technologies (mostly below 100 US$/ha) are primarily found within the cropping management and grazing land management group, although their maintenance costs can be considerable. The water management technologies are the most expensive (2000 – 10,000 US$/ha), but this group also has the highest potential of increasing the profits, thus making the investments very worthwhile. Furthermore, the maintenance costs are usually rather low, i.e. below 300 US$ / ha / year.

The cost-benefit analysis showed that nearly half of the land users earn most of their income outside of their farm. It was also found that, for the most part, technologies are profitable in the long run, but less, and in some cases not at all, profitable in the short run. Furthermore, land users themselves were found to pay around a third of the implementation costs (often in the form of labour), but usually all of the maintenance costs. This suggests that providing funding to implement technologies, e.g. through revolving funds or payments for ecosystem services, can be an effective way to enhance adoption, as the implementation costs are what makes measures unprofitable in the short run. This is especially the case for the more expensive cross-slope barriers and water management technologies. However, despite the constraints due to investment costs, there was a growing spontaneous adoption trend for more than half of the technologies.

SLM Approaches

Eight SLM approaches were studied within DESIRE and are discussed in detail in this book. In at least half of these cases, the local community was involved right from the very beginning. The decision to implement certain measures was still often taken by SLM specialists, but always in consultation with land users. All approaches work with an existing advisory service system, which ensures the long-term continuation of the approach activities. In many countries, agricultural advisory services have been reduced due to economic pressure. However, these services have proven to be a key for up-scaling SLM and should, as a result, be strengthened to enable promotion, further development and adaptation of SLM to changing environments and needs.

Approaches were perceived to have moderate to great impacts on SLM, and most approaches were found to contribute to improved livelihoods, decreased poverty and improved situations for socially and economically disadvantaged groups. The main reasons that land users choose to implement SLM measures were found to be increased production, profitability, and/or payments or subsidies. Environmental consciousness played a minor role. Thus, the challenge is to devise policies that are beneficial to environmental, economic and social concerns, i.e. decreasing degradation and improving ecosystems, while at the same time enhancing agricultural productivity and the livelihoods of land users. Research is needed to show and quantify these desired impacts of SLM practices. Making land users more aware of environmental issues and short- and long-term advantages, such as increased profitability, as well as including them in assessing the benefits of SLM – by being part of the research – will increase their motivation to implement SLM measures.

Policy points

This final section summarises the main conclusions arising from the DESIRE project that are of relevance to policy makers:

- SLM options need to be developed and evaluated by capitalising on close collaboration of scientists with stakeholders, and tailoring options to local needs and priorities.
- It is important to consider local knowledge and traditional approaches to land management alongside the latest technologies emerging from the research community and work to combine insights from both of these sources.
- A structured process where stakeholders work together at a local level to identify, evaluate and select SLM options for field testing has proven to be effective. The implementation and monitoring phase needs to take into account the criteria for success, as identified by the stakeholders during the participatory planning process.
- Standardized assessment and documentation, with the help of the WOCAT tools, enables the evaluation of current practices, the comparison of implemented SLM technologies and approaches across sites, and the mutual sharing of experiences through a variety of formats.[4]
- Rigorous impact assessment is required to evaluate whether the expected bio-physical and socio-economic benefits have been realised.
- SLM has multiple ecological, economic and social benefits, which go beyond the potential to reduce land degradation and desertification, e.g. addressing global concerns of water scarcity, resource use efficiency, energy supply, food security, poverty alleviation, climate change and biodiversity conservation.
- When taking into account the multiple benefits, investments in SLM are completely justified and may require funding schemes from private and public sectors, especially when involving small-scale land users and marginalized people.


Turkey, Erik van den Elsen

[3] IAASTD, 2009. Summary for Decision Makers of the Global Report. International Assessment of Agricultural Knowledge, Science and Technology for Development. Island Press, 46 pp.

[4] Accessible at www.wocat.net and through the DESIRE Harmonised Information System at www.desire-his.eu

Part 2

Case studies

Cape Verde, Erik van den Elsen.

Desire for Greener Land

Case studies of sustainable land management

30 technologies and 8 approaches documented under the WOCAT methodology by DESIRE contributors


Transport of freshwater from local streams
p 121
Olive groves under no tillage operations
p 81
Drip irrigation
p 133
Controlled grazing in deciduous woods
p 173
Russian
Concerted thinking on common problems of water scarcity
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Italy
Turkey
Woven wood fences
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P. R. China
Tunisia
Greece
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Fodder crop production
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Rangelands resting
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Dryland watershed management approach
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Botswana
Roof rainwater harvesting system
p 137
Biogas
p 193
WOCAT

2.1 SLM case studies

Case studies – titles and short descriptions

SLM Technology

Cropping management

Water management

Case studies – titles and short descriptions

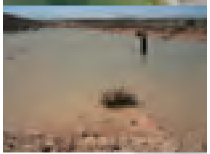
SLM Technology

Water management (continued)

Greece

Transport of freshwater from local streams
Freshwater transport from local streams for irrigation purposes, in order to replace the traditional form of irrigation (by pumping saline groundwater from wells).

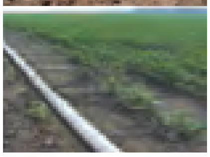
p 121



Tunisia

Recharge well
A recharge well comprises a drilled hole, up to 30-40 m deep that reaches the water table, and a surrounding filter used to allow the direct injection of floodwater into the aquifer.

p 125



Turkey

Drip irrigation
Drip irrigation is a method designed for minimum use of water and labour for the optimum irrigation of plants in arid and semi-arid regions.

p 129

Russia

Drip irrigation
Drip irrigation systems gradually apply water into the zone around the stem of the irrigated plant.

p 133

Botswana

Roof rainwater harvesting system
Roof rainwater catchment system using galvanised iron roof material, feeding an underground water tank.

p 137

Cross-slope barriers

China

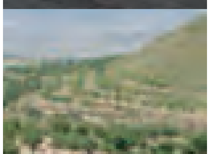
Progressive bench terrace
Bench terraces are progressively expanded to form a fully developed terrace system in order to reduce runoff and soil erosion on medium- to high- angled loess slopes.

p 141

Turkey

Woven wood fences
Wooden fences are an effective and relatively cheap way of conserving soil from water erosion by decreasing overland flow. They also increase crop yield by encouraging better infiltration.

p 145



Spain

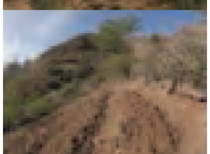
Vegetated earth-banked terraces
Earth-banked terraces in cereal and almond cropland covered with drought-resistant shrubs.

p 149

Morocco

Olive tree plantaions with intercropping
Contour planting of olive trees with crops, legumes and vegetables intercropping.

p 153



Cape Verde

Aloe Vera living barriers
A technique which uses the structure of a cross-slope barrier of Aloe vera to combat soil erosion by decreasing surface wash and increasing infiltration.

p 157

Mexico

Land reclamation by agave forestry with native species
Agave forestry land reclamation system with native agaves, trees, shrubs and grasses planted through participatory action for a sustainable production generating high incomes.

p 161

Case studies – titles and short descriptions

SLM Technology

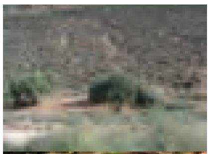
Cross-slope barriers (continued)

Morocco

Gully control by plantation of Atriplex
Rehabilitation of a gullied slope and gully control, by plantation of *Atriplex halimus* fodder shrubs.

p 165

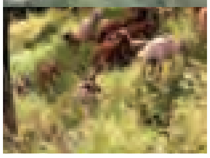
Grazing land management



Tunisia

Rangeland resting
This technique is based on the principle of leaving the rangeland protected (by excluding grazing during 2-3 years) to allow the plant cover to recover.

p 169

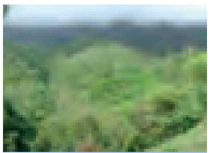


Italy

Controlled grazing in deciduous woods as an alternative to grazing on rangeland
Controlled grazing in deciduous woods seasonally limited in summer when grass cover in rangeland suffers water stress.

p 173

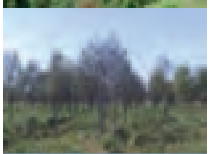
Forest management



Cape Verde

Afforestation
Afforestation is one of the key technologies to address the fragility of ecosystems: it provides better protection against erosion and makes better use of rainfall in order to maintain the sustainability of agricultural systems.

p 177



Morocco

Assisted cork oak regeneration
Assisted cork oak regeneration in the Sehoul forest, by acorn seeding and seedling plantation (derived from a plant nursery), involving careful husbandry and long intervals between cultivation.

p 181

Portugal

Primary strip network system for fuel management
Linear strips are strategically located in areas where total or partial removal of the forest biomass is possible. This technology contributes towards preventing the occurrence and spread of large forest fires and reducing their consequences for the environment, people, infrastructures, etc.

p 185

Portugal

Prescribed fire
Use of prescribed fire (or 'controlled burn') to reduce the fuel load in the form of live and dead plant material and thus to prevent the likelihood of more damaging wildfire.

p 189

Botswana

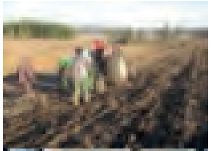
Biogas
Production of methane gas from cow-dung for use in household cooking, heating and lighting in order to reduce firewood demand.

p 193

Case studies – titles and short descriptions

SLM Approach

SLM Approaches



Chile

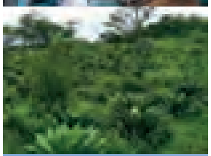
Dissemination of soil conservation technologies in dryland areas
Dissemination of no tillage with subsoiling in the Municipality of Yumbel

p 197

Cape Verde

Training, information and awareness raising
Integration of stakeholders in the implementation of natural resource conservation activities.

p 201



Mexico

Participative actions for economic benefits of agave forestry
Land reclamation with local agave (to produce Mezcal) associated with trees, shrubs and grasses planted through participative actions for economic benefit.

p 205

Morocco

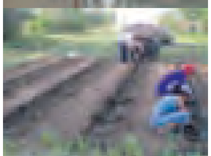
Development of rainfed agriculture
Development of unfavourable zones by integrating all components which can enhance the production, increase incomes and provide a sustainable natural resources management

p 209

Portugal

Forest Intervention Area (ZIF)
This approach assembles and organizes small forest holders and defines a joint intervention for forest management and protection.

p 213



Russia

Concerted thinking on common problems of water scarcity
Testing and disseminating a water saving technology like drip irrigation.

p 217

Spain

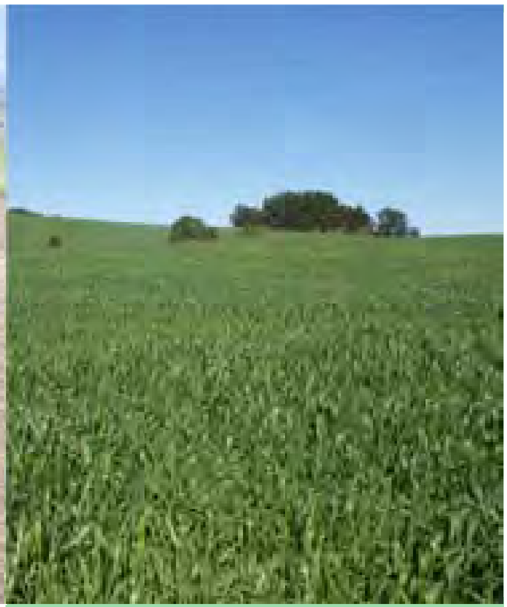
Regional rural development programme
Regional development programme to protect natural resources and stimulate rural economies.

p 221

Tunisia

Dryland watershed management approach
Integrated land and water management approach, including vegetative, management, and agronomic measures.

p 225



Above left: No tillage agriculture (Photo: Carlos Ruiz)
Above right: Wheat sown with no tillage (Photo: Carlos Ovalle)

No tillage preceded by subsoiling

Chile - *Cero labranza con subsolado (Spanish)*

No tillage preceded by subsoiling consists in the use of a subsoiler at a 50 cm depth every 5 years before performing no tillage agriculture.

In the "secano interior" of the Mediterranean climate area of central Chile, water erosion and inappropriate agricultural systems along hillslopes are the major causes of soil degradation.

Subsoil tillage is performed with a three-pointed 50-cm chisel plough (see photo), without turning the soil. Subsoiling is needed every five years to break the hard pan after soil compaction. Then crops are directly seeded without any tillage and with stubble left on the field.

Subsoiling before zero tillage agriculture mitigates water erosion compared to the traditional tillage. In heavy rainfall events, zero tillage reduced soil loss by more than 72% compared to conventional tillage. In addition, the runoff coefficient during the rainy period was 70% lower with zero tillage. These results show the importance of conservation tillage and crop stubble management for decreasing erosion, especially in years when extreme rainfall events lead to a high potential for soil erosion. In relation to soil compaction, comparing the resistance to penetration in the soil profile, the traditional tillage system showed a strongly compacted layer at a depth of 10 cm (>1300 kPa), which increased to over 2000 kPa at depths of 15-20 cm. In contrast, no tillage preceded by subsoiling showed less compaction, beyond 20 cm below the threshold of 2000 kPa, defined by several authors as the critical threshold for radicular growth. Moreover, cereal production showed higher biomass and grain yield. It is concluded that subsoiling before no tillage agriculture with stubble retained on the surface was the best option to mitigate soil erosion.

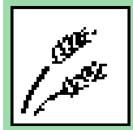
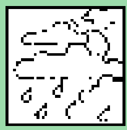
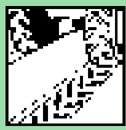
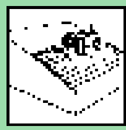
The main disadvantage of the system is that the farmer requires more capital to lease machinery, which in the traditional system is done with animal traction, and the horses or oxen are from their own property. However, the improved yield covers the machinery lease costs. Additionally, the system pushes small farmers into co-operatives, because it is not possible for everyone to own the equipment. To resolve this problem the project promoted the creation of small enterprises (of 10 people) to jointly purchase no-tillage machinery.

The area has a subhumid Mediterranean climate with an average annual precipitation of 695 mm (80% concentrated in winter), with five months of drought. Soils are Alfisols of the Cauquenes type, classified as Ultic Palexeralfs. The soil is made up of materials of granite origin with moderate acidic conditions and low organic carbon. Soil clay content is 15% between 0 and 18 cm depth, below this depth it is higher than 44%. Topography is a hillside with 10 to 20 % slope and the main traditional crop rotation is oat-wheat or wheat-natural pasture.

Location: Bíobio and Maule Region
Region: Cauquenes
Technology area: 10 km^2
Conservation measure: agronomic
Stage of intervention: mitigation / reduction
Origin: externally - recent (<10 years ago)
Land use: cropland
Climate: subhumid, temperate
WOCAT database reference: QT CHL01 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/secano-interior-chile
Related approach: Conservation tillage experimental farm (QA CHL01)
Compiled by: Carlos Ovalle, Instituto de Investigaciones Agropecuarias
Date: 9th Mar 2009, updated 6th Jun 2011

Classification

Land use problems: The soil shows severe water erosion. 75% of the area has slope over 15% and most soils are moderately to severely eroded. Soils with low infiltration (only 4%) are very compacted, because of agricultural practices.

Land use	Climate	Degradation	Conservation measure
			
annual cropping	subhumid, temperate	physical soil deterioration: compaction	agronomic: subsurface treatment

Stage of intervention

■	Prevention
▨	Mitigation / Reduction
□	Rehabilitation

Origin

□	Land user's initiative
□	Experiments / research
■	Externally introduced: < 10 years ago

Level of technical knowledge

□	Agricultural advisor
■	Land user

Main causes of land degradation:
Direct causes – human induced: soil and crop management; natural: Heavy / extreme rainfall
Indirect causes: poverty / wealth

Main technical functions:
- increase of infiltration
- improvement of topsoil structure (compaction)
- increase / maintain water stored in soil

Secondary technical functions:
- increase in organic matter

Environment

Natural Environment

Average annual rainfall (mm)

□	> 4000
□	3000-4000
□	2000-3000
□	1500-2000
□	1000-1500
□	750-1000
■	500-750
□	250-500
□	< 250

Altitude (m a.s.l.)

□	> 4000
□	3000-4000
□	2500-3000
□	2000-2500
□	1500-2000
▨	1000-1500
■	500-1000
□	100-500
□	<100

Landform

□	plateau / plains
□	ridges
□	mountain slopes
■	hill slopes
▨	footslopes
□	valley floors

Slope (%)

□	flat
□	gentle
□	moderate
■	rolling
▨	hilly
□	steep
□	very steep

Soil depth (cm)

□	0-20
□	20-50
□	50-80
□	80-120
■	>120

Growing season(s): 300 days (Mar - Nov)
Soil texture: medium (loam)
Soil fertility: very low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: good

Soil water storage capacity: low
Ground water table: 5 - 50 m
Availability of surface water: poor
Water quality: good drinking water
Biodiversity: medium

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount)
Sensitive to climatic extremes: droughts / dry spells

Human Environment

Cropland per household (ha)

☐	<0.5
☐	0.5-1
☐	1-2
■	2-5
☐	5-15
☐	15-50
☐	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: Individual privileged small scale land users, mainly men
Population density: 10-50 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, titled
Land use rights: individual
Water use rights: individual
Relative level of wealth: mainly poor land users, which own 60% of the land

Importance of off-farm income: 10-50% of all income:
Access to service and infrastructure: low: drinking water and sanitation; moderate: health, education, technical assistance, employment, energy, roads & transport, financial services
Market orientation: mixed (subsistence and commercial)

Technical drawing
Photo of subsoiling drill (photo by Carlos Ruiz).
The subsoiler is a 3-point chisel plough that breaks up the soil hardpan to a depth of 30 to 50 cm

Implementation activities, inputs and costs

Establishment activities

1. No tillage machinery
2. Subsoiling every 5 years

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	50	100
Equipment		
- renting seeder machine	60	0
- renting subsoiling machine	70	0
TOTAL	**180**	**28**

Maintenance/recurrent activities

1. Herbicide application
2. Seeding
3. Fertilization

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	30	100
Equipment		
- renting seeder machine	60	0
Agricultural		
- seeds	50	0
- fertilizer	174	0
- herbicide	20	0
TOTAL	**334**	9

Remarks:
Availability of machinery is the most determining factor affecting the costs.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ increased crop yield	++ increased expenses on agricultural inputs
++ decreased labour constraints	
++ decreased workload	
++ simplified farm operations	
+ reduced risk of production failure	
+ increased farm income	

Socio-cultural benefits	Socio-cultural disadvantages
+++ improved conservation / erosion knowledge	
+++ improved food security /self sufficiency	
+ community institution strengthening	

Ecological benefits	Ecological disadvantages
++ improved soil cover	
++ increased biomass / above ground C	
++ increased nutrient cycling recharge	
++ reduced soil loss	
++ reduced soil crusting / sealing	
++ reduced soil compaction	
+ increased soil organic matter / below ground C	

Off-site benefits	Off-site disadvantages
++ reduced surface runoff	
+ increased water availability	

Contribution to human well-being/livelihoods

++ improved tillage improves crop yields and thus household income increases

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	positive	positive
Maintenance/recurrent	positive	positive

Acceptance/adoption:

The adoption of the technology has been subject to the establishment of transfer programmes with smallholder farmers. In particular, in two communes of the "secano interior" (Ninhue and Yumbel), 100% of the families who were part of the technology transfer programme on no tillage adopted the technology. In terms of the area covered, the programme covered 1000 ha and 35% of the area adopted no tillage. Only a few land user families have implemented the technology voluntarily.
There is no trend towards (growing) spontaneous adoption of the technology.

Concluding statements

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
No tillage preceded by subsoiling as part of the incentive programme for the recovery of degraded soils managed by the Agriculture and Livestock Service (SAG) → Adjusting incentives according to timing of the expenses and investments and also conditioning incentives to the adoption of the technologies	The availability of machines is the main obstacle for adopting zero tillage and subsoiling →To create and promote small companies of agricultural machinery, managed by farmers themselves. Two examples already exist in the counties of San Carlos and Ninhue.

Key reference(s): Del Pozo, A., Del Canto, P. 1999. Areas agroclimaticas y sistemasproductivos en la VII y VIII Región. (INIA)
Contact person(s): Ovalle Carlos, Instituto de Investigaciones Agropecuarias. covalle@inia.cl

Above left and right: Olive grove under no-tillage land management practice in the area of Chania, Crete (Photo: Costas Kosmas)

Olive groves under no–tillage operations

Greece – *Ελαιώνες σε ακαλλιέργεια (Greek)*

Olive groves under no tillage and no herbicide application.

Sustainable farming may include several measures for protecting natural resources. One measure, that of no-tillage, relates to reduced soil erosion. This may have favourable effects on soil aggregation and protection from soil crusting and soil erosion. In a no-tillage system, the residues are concentrated on the surface of the soil, which enhances aggregate stability and protects the soil from erosion.

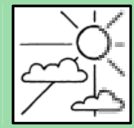
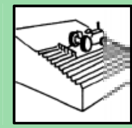
The most frequently used cover crop is *Oxalis pescaprae,* a species considered as a weed but with a positive effect on soil and water conservation. It is left to grow during winter to improve water infiltration into the soil and to help prevent soil erosion. Owing to its high sensitivity to drought, *Oxalis* tends to reach wilting point in late spring due to lack of water in the upper soil layer. Disc-ploughing once every four to five years is necessary to destroy the perennial vegetation and incorporate fertilizers and plant residues into the soil. This practice is common locally and was established 30 years ago by the collaboration of national specialists and land users. It has been applied in a variety of natural and human environmental conditions typical of the Mediterranean region.

There is no extra cost involved in applying the technology. In fact, farm income increases, since production costs decrease without any reduction in olive oil production.

Location: Kissamos province
Region: Chania-Crete
Technology area: 532 km^2
Conservation measure: agronomic
Stage of intervention: mitigation / reduction of land degradation
Origin: Land users - 10-50 years ago
Land use: Cropland and mixed use
Climate: temperate
WOCAT database reference: QT GRE01 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/crete-greece
Related approach: Olive groves under no tillage operations (QA GRE01)
Compiled by: Costas Kosmas, Agricultural University of Athens
Date: 12th Jan 2009 updated 11th May 2011

Classification

Land use problems: increasing production costs when the technique is not applied, high soil erosion rates and a decrease in groundwater recharge

Land use		Climate	Degradation	Conservation measure
				
tree and shrub cropping	agroforestry	semi-arid, temperate	soil erosion by water: loss of topsoil / surface erosion	agronomic: soil surface treatment

Stage of intervention

- Prevention
- Mitigation / Reduction
- Rehabilitation

Origin

- Land user's initiative: 10-50 years ago
- Experiments / research: < 10 years ago
- Externally introduced

Level of technical knowledge

- Agricultural advisor
- Land user

Main causes of land degradation:
Direct causes - human induced: soil management

Main technical functions:
- control of dispersed runoff: retain / trap

Secondary technical functions:
- increase of surface roughness

Environment

Natural Environment

Average annual rainfall (mm)

- > 4000
- 3000-4000
- 2000-3000
- 1500-2000
- 1000-1500
- 750-1000
- 500-750
- 250-500
- < 250

Altitude (m a.s.l.)

- > 4000
- 3000-4000
- 2500-3000
- 2000-2500
- 1500-2000
- 1000-1500
- 500-1000
- 100-500
- <100

Landform

- plateau / plains
- ridges
- mountain slopes
- hill slopes
- footslopes
- valley floors

Slope (%)

- flat
- gentle
- moderate
- rolling
- hilly
- steep
- very steep

Soil depth (cm)

- 0-20
- 20-50
- 50-80
- 80-120
- >120

Growing season(s): 150 days (November to April)
Soil texture: medium (loam), fine / heavy (clay)
Soil fertility: medium, low, very low
Topsoil organic matter: medium (1-3%), low (<1%)
Soil drainage/infiltration: medium

Soil water storage capacity: high
Ground water table: 50 m
Availability of surface water: good
Water quality: good drinking water
Biodiversity: high

Tolerant of climatic extremes: heavy rainfall events (intensities and amount)
Sensitive to climatic extremes: arid climatic conditions

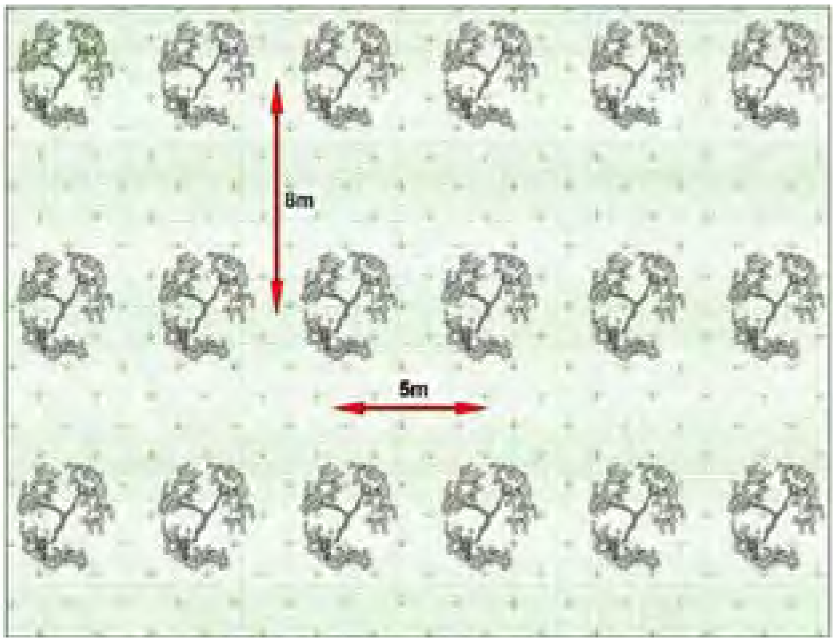
Human Environment

Mixed land per household (ha)

☐	<0.5
☐	0.5-1
☐	1-2
■	2-5
▒	5-15
☐	15-50
☐	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: Individual small-scale land users and average land users, mainly men
Population density: 10-50 persons/km^2
Annual population growth: 1% - 2%
Land ownership: individual, titled
Land use rights: open access
Water use rights: communal (organised)
Relative level of wealth: average, which represent 75%; 90% of the total land areas is owned by average land users.

Importance of off-farm income: less than 10% of all income:
Access to service and infrastructure: moderate: education, technical assistance, roads & transport;
high: health, market, financial services
Market orientation: mixed (subsistence and commercial)
Mechanization: mechanised
Livestock grazing on cropland: yes



Technical drawing

Olive groves occur widely throughout Crete (Greece). One of the main cultivation practices adopted recently is minimum or no tillage. Under this land management practice, weeds are allowed to grow, covering and protecting the soil surface from raindrop impact. The most widely distributed weed is *Oxalis pescaprae*, a plant species that has positive effects on soil and water conservation. *Oxalis* grows during winter improving water infiltration into the soil and helping to prevent soil erosion. Owing to its high sensitivity to drought, *Oxalis* reaches wilting point during late spring due to a lack of soil water in the upper soil layer. The plant is indigenous to South Africa and highly invasive. The plant has a reputation for being very difficult to eradicate once it has become established. Olive trees, planted close together, partially prevent the growth of understorey vegetation. In the Crete study area, rows of olive trees are spaced at intervals of 8 m and trees are planted 5 m apart in the rows (C. Kosmas)

Implementation activities, inputs and costs

Establishment activities

1. Removal of weeds if they interfere significantly with the collection of the olive crop

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
TOTAL	**0**	**0**

Maintenance/recurrent activities

no maintenance

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
TOTAL	**0**	**0**

Remarks:
No factors affect costs since Oxalis grows in the area under natural conditions

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
++ increased farm income (2200-2500 €/ha)	+ hindered farm operations

Socio-cultural benefits	Socio-cultural disadvantages
++ improved conservation / erosion knowledge	

Ecological benefits	Ecological disadvantages
+++ reduced soil crusting +++ reduced surface runoff ++ increased water quantity ++ increased soil moisture ++ reduced soil loss ++ reduced soil compaction + reduced demand on irrigation water	

Off-site benefits	Off-site disadvantages
+++ reduced downstream flooding ++ reduced groundwater / river pollution	

Contribution to human well-being/livelihoods

++ increase in farmers income and reduction of the off-site effects

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	positive	positive
Maintenance/recurrent	positive	positive

Acceptance/adoption:

In all, 55% of land user families (1850 families; 45% of area) have implemented the technology with external material support.
In all, 45% of land user families (800 families; 65% of area) have implemented the technology voluntarily.
There is moderate (growing) trend towards spontaneous adoption of the technology.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Technologies for conserving soil and water resources and combating desertification in Crete mainly relate to land management. Olive groves are widespread on the island as a result of the importance of olive oil for everyday cooking. Furthermore, olive groves can survive adverse weather and soil conditions providing a significant income for farmers for a relatively low labour input. Land management practices have been adopted in the area based on tradition and knowledge transfer by local institutes and specialists. No-tillage land management practice with olives can be considered as an important technique to protect against land degradation and desertification and increase farmers' incomes → education of farmers	A slight decrease in water availability for the growing trees → no solution to this problem
Production costs can be cut, but may create problems for olive harvesting → the necessity to cut weeds during harvesting	The field is 'clean' in readiness for harvesting → the necessity to cut weeds during harvesting

Key reference(s): -
Contact person(s): Costas Kosmas, Agricultural University of Athens. E-Mail: lsos2kok@aua.gr

Above left: Crop residue in August of cereals that were harvested around May/June. This field will remain like this until March/April next year when it will be ploughed for sowing in autumn (Photo: Joris de Vente)
Above right: Cereal harvest in June. (Photo: Joris de Vente)

Reduced contour tillage of cereals in semi-arid environments

Spain - *Labranza reducida de cereal en contra de la pendiente en ambientes semi-áridos (Spanish)*

Reduced contour tillage in a rotational system of winter cereals and fallow land

This technology is a type of conservation tillage with minimal economic effort and is adapted to semi-arid conditions. Tillage is reduced to a maximum of three times surface (20-30cm) tillage in two years with a disc- or a chisel-plough. The disc-plough is only used where there is a dense weed or crop residue cover. The disc-plough breaks-up the soil top layer better than the chisel-plough, while the chisel tends to plough slightly deeper (~30cm) than the disc-plough (~20cm). The advantage of the chisel-plough is that it leaves a higher surface roughness and is less destructive to soil aggregates. Under conventional tillage, fields are ploughed up to five times every two years, once with a mouldboard plough. In both systems, cereals are cropped in a rotational system with fallow land. Cereals are sown in autumn (October) and harvested in June followed by a fallow year. Under reduced tillage the crop residues are left on the field throughout the autumn and winter periods. This provides increased protection against soil erosion. Tillage is performed on fallow land in early spring (March-April) to prepare the land for sowing in October. With conventional tillage, fields are ploughed with a mouldboard plough in autumn. Traditional sowing machinery can be used so no investments are needed in specialised equipment. Tillage is performed parallel to the contour lines to prevent rill and gully formation. No herbicides are required since annual weeds are mixed with the upper soil layer during ploughing. Owing to increased organic matter content and a better infiltration capacity, soil water retention capacity, soil humidity and crop yields will increase within 3-5 years after implementation.

The aim of this technology is to increase the soil organic matter content by retaining it in soil aggregates and to reduce soil erosion by water and tillage. The higher infiltration capacity and better surface cover with crop residues in autumn and winter protects the soil against water erosion, reducing soil erosion by over 50% and runoff by 30%. In addition, the better organic matter content increases overall soil quality in terms of soil structure and water holding capacity. Compared to traditional multiple tillage operations with a mouldboard plough, under reduced tillage, tillage erosion is reduced by having fewer tillage operations, but also through tillage of fallow land resulting in lower tillage erosion rates than secondary tillage operations of already loosened soil. Fuel use by tractors is decreased, leading to a reduction of 40% in production costs and reduced CO_2 emissions. Some studies showed that in first 2-3 years after implementation, the soil can be denser and have a lower infiltration capacity than under traditional tillage regimes. Yet, when the organic matter content and soil structure have increased, infiltration rates are higher than under traditional ploughing and result in increased soil water content and crop yields.

The technology is applied on loamy soils with a calcareous substrate, of shallow to medium depth, and slopes are gentle to moderate (5-15%). The climate is semi-arid with a mean annual rainfall of around 300 mm. Droughts, centred in summer commonly last for more than 4-5 months. Annual potential evapotranspiration rates greater than 1000 mm are common. The production system is highly mechanised and market oriented but depends strongly on agricultural subsidies.

Location: Murcia
Region: Guadalentín catchment
Technology area: 10 - 100 km^2
Conservation measure: agronomic
Stage of intervention: prevention of land degradation, mitigation / reduction of land degradation
Origin: Land Users - recent (<10 years ago), Experiments - recent (<10 years ago)
Land use: cropland
Climate: semi-arid, subtropics
WOCAT database reference: QT SPA01 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/guadalentin-spain
Related approach: Regional rural development programme (QA SPA01)
Compiled by: Joris de Vente, EEZA-CSIC
Date: 12th Jun 2008 updated 01st Jul 2011

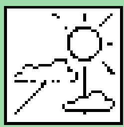
Classification

Land use problems: There is a lack of water for irrigation of crops limiting the crop types that can be planted as well as the crop yield of dryland farming. A lack of water availability seriously limits the production potential of the soil and results in a low vegetation/crop cover. The relatively high soil erosion rates cause various off-site related problems (i.e. flooding, reservoir siltation) and on-site problems (i.e. gully formation and reduced soil depth).

Land use

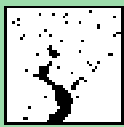
annual cropping (rainfed)

Climate

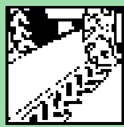


semi-arid, subtropics

Degradation



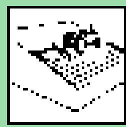
water degradation: aridification,



physical soil deterioration: sealing and crusting,

soil erosion by water: loss of topsoil / surface erosion

Conservation measure



agronomic: vegetation/soil cover, soil surface treatment, subsurface treatment

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative: <10 years ago
Experiments / research: <10 years ago
Externally introduced:

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - human induced: soil management, disturbance of water cycle (infiltration / runoff)
Indirect causes: inputs and infrastructure

Main technical functions:
- control of raindrop splash
- control of dispersed runoff: retain / trap
- control of dispersed runoff: impede / retard
- control of concentrated runoff: impede / retard
- improvement of ground cover
- improvement of surface structure (crusting, sealing)
- improvement of topsoil structure (compaction)
- improvement of subsoil structure (hardpan)
- increase in organic matter
- increase of infiltration
- increase / maintain water stored in soil

Secondary technical functions:
- increase of surface roughness
- increase in nutrient availability (supply, recycling)

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 220 days (Nov - Jun)
Soil texture: medium (loam)
Soil fertility: low
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: poor (eg sealing /crusting)

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: for agricultural use only
Biodiversity: low

Tolerant of climatic extremes: seasonal rainfall increase, heavy rainfall (intensities and amount), wind storms / dust storms, floods, decreasing length of growing season.
Sensitive to climatic extremes: temperature increase, seasonal rainfall decrease, droughts / dry spells
If sensitive, what modifications were made / are possible: The crop type is sensitive to changes in water availability under the semi-arid conditions.

Human Environment

Cropland per household (ha)

☐	<0.5
☐	0.5-1
☐	1-2
☐	2-5
☐	5-15
■	15-50
■	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: Individual and common small scale land users, mainly men
Population density: 10-50 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, titled
Land use rights: individual (all cropland is privately owned)
Water use rights: individual. Water use is organised by permits to water extraction from aquifers on an individual basis. Water rights are provided and controlled by the water authority of the Segura river basin.
Relative level of wealth: average, which represents 80% of land users; 75% of the total land area is owned by average land users

Importance of off-farm income: > 50% of all income: There is no difference in the ones who apply the technology and those who do not. Most farmers do have an off-farm income for example from hunting, work in a factory or office.
Access to service and infrastructure: moderate: employment, energy; high: education, technical assistance, market, roads & transport, drinking water and sanitation, financial services
Market orientation: commercial / market
Mechanization: mechanised
Livestock grazing on cropland: yes

Technical drawing:
Left: Photo of the disc-plough used for superficial ploughing (~20cm depth) where there is a large amount of crop residue and/or perennial vegetation. Right: Chisel-plough (Photos: Joris de Vente)

Implementation activities, inputs and costs

Initial investment

1. Disc-plough

Establishment inputs and costs per unit

Inputs	Costs (US$)	% met by land user
Equipment - tools	794	100
TOTAL	**794**	**100**

Maintenance/recurrent activities

1. Tillage with disc-plough

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	12	100
Equipment - machine use (tractor & fuel)	50	100
TOTAL	**62**	**100**

Remarks: Fuel price is the most determinate factor affecting the costs. The costs are indicated per ha of land where the technology is implemented. The disc plough costs $7937, but assuming an average farm size of 10 ha, this means a per ha cost of $794. The local wage rate is 79 US$/day. (Prices are for spring 2008).

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+ increased crop yield + increased farm income + decreased workload	+ increased expenses on agricultural inputs

Socio-cultural benefits	Socio-cultural disadvantages
++ improved conservation / erosion knowledge	

Ecological benefits	Ecological disadvantages
+++ reduced soil loss ++ reduced surface runoff ++ improved soil cover + improved harvesting / collection of water + increased soil moisture + increased nutrient cycling recharge + reduced emission of carbon and greenhouse gases + reduced soil crusting / sealing and compaction	

Off-site benefits	Off-site disadvantages
++ reduced damage on neighbours fields + reduced downstream flooding + reduced downstream siltation + reduced wind transported sediments + reduced damage on public / private infrastructure	

Contribution to human well-being/livelihoods

+ Farm income may increase with up to12%. There is no known effect on education, health etc. The subsidies applied for cereal production in a rotation system of fallow & for contour ploughing contribute to improved livelihood of most farmers.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	slightly negative	slightly positive
Maintenance/recurrent	slightly positive	slightly positive

When a disc-plough was not already used in normal farming operations, this implies a slightly negative influence on farm income during establishment.

Acceptance/adoption:
There are no subsidies for reduced tillage. Nevertheless, 100% of land user families have implemented the technology with external material support since there are subsidies for parts of the technology such as contour ploughing and rotational farming allowing a fallow period (1-2 years) after harvest. Practically 100 % of farmers use these subsidies; still reduced tillage is implemented 100% voluntary. There is a little trend towards spontaneous adoption of the technology. There seems to be a growing public awareness of the fact that frequent deep rotational ploughing is not always necessary and results in higher production costs.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
This is a low-cost technology that requires limited initial investments in equipment and potentially results in a slightly increased farm income, as well as a decrease in land degradation and an increase in soil quality and water-holding capacity → In some higher areas with sufficient rainfall, the technology might be adapted to conservation tillage with direct sowing, reducing the tillage operations even more. However, this implies an important investment in machinery and a high level of organisation at the agricultural cooperation level.	The most important weakness of this technology is that it does not significantly improve farm income and so may not be stimulating enough for farmers to apply → Provide information on all the advantages of good soil management that include many costs for society (including floods, reservoir siltation, etc.) and stress the fact that reduced tillage will lead to less work for the same or slightly higher profit.
An increased soil surface cover throughout autumn and winter provides a good protection against soil erosion reducing rill and gully formation → Sometimes a field is left fallow for two consecutive years, but it is still ploughed between them. This ploughing might be avoided as well.	In order to apply for subsidies for cereal cultivation in a rotation system with fallow, farmers are obliged to plough after each fallow period to control weeds, even when two consecutive years of fallow are applied. This is considered unnecessary → It might be worthwhile to test the need for this and look for alternatives without ploughing.

Key reference(s): López-Fando, C., Dorado, J. and Pardo, M.T., 2007. Effects of zone-tillage in rotation with no-tillage on soil properties and crop yields in a semi-arid soil from central Spain. Soil and Tillage Research, 95(1-2): 266-276; Ozpinar, S., 2006. Effects of tillage systems on weed population and economics for winter wheat production under the Mediterranean dryland conditions. Soil and Tillage Research, 87(1): 1-8; Holland, J.M., 2004. The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agriculture, Ecosystems & Environment, 103(1): 1-25
Contact person(s): Joris de Vente, EEZA-CSIC, Spain, Joris@sustainable-ecosystems.org

Above left: almond plantation with reduced tillage regime (Photo: Joris de Vente)
Above right: ploughing of a field with reduced tillage just before summer starts (Photo: Joris de Vente)

Reduced tillage of almonds and olives

Spain – *Labranza reducida de almendros y olivos (Spanish)*

Reduced tillage of almonds and olives to improve physical and chemical soil properties and reduce runoff and soil erosion.

Reduced tillage of almond and olive orchards is used to decrease fuel use and emission of greenhouse gases and maintain a higher surface cover by weeds during winter time in order to protect the soil from erosion.

Under reduced tillage, the fields are ploughed twice a year: once in autumn (November) and once in late sping (June), whereas under conventional tillage fields are ploughed 3-5 times per year. The aim of reduced tillage is to maintain better surface cover during winter months to reduce runoff and soil erosion. After several years this will result in a higher soil organic matter content, a better soil structure, and a higher soil water infiltration capacity. The soil cover by weeds reduces the sensitivity of the soil to surface crusting and reduces surface runoff and soil erosion by up to 60%. Workload and energy use with reduced tillage is up to 50% lower than under conventional agriculture. The increased farm income prevents land abandonment of marginal lands with low productivities under conventional farming. Reduced tillage of almonds does not require special establishment activities or investments in specialized equipment.

Reduced tillage can easily be combined with green manure and ecological agriculture as is described in QT SPA05: ecological production of almonds and olives using green manure. Soils have mostly a shallow to medium depth (between 20-60 cm), and slopes are gentle to moderate between 5 and 15%. The climate is semi-arid with a mean annual rainfall around 300 mm. Droughts, centred in summer, commonly last for more than 4-5 months. Annual potential evapotranspiration rates greater than 1000 mm are common. The production system is highly mechanized and market oriented but depends strongly on agricultural subsidies. All cropland is privately owned.

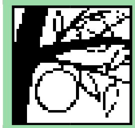
Location: Murcia
Region: Guadalentín catchment
Technology area: 10 - 100 km2
Conservation measure: agronomic
Stage of intervention: prevention of land degradation, mitigation / reduction of land degradation
Origin: externally - recent (<10 years ago)
Land use: cropland and mixed use
Climate: semi-arid, subtropics
WOCAT database reference: QT SPA06 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/guadalentin-spain
Related approach: Regional rural development programme (QA SPA01)
Compiled by: Joris de Vente, EEZA-CSIC
Date: 19th Jun 2008 updated 4th Jul 2011

Editors' comments: This technology can easily be combined with ecological production of almonds and olives using green manure (QT SPA05). This technology also applies reduced tillage under almonds but in addition seeds a mixture of cereals and leguminous species to increase soil fertility following the principles of ecological agriculture.

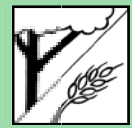
Classification

Land use problems: Lack of water for irrigation of crops limiting the crop types that can be planted as well as the crop yield of dryland farming. A lack of water availability seriously limits the production potential of the soil and results in a low vegetation/crop cover. The relatively high soil erosion rates cause various off-site related problems (i.e. flooding, reservoir siltation) and on-site problems (i.e. gully formation and reduced soil depth).

Land use



tree and shrub cropping (rainfed)

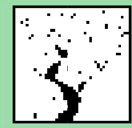


agroforestry

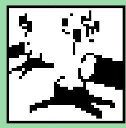
Climate

semi-arid, subtropics

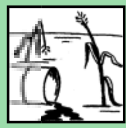
Degradation



soil erosion by water: offsite degradation effects

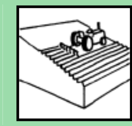


biological degradation: increase of pests/diseases, loss of predators, loss of soil life



chemical soil deterioration: soil pollution, fertility decline and reduced organic matter content

Conservation measure



agronomic: reduced tillage

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative: 10-50 years ago
Experiments / research: 10-50 years ago
Externally introduced: < 10 years ago

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - human induced: soil management, crop management (annual, perennial, tree/shrub)
Indirect causes: education, access to knowledge and support services

Main technical functions:
- improvement of ground cover
- control of dispersed runoff: retain / trap
- control of dispersed runoff: impede / retard
- control of concentrated runoff: retain / trap

Secondary technical functions:
- increase in organic matter
- increase of infiltration
- increase / maintain water stored in soil

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 220 days (Nov - Jun)
Soil texture: medium (loam)
Soil fertility: low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: poor (eg sealing /crusting)

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: for agricultural use only
Biodiversity: low

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount), wind storms / dust storms, floods, decreasing length of growing period
Sensitive to climatic extremes: droughts / dry spells
If sensitive, what modifications were made / are possible: The crop type is sensitive to changes in water availability under the semi-arid conditions.

Human Environment

Cropland per household (ha)

☐	<0.5
☐	0.5-1
☐	1-2
☐	2-5
☐	5-15
■	15-50
■	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: Individual and common small scale land users, mainly men
Population density: 10-50 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, titled
Land use rights: individual (all cropland is privately owned).
Water use rights: individual. Water use is organised by permits to water extraction from aquifers on individual basis. Water rights are provided and controlled by the Water authority of the Segura river basin.
Relative level of wealth: average, which represents 80% of land users; 75% of the total land area is owned by average land users

Importance of off-farm income: > 50% of all income: There is no difference in the ones who apply the technology and those who don't. Most farmers do have an off-farm income for example from hunting, work in a factory, or office.
Access to service and infrastructure: moderate: employment, energy; high: education, technical assistance, market, roads & transport, drinking water and sanitation, financial services
Market orientation: commercial / market
Mechanization: mechanized
Livestock grazing on cropland: yes

Technical drawing

Autumn ploughing of an almond orchard with reduced tillage (Photo: Joris de Vente)

Implementation activities, inputs and costs

Initial investment

No initial investment

Maintenance/recurrent activities

1. Ploughing twice a year instead of 3-5 times (resulting in a reduction of the costs compared to the conventional tillage practice)

Maintenance/recurrent inputs and costs per ha per year compared to conventional ploughing

Inputs	Costs (US$)	% met by land user
Labour	- 25	100
Equipment - machine use	- 72	100
TOTAL	**- 97**	**100**

Remarks:
Costs were assessed comparing conventional land management with reduced tillage, which needs less inputs thus meaning a saving compared to conventional practice. Fuel price is the most determining factor affecting the costs. The local wage rate is 79 US$/day. Prices are for spring 2008.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
++ decreased workload + increased farm income	

Socio-cultural benefits	Socio-cultural disadvantages
++ improved conservation / erosion knowledge + increased recreational opportunities	

Ecological benefits	Ecological disadvantages
+++ reduced surface runoff +++ reduced soil loss ++ improved soil cover ++ increased soil organic matter / below ground C ++ reduced emission of carbon and greenhouse gases + increased soil moisture + reduced soil crusting / sealing + increased plant diversity	

Off-site benefits	Off-site disadvantages
++ reduced damage on neighbours fields + reduced downstream siltation	

Contribution to human well-being/livelihoods

+ farm income of most farmers has increased due to lower production costs

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	slightly positive	slightly positive
Maintenance/recurrent	slightly positive	slightly positive

Acceptance/adoption:
One hundred per cent of land user families have implemented the technology voluntarily. There is currently no support for reduced tillage of almond orchards. There is moderate trend towards (growing) spontaneous adoption of the technology.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Reduced tillage has a very positive effect on the reduction of erosion and runoff, on soil quality and biodiversity → If maintained it will lead potentially to higher yields after several years.	On the short term no increase in yield is obtained → Combine the technique with green manure or ecological agriculture as described in QT SPA05
Production costs are reduced → Yield and farm income may be increased by combining this technology with green manure under ecological agriculture (QT SPA05)	

Key reference(s): Holland, J.M., 2004. The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agriculture, Ecosystems & Environment, 103(1): 1-25.

Contact person(s): Joris de Vente, EEZA-CSIC, Spain, Joris@sustainable-ecosystems.org

Above left: Wheat in the crop rotation after peas (Photo: Soledad Espinoza)
Above right: Peas in the crop rotation (Photo: Carlos Ovalle)

Crop rotation with legumes

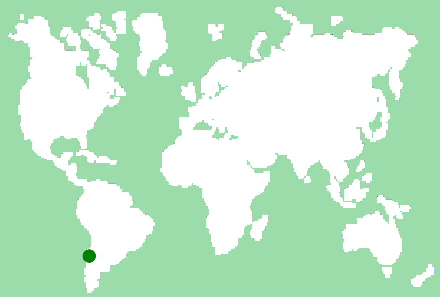
Chile – *Rotación de cultivos con leguminosas (Spanish)*

Biological Nitrogen Fixation (BNF) of legumes as a source of N in crop rotations with cereals in Mediterranean Chile

In the past, legumes were commonly used as a biological and economic source of N for farming systems. Nowadays, N-fixing legumes have been recovering as viable crops because of the increased cost of N fertilizer and the need to develop more sustainable farming systems. These systems combine phases of legumes of different duration, in which N is fixed and accumulates in the soil, followed by phases of cereal growing during which accumulated N is extracted. In this new rotation for rainfed agricultural systems in Central Chile, four legume-wheat rotations were compared to a monoculture crop rotation (wheat followed by oat). The legume species are: the narrow-leaf lupin (*Lupinus angustifolium*); Wonga (early-flowering and high-yielding narrow-leafed lupin variety), yellow lupin (*Lupinus luteus*); Motiv, Peas (*Pisum sativum*); Rocket and a fodder mixture of vetch (*Vicia atropurpurea*) with oats. Legume seeds were inoculated with a specific Rhizobium. In the year following the legume crop, wheat was seeded without N fertilisation on the incorporated residues of grain legumes and green manure (vetch with oats). The BNF in the grain legumes varies from 124 to 178 kg N $ha^{-1,}$ depending on the type of legume. Peas are the most efficient fixing legume crop. In the lupins - wheat (*L. angustifolius*) rotation without application of N to the wheat after lupins, production of wheat was between 79 and 110% of that when fertilised with N. In the peas - wheat rotation, a yield equivalent to 72 and 105% of the wheat fully fertilised with N was obtained. While peas (*Pisum sativum)* can be eaten as a green vegetable, lupins and *Vicia* are used as fodder supplements for animals.

The new rotations were developed and evaluated experimentally. Then, through a technology transfer programme, the technology was transferred to real conditions with farmers in a programme covering 250 ha in the municipality of Yumbel.

The area has a subhumid Mediterranean climate with an average annual precipitation of 695 mm (80% concentrated in winter), with five months of drought. Soils are Alfisols of the Cauquenes type, classified as Ultic Palexeralfs. The soil is formed from weathered granite with moderately acidic conditions and low organic carbon. Clay content in the soil is 15% at depths of 0-18 cm depth. Below this depth, it is above 44%. The topography comprises a hillslope with a gradient of 10-20 % and the main traditional crop rotation is oat-wheat or wheat-natural pasture. The farmers are smallholders working on their own land. The sizes of the holdings on the dryland soils vary from 5 to 20 ha.



Location: Secano interior, Mediterranean Chile
Region: Cauquenes and Bíobio
Technology area: 250 km^2
Conservation measure: agronomic
Stage of intervention: prevention of land degradation
Origin: through experiments / research, < 10 years ago
Land use: annual cropping
Climate: subhumid, temperate
WOCAT database reference: QT CHL02 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/secano-interior-chile
Related approach: not documented
Compiled by: Carlos Ovalle and Soledad Espinoza, Instituto de Investigaciones Agropecuarias (INIA La Cruz)
Date: 10th Nov 2011

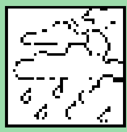
Classification

Land use problems: In rainfed areas of the Mediterranean region of Chile, bread wheat (*Triticum aestivum*) is mainly produced in rotation with oats (*Avena sativa*) and therefore N is obtained from the soil and synthetic N fertilizers applied during sowing and ploughing. These intensive crop rotations have resulted in deterioration of the physical properties and a depletion of soil fertility as a result of the drastic reduction in organic matter content of these soils.

Land use

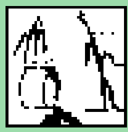
annual cropping

Climate



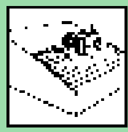
subhumid, temperate

Degradation



chemical soil deterioration: reduced organic matter content

Conservation measure



agronomic: vegetation / soil cover

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative
Experiments / research: <10 years ago
Externally introduced: <10 years ago

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - human induced: soil management; natural: change in temperature, change of seasonal rainfall, heavy / extreme rainfall
Indirect causes: education, access to knowledge and support service

Main technical functions:
- increase in organic matter
- increase in nutrient availability (mineral N in the soil)
- promotion of new crops and varieties

Secondary technical functions:
- improvement of ground cover

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 180 days (May - Nov)
Soil texture: fine / heavy (clay)
Soil fertility: very low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: poor (eg sealing /crusting)

Soil water storage capacity: very low
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: good drinking water
Biodiversity: low

Tolerant of climatic extremes: temperature increase, seasonal rainfall decrease
Sensitive to climatic extremes: long dry spells
If sensitive, what modifications were made / are possible: This technology should be complemented with no tillage and subsoiling of the soil (see QT CHL01).

Human Environment

Mixed land per household (ha)

☐	<0.5
☐	0.5-1
☐	1-2
☐	2-5
☐	5-15
■	15-50
☐	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: Individual small scale land users, mainly men
Population density: 10-50 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual
Land use rights: individual
Water use rights: individual
Relative level of wealth: mainly poor land users, which represent 80% of land users; 60% of the total land area is owned by poor land users

Importance of off-farm income: 50-70 % of the total income
Access to service and infrastructure: good: energy, drinking water and sanitation; moderate: health, education, technical assistance, employment, roads & transport,
Low: financial services
Market orientation: mixed (subsistence and commercial)

Technical drawing
Lupins forming part of the crop sequence (*Lupinus angustifolium)* Photo: Soledad Espinoza

Implementation activities, inputs and costs

Establishment activities

None

Maintenance/recurrent activities

The additional activities compared to the normal monocropping are:

1. Seeding legumes
2. Application of fertilizer
3. Harvesting with special machinery

The farmer needs legume seeds, fertilizer and proper machinery for seeding and harvesting

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	146	100
Equipment - renting seeder machine - renting harvester	293	60
Agricultural - seeds - *p* fertilizers - herbicide	306	80
TOTAL	745	76

Remarks: There are not establishment inputs and costs because in annual crops all the cost are recurrent

Assessment

Impacts of the Technology	
Production and socio-economic benefits	**Production and socio-economic disadvantages**
+++ increased crop yield +++ increased fodder production ++ increased fodder quality ++ reduced risk of production failure ++ increased farm income ++ increased product diversification (lupin, peas) ++ diversification of income sources (new products)	+ increased labour constraints
Socio-cultural benefits	**Socio-cultural disadvantages**
+++ improved conservation / erosion knowledge +++ improved food security /self sufficiency + improved health	
Ecological benefits	**Ecological disadvantages**
+++ increased biomass / above ground C +++ increased soil organic matter / below ground C ++ reduced hazard towards adverse events ++ improved soil cover ++ increased nutrient cycling recharge ++ reduced soil loss and soil crusting / sealing	
Off-site benefits	**Off-site disadvantages**
++ reduced surface runoff + increased water availability	

Contribution to human well-being/livelihoods: The incorporation of the legume to the crop rotation improves livelihoods, as the farmer has new products such as vegetables (peas) or grain legumes to be sold in the local market, or used as a good supplement for their animals (sheep or cattle) in the case of lupins, which additionally allows improvement of lamb and wool production.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	Positive	positive
Maintenance/recurrent	Positive	positive

Acceptance/adoption: This is a new approach to the cereal production system in rainfed areas. Initially the adoption has been slow, as the results obtained in the project are recent. The crop rotation with legumes has been adopted by 50 families covering an area of 250 ha in the municipality of Yumbel. However, the technology has been incorporated into the System of Incentives for the Recovery of Degraded Soils supported by the Ministry of Agriculture of Chile. Hence it is expected that in the future the adoption of this technology increases up to 20,000 ha in the “secano interior” of south-central Chile.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Reduces the costs of fertiliser: the incorporation of legumes in the rotation cycle means a saving of 30% of nitrogen fertilizer in cereal production costs → keep the phases of legumes sufficiently frequent and long	Necessity of more training for the farmers → improve / enhance agricultural extension
Increases the economic benefits. When analysing the whole farming system, replacing the traditional rotation of wheat followed by natural pasture, implies two economic benefits for the producer: increasing the income by the incorporation of a new crop (legumes) and the reduction of costs in the fertilization of cereals.	
Increase soil organic matter: the new rotation system means a new concept in the management of crop residues. These should be incorporated into the soil, which in the medium and long term will involve an increase in the soil organic matter content → ensure application of the new management of crop residues	
The new rotation system involves an increase in productivity of the land, as it incorporates new cultures and improves the physical and chemical conditions of the soils.	

Key reference(s): Espinoza, S., Ovalle, C., del Pozo, A., Zagal, E., Urquiaga, S. 2011. Biological Fixation of N2 in mono and polyspecific legume pasture in the humid Mediterranean zone of Chile. Chilean Journal of Agricultural Research. 71(1):132-139.

Contact person(s): Ovalle Carlos, Instituto de Investigaciones Agropecuarias. covalle@inia.cl

Above left: A series of two cultivation areas on slopes, with lupin above (on poor and stony soil) and maize below (on thicker soil) (Photo: Jamal Al Karkouri)
Above right: Detailed view of the white lupin (Photo: Jamal Al Karkouri)

Crop rotation: cereals / fodder legumes (lupin)

Morocco – *Bernicha (amazigh – berber language)*

Crops rotation: cereals / fodder legumes (lupin), with a biennial crop rotation

Farming is the main activity of the Sehoul population. In the past, it was based on subsistence cultivation and especially on extensive breeding outside the farm. The cultivation practice mostly applied was barley monoculture. Nowadays, crop rotation is more and more diversified (use of other cereal species and mainly legumes). Because of land degradation on forest pasture, farmers increasingly use their farm land for fodder or legume production such as oats and lupin. White lupins were introduced in the region during the colonial era (1912-1956), through individual initiatives with no external support. The advantages of lupin cultivation are its ability to grow on poor and stony soils and, like other leguminous crops, it does not need nitrogen fertilizers because of its ability to fix nitrogen from the air, which reduces the costs. Additionally, lupin does not require much water (a minimum of 350 mm per year is sufficient). Considering the importance of pastoral activity in the production system of the Sehoul district, this technology meets the expectations of the population as follows. Firstly, there is improvement of fodder production. Lupin is a leguminous crop which can be eaten by ruminants either as green fodder or as grain. Secondly, there is soil improvement through a better structure, an increased soil organic matter content and better nitrogen retention that can be used for the next cultivation. Thirdly, there is a better soil cover because lupin is an invasive plant with efficient roots for finding nutrients, which allows its cultivation on poor soils.

The lupin cultivation technique consists of the following: spreading the seed in October-November, and possibly until mid-December. Early sowing shows good yields, because cold temperatures cause early blossoming. For white lupin, sowing density is about 100 kg/ha. Ploughing (20-25 cm deep ploughing is sufficient) to bury the seed is performed with a swing plough and two mules on slopes, and with a metallic plough or a tractor on plains. No weeding or fertilization activities are required because of the lupin's good nitrogen fixation capacity. However, an additional second or third ploughing can improve the harvest, but is often constrained by a lack of means. A first grazing is allowed in March but afterwards it is left so that it can recover again. Harvesting is done manually with sickles in August and residues are grazed again. Seed production is 8-10 quintals/ha, biomass is 3000 kg/ha.

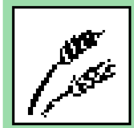
This technology is applied on plateau margins with steep slopes, where traditional small-scale land use includes predominantly winter crop cultivations (wheat and barley) and secondary spring food cultivations (broad beans, chickpea, maize). On the plateau, bigger and better maintained farms perform irrigated cultivation with ground water. The cork oak forests are coveted as pasture land and firewood source and therefore they are regarded as important for their free natural fodder resources. Pasture land (except forests) covers a small area (12% of the Sehoul area) because of land appropriation and cultivation. Only the collective and the fallow lands are now used as pasture lands and generally show important and alarming degradation processes.

Location: Sehoul
Region: Salé province
Technology area: 2 km^2
Conservation measure: agronomic
Stage of intervention: prevention of land degradation
Origin: introduced by colonists, more than 50 years ago
Land use: cropland
Climate: subhumid, subtropics
WOCAT database reference: QT MOR012e on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/sehoul-morocco
Related approach: not documented
Compiled by: Al Karkouri Jamal, University IbnTofail, Kénitra
Date: 21 Mar 2011, updated 19 Oct 2011

Classification

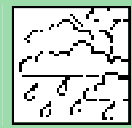
Land use problems: Decrease of productivity, continued exploitation on poor land leading to sealing and crusting, poor soils, cultivation with low ground cover, soil depletion, decrease of fertility and organic matter

Land use



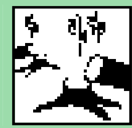
annual cropping (rainfed)

Climate



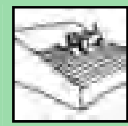
subhumid, subtropics

Degradation



biological degradation: quantity/ biomass decline

Conservation measure



agronomic: organic matter/ soil fertility

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative:
Experiments / research
Externally introduced
Other: introduced by colonists: > 50 years ago

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - human induced: deforestation / removal of natural vegetation (incl. forest fires)
Direct causes - natural: other natural causes (soil fragility because of very thin topsoil surface layer and low organic matter content)
Indirect causes: poverty / wealth

Main technical functions:
- improvement of ground cover
- increase of biomass (quantity)

Secondary technical functions:
- increase in organic matter
- increase in nutrient availability (supply, recycling,…)
- promotion of vegetation species and varieties (quality, e.g. palatable fodder)

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 300 days (October to July)
Soil texture: medium (loam)
Soil fertility: low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: poor (e.g. sealing /crusting)

Soil water storage capacity: low
Ground water table: 5 - 50 m
Availability of surface water: good
Water quality: good drinking water
Biodiversity: low

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase
Sensitive to climatic extremes: seasonal rainfall decrease, heavy rainfall events (intensities and amount), wind storms / dust storms, floods, droughts / dry spells
If sensitive, what modifications were made / are possible: design the layout of the technology along the contour, split field into strips

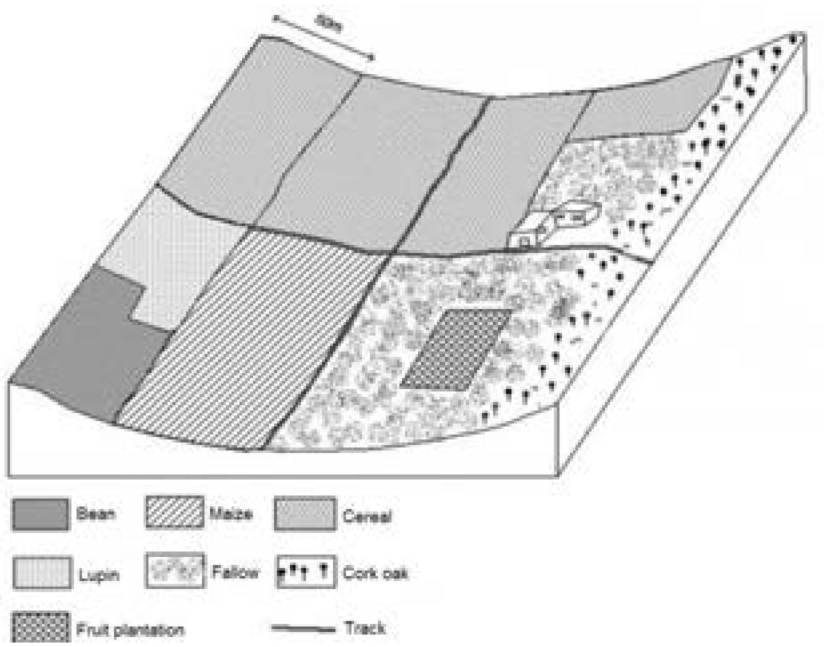
Human Environment

Cropland per household (ha)

	<0.5
	0.5-1
	1-2
	2-5
	5-15
	15-50
	50-100
	100-500
	500-1,000
	1,000-10,000
	>10,000

Land user: Individual/household, small-scale land users, common / average land users, mainly men
Population density: 10-50 persons/km^2
Annual population growth: 0.5% - 1%
Land ownership: individual, titled
Land use rights: open access (not organised) (Mainly "melk" (private property, 52%) and associations (13%))
Water use rights: (Mainly "melk" (private property, 52%) and associations (13%))
Relative level of wealth: very poor, which represents 20% of land users; 60% of the total land area is owned by very poor land users

Importance of off-farm income: less than 10% of all income: There are no major differences
Access to service and infrastructure: low: health, education, employment (e.g. off-farm), drinking water and sanitation, financial services; moderate: technical assistance, market, energy, roads & transport
Market orientation: subsistence (self-supply), mixed (subsistence and commercial)
Mechanization: manual labour, animal traction
Livestock grazing on cropland: yes



Technical drawing

The lupin plot occupies the upper part of the watershed, characterized by very fragile soils because of their thinness (20-40cm) and low organic matter content. (Jamal Al Karkouri and Issam Machmachi)

Implementation activities, inputs and costs

Initial Investment

There are no special investment costs. The following costs are also required for the conventional cereal monocropping:
- animal traction (2 mules): 2703 US$
- cart: 203 US$
- metallic plough: 42 US$
- swing plough: 20 US$
- sickles (4): 12 US$

Lifetime of a swing plough is 10 years and, of all the other equipment, is 30 years

Establishment inputs and costs

Inputs	Costs (US$)	% met by land user
TOTAL	**0**	**-**

Recurrent activities

Normal recurrent activities and labour costs include
- ploughing: 30 US$
- spreading the seeds: 10 US$
- harvesting: 15 US$
- collecting: 15 US$

There are no additional costs for lupin cultivation except the seeds.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	0	-
Agricultural - seeds	42	100
TOTAL	**42**	**100**

Remarks:
Equipment and seed costs concern the hectare of cultivated land. The labour costs for a working day are 5 US$ per person.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ increased product diversification ++ reduced expenses on agricultural inputs + increased crop yield + increased fodder production + increased farm income	+ reduced fodder production + increased expenses on agricultural inputs
Socio-cultural benefits	**Socio-cultural disadvantages**
Ecological benefits	**Ecological disadvantages**
+++ increased nutrient cycling recharge +++ increased soil organic matter / below ground C +++ reduced soil loss +++ increased plant diversity ++ increased soil moisture	
Off-site benefits	**Off-site disadvantages**
+ increased water availability	+ reduced sediment yields

Contribution to human well-being/livelihoods

++ this technology allows a better yield and a farm income increase

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	positive
Maintenance/recurrent	neutral / balanced	slightly positive

Rotation benefits can only appear in the long-term, after the amortization of implementation expenses.

Acceptance/adoption:

100% of land user families (40 families; 100% of area) have implemented the technology voluntary. There is no trend towards (growing) spontaneous adoption of the technology. This technology is in decline because of the use of fertilizers which allow a crop/crop rotation and because of the increased seeds prices. As for food leguminous plants, this cultivation requires the mobilization of the family labour, nowadays not available taking into account the factor of emigration.

Concluding statements

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
Maintenance of the soil fertility → Encourage the crop rotation by subsidy of the administration	Erosion risks for the spring cultivations (maize), because the soil is bare during a high rainfall period. → Introduce a catch crop cultivation before the legumes or maize cultivation in order to cover the soil during the heavy rains. Mulching can also be done.
Low-cost technology → Make demonstrations for the benefit of the population	Very demanding on the family and animal workforce → Mechanization
Technology not very demanding in SWC knowledge → Technical support to use the technology better	Reduce the use of crop rotation and move the animals away from the exploited land occupied by cultivations throughout the year. → Replace legumes by fodder crop on the open-field
Better soil fertility management → Make demonstrations for the benefit of the population	

Key reference(s): GHOULIMI. S., 1999 Les communes rurales et les problèmes de développement local. Cas de la commune des Sehouls. Thèse de DES. Géographie humaine. 283 p.

Contact person(s): Jamal, Al Karkouri, University IbnTofail. Kenitra, Maroc, alkarkourij@yahoo.fr

Above left: ecological almond plantation with a dense understorey of leguminous and cereal species in spring (Photo: Joris de Vente)
Above right: detailed view of flowering green manure (*Vicia sativa* and barley) in early spring (Photo: Joris de Vente)

Ecological production of almonds and olives using green manure

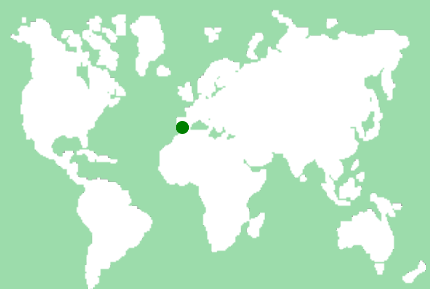
Spain - *Agricultura ecológica de almendros y olivos con abono verde (Spanish)*

Ecological production of almonds and olives under dryland conditions using green manure to increase soil fertility, to protect against soil erosion and to obtain a high-value product.

Ecological agriculture is a strictly controlled production system that does not use synthetic chemical products like fertilizers, insecticides or pesticides. Also genetically modified organisms and materials are not used. Green manure or low quantities of organic fertilizers, preferably from dung (sheep, goat, cow, chicken), are used to increase and maintain soil fertility. Green manure is provided by seeding a mixture of leguminous nitrogen-fixing species and cereals in autumn (October) and incorporating this into the soil with tillage in springtime (May). To optimize the fertilizer effect, there is still scientific discussion on the need for mowing the green manure and letting it dry for several days before it is ploughed into the soil. For this system, no ploughing is performed in winter, which reduces fuel use and emission of greenhouse gases. In addition to its fertilising effect, green manure provides a continuous surface cover during winter time protecting the soil from erosion. The products grown under this ecological system command a higher market price than those grown under conventional production schemes.

The aim of ecological agriculture is to protect biodiversity and the environment and maintain or improve soil fertility and reduce soil, water, and air pollution. Under ecological agriculture and by using green manure, soil cover, soil organic matter, and soil biological activity will increase, which positively affects soil structure, soil fertility and soil water infiltration capacity. This reduces the sensitivity of the soil to surface crusting and it reduces surface runoff and soil erosion by up to 60%. Workload and energy use are up to 50% lower than under conventional agriculture, and benefits may increase around 40% due to higher yields. Moreover, a higher market price of ecologically produced almonds and olives will lead to increased farm income. This better economic return discourages land abandonment of marginal lands with low productivities under conventional farming. Ecological almonds and olives production does not require special establishment activities or investments in specialized equipment.

Infestations by, for example, insects and caterpillars are treated twice yearly by degradable products based on copper salts (Oxicloruro, max 3‰ solution) and mineral oils in winter, or the spores and proteins produced by the bacteria *Bacillus thuringiensis* or based on natural pyrethrins (from the Chrysanthemum cinerariaefolium; max 1.5 l/ha) in springtime. In ecological agriculture, farmers are obliged to take advice and instructions regarding plague control and fertilizer use from technicians specialized in ecological agriculture. Soils mostly have a shallow to medium depth (between 20-60 cm), and slopes are gentle to moderate (between 5 and 15%). The climate is semi-arid with a mean annual rainfall around 300 mm. Droughts, in summer, commonly last for more than 4-5 months. Annual potential evapotranspiration rates larger than 1000 mm are common. The production system is highly mechanised and market-oriented but depends strongly on agricultural subsidies. All cropland is privately owned.



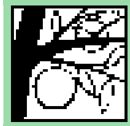
Region: Murcia, Guadalentín catchment
Technology area: 10 - 100 km^2
Conservation measure: agronomic
Stage of intervention: prevention of land degradation, mitigation / reduction of land degradation
Origin: externally - recent (<10 years ago)
Land use: cropland and mixed use
Climate: semi-arid, subtropics
WOCAT database reference: QT SPA05 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/guadalentin-spain
Related approach: Regional rural development programme (QA SPA01)
Compiled by: Joris de Vente, EEZA-CSIC
Date: 19th Jun 2008 updated 4th Jul 2011

Editors' comments: This technology is similar to reduced tillage of almonds and olives (QT SPA06). The main difference consists of seeding green manure to increase soil fertility following the principles of ecological agriculture, while in QT SPA06 nothing is seeded below the Almonds.

Classification

Land use problems: There is a lack of water for irrigation of crops limiting the crop types that can be planted as well as the crop yield of dryland farming. A lack of water availability seriously limits the production potential of the soil and results in a low vegetation/crop cover. The relatively high soil erosion rates cause various off-site related problems (i.e. flooding, reservoir siltation) and on-site problems (i.e. gully formation and reduced soil depth).

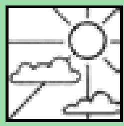
Land use



tree and shrub cropping (rainfed)

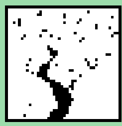
agroforestry

Climate

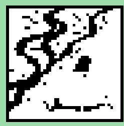


semi-arid, subtropics

Degradation



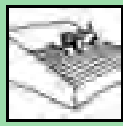
soil erosion by water: offsite degradation effects



water degradation: decline of groundwater quality

chemical soil deterioration: soil pollution, fertility decline and reduced organic matter content

Conservation measure



agronomic: green manure

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative: 10-50 years
Experiments / research: 10-50 years
Externally introduced: < 10 years ago

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - human induced: soil management, crop management (annual, perennial, tree/shrub)
Indirect causes: education, access to knowledge and support services

Main technical functions:
- improvement of ground cover
- control of dispersed runoff: retain / trap
- control of dispersed runoff: impede / retard
- increase in nutrient availability (supply, recycling)

Secondary technical functions:
- increase in organic matter
- increase of infiltration
- increase / maintain water stored in soil
- improvement of water quality, buffering/filtering water

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 220 days (Nov - Jun)
Soil texture: medium (loam)
Soil fertility: low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: poor (e.g. sealing /crusting)

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: for agricultural use only
Biodiversity: low

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount), wind storms / dust storms, floods, decreasing length of growing period
Sensitive to climatic extremes: droughts / dry spells.
If sensitive, what modifications were made / are possible: The crop type is sensitive to changes in water availability under the semi-arid conditions.

Human Environment

Cropland per household (ha)

☐	<0.5
☐	0.5-1
☐	1-2
☐	2-5
☐	5-15
■	15-50
■	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: Individual and common small scale land users, mainly men
Population density: 10-50 persons/km2
Annual population growth: < 0.5%
Land ownership: individual, titled
Land use rights: individual (all cropland is privately owned).
Water use rights: individual. Water use is organised by permits to water extraction from aquifers on individual basis. Water rights are provided and controlled by the Water authority of the Segura river basin.
Relative level of wealth: average, which represent 80% of land users; 75% of the total land area is owned by average land users

Importance of off-farm income: > 50% of all income: There is no difference in the ones who apply the technology and those who don't. Most farmers do have an off-farm income for example from hunting, work in a factory, or office.
Access to service and infrastructure: moderate: employment, energy; high: education, technical assistance, market, roads & transport, drinking water and sanitation, financial services
Market orientation: commercial / market
Mechanization: mechanized
Livestock grazing on cropland: yes

Technical drawing

Mixture of barley and vetch (*Vicia sativa*) seeds used for seeding green manure. (Photo: Joris de Vente)

Implementation activities, inputs and costs

Initial investment

No initial investment

Maintenance/recurrent activities

1. ploughing green manure
2. seeding green manure
3. organic fertilizer of cow dung (optional)
4. ecological treatment against plagues days

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	25	37
Equipment - machine use	72	37
Agricultural		
- seeds	96	37
- organic fertilizer (optional)	79	37
- biocides (only when needed)	159	37
TOTAL	**431**	**37**

Remarks:
Fuel price, ecological pesticides and organic fertilizer are the most determining factors affecting the costs. Cow dung costs approximately US $350 per tonne and will therefore increase the costs significantly if applied. The costs are calculated assuming the application of green manure, ecological pesticides and organic fertilizer. However, many farmers decide not to use organic fertilizer because of their high costs. As part of the Rural Development Programme (QASPA01), ecological agriculture receives a subsidy of 476 US $ per ha during the first 3 years of production, after which the subsidy is reduced to 380 US $ per ha. The local wage rate is 79 US$/day. Prices are for spring 2008.

Assessment

Impacts of the Technology

Production and socio-economic benefits

+++ (2 of 3) increased crop yield
+++ (2 of 3) decreased workload
+++ (1 of 3) increased farm income

Production and socio-economic disadvantages

+ (1 of 3) use of organic fertilizer and biocides is expensive and requires subsidies

Socio-cultural benefits

++ improved conservation / erosion knowledge
++ improved health (reduced soil and groundwater contamination)
+ improved cultural opportunities (people nourish and care more for their land)
+ increased recreational opportunities (more attractive cultural landscape)

Socio-cultural disadvantages

Ecological benefits

+++ reduced surface runoff
+++ reduced soil loss
+++ increased biological pest disease control
++ improved soil cover
++ increased soil organic matter / below ground C
++ reduced emission of carbon and greenhouse gases
++ increased animal diversity
++ increased plant diversity
++ increased beneficial species
+ increased nutrient cycling recharge
+ reduced soil crusting / sealing

Ecological disadvantages

Off-site benefits

++ reduced damage on neighbours fields
+ reduced groundwater / river pollution
+ reduced downstream siltation

Off-site disadvantages

Contribution to human well-being/livelihoods

+ farm income of most ecological farmers has increased due to higher market price, higher yield and subsidies

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	neutral/balanced	neutral/balanced
Maintenance/recurrent	slightly positive	slightly positive

First years require some adaptation, but after 1-2 years the higher market price and crop yield will generate a slightly higher income.

Acceptance/adoption:
In all, 95% of land user families have implemented the technology with external material support. The majority are convinced by the subsidies provided for ecological agriculture. Only 5% of land user families have implemented the technology voluntarily. There is a limited number of farmers who had already started this form of farming before the existence of subsidies. There is a moderate (growing) trend towards spontaneous adoption of the technology. The trend is spontaneous, but strongly driven by available subsidies.

Concluding statements

Strengths and → how to sustain/improve

Ecological agriculture and green manure have a very positive effect on soil quality, biodiversity and reduction of runoff and erosion → Reduced costs related to pest control

High quality products of ecological agriculture provide a good impression and an attractive product → Better marketing of eco-almond and olives

High quality products with a good market price are produced → Costs of pest control should fall

Weaknesses and → how to overcome

Application of organic fertilizers and ecological pest control is relatively expensive and depend on subsidies especially in the first few years of implementation → Look for cheaper methods and combine possibly with other techniques such as reduced tillage to further reduce the costs. After several years, normally less pest control is required due to increased natural control and ecosystem integrity.

Key reference(s): Regional advisory board on ecological agriculture: CARM 2008, http://www.caermurcia.com; Programa de Desarrollo Rural de la Región de Murcia http://www.carm.es/neweb2/servlet/integra.servlets.ControlPublico?IDCONTENIDO=4689&IDTIPO=100&RASTRO=c431$m1219

Contact person(s): Joris de Vente, EEZA-CSIC, Joris@sustainable-ecosystems.org

Above left: Fodder production as animal food in central Anatolia (Photo: İnci Tolay, Eskişehir)
Above right: Extensive irrigated fodder crop production in semi-arid central Anatolia (Photo: İnci Tolay, Eskişehir)

Fodder crop production

Turkey - *Yem Bitkileri Yetiştiriciliği (Turkish)*

Production of fodder crops every year both for feeding livestock and increasing soil fertility.

Fodder crops (maize, alfalfa, sainfoin, common vetch, triticale, oat, fodder beet, wheat and barley) are grown for hay production for livestock feeding. Growing fodder crops is a part of sustainable agriculture. The soil is protected in dry farming areas by covering the soil surface and leguminous fodder species (alfalfa, sainfoin, common vetch), which increases the soil fertility by nitrogen fixation. Applying the technology does not require extra inputs different from other agricultural crops. All that is needed is to identify a crop rotation plan including fodder production and regular agricultural crops.

Different fodder crops (legumineous and gramineous plants) are produced to feed the farmers' own livestock. By enabling widespread and dense surface cover, It helps both in dry farming and irrigated areas to protect the soil from water and wind erosion.

Usually the soil is first ploughed. Soil cultivation machinery (tractor, disc plough, wide-sweep cultivator, disc harrow, fertilizer and seed drill) is used to prepare the soil for cultivation, to fertilize the soil and to sow the seeds. After seeding and growing of the crops, special machinery is used for harvesting.

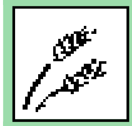
Farmers who produce both livestock and field crops in particular can use this technology and get an improved benefit. They can increase income and at the same time protect their soil.

Location: Eskişehir
Region: Keskin Watershed
Technology area: 10 - 100 km^2
Conservation measure: agronomic
Stage of intervention: prevention of land degradation
Origin: land user's initiative (> 50 years ago)
Land use: cropland
Climate: semi-arid, temperate
WOCAT database reference: QT TUR04 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/eskiehir-turkey
Related approach: Fodder Crops for Sustainable Agriculture (QA TUR04)
Compiled by: İnci Tolay, Eskişehir Osmangazi University, Faculty of Agriculture
Date: 30th Jul 2008, updated 7th Jul 2011

Classification

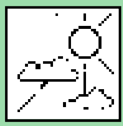
Land use problems: Insufficient technical help and interest to agriculture problems by government, urbanization pressure, land fragmentation, monoculture in dry farming areas, insufficient irrigation and rainfall, overgrazing, false cultivation techniques.

Land use



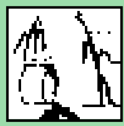
annual cropping (rainfed, partly supplementary irrigation)

Climate



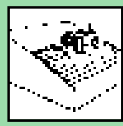
semi-arid, temperate

Degradation



chemical soil deterioration: fertility decline and reduced organic matter content

Conservation measure



agronomic: organic matter/ soil fertility

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative (>50 years ago)
Experiments / research
Externally introduced

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - Human induced: crop management (annual, perennial, tree/shrub)
Indirect causes: land tenure, governance / institutional

Main technical functions:
- improvement of ground cover

Secondary technical functions:
- increase of infiltration

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateaux / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 180 days (Nov – Apr)
Soil texture: mainly medium (loam), partly coarse (sandy) and fine (clay)
Soil fertility: medium
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: medium

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: medium
Water quality: good drinking water
Biodiversity: low

Tolerant of climatic extremes: seasonal rainfall increase, heavy rainfall events, high winds, floods
Sensitive to climatic extremes: temperature below 10 ^{0}C and above 35 ^{0}C; water stress in soil, decreasing length of growing period

Human Environment

Cropland per household (ha)

■	<0.5
□	0.5-1
□	1-2
□	2-5
□	5-15
□	15-50
□	50-100
□	100-500
□	500-1,000
□	1,000-10,000
□	>10,000

Land user: Individual medium-scale land users
Population density: 10-50 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, titled
Land use rights: individual
Water use rights: leased
Relative level of wealth: average – which represents 96% of the land users; 70% of the total land area is owned by average land users

Importance of off-farm income: less than 10% of all income: only 1% of land users have an off-farm income
Access to service and infrastructure: low: employment; moderate: health, education, technical assistance, market, drinking water and sanitation, financial services; high: energy, roads and transport
Market orientation: commercial / market
Mechanization: mechanised
Livestock grazing on cropland: yes

Technical illustration

A special harvesting machine used to bale fodder (Photo: http://turhaltarim.gov.tr/images)

Implementation activities, inputs and costs

Initial investments

1. Harvesting machinery (cutting): The cost is calculated per ha, assuming a large cropping area and without considering the lifetime of the machine (no depreciation)

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Equipment	50	100
TOTAL	**50**	**100**

Maintenance/recurrent activities

1. Ploughing
2. Providing seeds from agricultural agencies
3. Fertilizing
4. (Irrigation)

These are the special activities and costs required for fodder production

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	(300)	100
Equipment		
- machine use	25	100
- ploughing	(175)	100
Agricultural		
- seeds	300	75
- irrigation	(280)	100
- fertilizer	100	100
- biocides	20	100
TOTAL	**445**	**83**

Remarks:
Costs in brackets include normal cropping activities and are therefore excluded from the total. Certified seed material and tillage costs (e.g. oil, machines) are the most determining factors affecting the costs. The local wage rate is 20 US$/day.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
++ increased crop yield ++ increased fodder production ++ increased fodder quality ++ increased farm income	++ increased demand for irrigation water + increased expenses on agricultural inputs (seeds, fertilizer, biocides)

Socio-cultural benefits	Socio-cultural disadvantages
++ improved conservation / erosion knowledge ++ improved food security / self-sufficiency ++ improved health	

Ecological benefits	Ecological disadvantages
++ improved harvesting / collection of water ++ increased soil moisture ++ reduced surface runoff ++ reduced wind velocity ++ improved soil cover ++ increased biomass / above ground C ++ increased nutrient cycling recharge ++ increased soil organic matter / below ground C ++ reduced soil loss ++ reduced salinity ++ increased beneficial species + increased plant and habitat diversity	+ decreased water quantity + lowering of ground water table

Off-site benefits	Off-site disadvantages
+ improved buffering / filtering capacity + reduced wind transported sediments	

Contribution to human well-being/livelihoods

++ The improved livestock feeding increases income

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	positive	very positive
Maintenance/recurrent	positive	very positive

Acceptance/adoption: Ninety-five per cent of land user families (95 families; 95% of area) have implemented the technology with external material support (financial support in cash). Five per cent of land user families (5 families; 5% of area) have implemented the technology voluntary. Because of the high costs of the inputs land users do not want to apply the technology without external support There is a slight (and growing) trend towards spontaneous adoption of the technology. Input prices are increasing and therefore farmers do not readily adopt the technology without some inducement.

Concluding statements

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
It improves the soil fertility → Technical and economic support is needed	Technology increases water use →Drip irrigation of the crops suitable for this can be a partial solution
It improves the livestock health by means of mixed fodder → Technical and economic support is needed	Land users awareness is low →They can be trained
Increased protection of soil from water erosion → Trials in plots should be done to demonstrate the magnitude of this advantage, so that the farmers can easily accept this technology	
It reduces the costs of fodder input → Subsidies should be continued	
It increases productivity of livestock → Technical knowledge should be given	

Key reference(s): Ryder, M.H., Fares, A., 2008. Evaluating cover crops (sudex, sunn hemp, oats) for use as vegetative filters to control sediment and nutrient loading from agricultural runoff in a Hawaiian watershed. J. Am. Water Res. Assoc. 44, 640–653. De Baets, S., Poesen, J., Meersmans, J., Serlet, L., 2011. Cover crops and their erosion-reducing effects during concentrated flow erosion. Catena, 85: 237–244.

Contact person(s): Assis. Prof. Dr. İnci Tolay, Eskişehir Osmangazi University, Faculty of Agriculture; incitolay@akdeniz.edu.tr

Above left: Jessour is the plural of a Jessr which is the hydraulic unit comprising a dyke, spillway, terrace (cropping area: fruit trees and annuals), and impluvium (runoff catchment area). (Photo: van Delden H.)
Above right: Jessour is an ancient runoff water harvesting technique widely practised in the arid highlands of southern Tunisia. After each rainfall event, significant volumes of runoff water accumulate on the terrace and infiltrate into the soil to sustain trees and crops. The spillway ensures sharing the runoff water with downstream users and the safe discharge of excess water. (Photo: Ouessar M.)

Jessour

Tunisia - *Jesser, Katra (Arabic)*

Jessour is an ancient runoff water harvesting technique widely practised in the arid highlands

Jessour technology is generally practised in mountain dry regions (less than 200 mm annually) with medium to high slopes. This technology was behind the installation of very old olive orchards based on rainfed agriculture in rugged landscapes which allowed the local population not only to ensure self-sufficiency but also to provide neighbouring areas many agricultural produces (olive oil, dried figs, palm dates, etc.).

Jessour is the plural of jessr, which is a hydraulic unit made of three components: the impluvium, the terrace and the dyke. The impluvium or the catchment is the area which collects and conveys runoff water. It is bordered by a natural water divide line (a line that demarcates the boundary of a natural area or catchment, so that all the rain that falls on this area is concentrated and drained towards the same outlet). Each unit has its own impluvium, but can also receive excess water from upstream units. The terrace or cropping zone is the area in which farming is practised. It is formed progressively by the deposition of sediment. An artificial soil will then be created, which can be up to 5 m deep close to the dyke. Generally, fruit trees (e.g. olive, fig, almond, and date palm), legumes (e.g. pea, chickpeas, lentil, and faba bean) and barley and wheat are cultivated on these terraces.

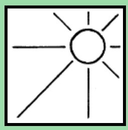
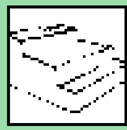
Although the jessour technique was developed for the production of various agricultural crops, it now also plays three additional roles: (1) aquifer recharge, via runoff water infiltration into the terraces, (2) flood control and therefore the protection of infrastructure and towns built downstream, and (3) wind erosion control, by preventing sediment from reaching the downstream plains, where windspeeds can be particularly high.

In the Jessour, a dyke (tabia, sed, katra) acts as a barrier used to hold back sediment and runoff water. Such dykes are made of earth, and are equipped with a central and/or lateral spillway (masref and/or manfes) and one or two abutments (ktef), assuring the evacuation of excess water. They are trapezoidal and measure 15-50 m in length, 1-4 m in width and 2-5 m in height. In old units, the dyke is stabilised with a covering of dry stones to overcome the erosive effects of water wave action on the front and back of the dyke. The spillway is made of stones arranged in the form of stairs, in order to dissipate the kinetic energy of the overflow.
This technology is currently encountered in the mountain ranges of Matmata of South Eastern Tunisia where the local agricultural activities are based mainly on rainfed agriculture and livestock breeding. However, high rates of migration to cities may threaten the long-term maintenance of those structures.

Location: Medenine
Region: Beni Khedache
Technology area: 100 km^2 - 1,000 km^2
Conservation measure: structural
Stage of intervention: mitigation / reduction of land degradation
Origin: land users - traditional (>50 years ago)
Land use: grazing land
Climate: arid, subtropics
WOCAT database reference: QT TUN09 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/zeuss-koutine-tunisia
Related approach: Dryland watershed management approach (QA TUN09)
Compiled by: Mohamed Ouessar, Mongi Ben Zaied, Mongi Chniter, Institut des Régions Arides (IRA)
Date: 22nd Sep 2008 updated 10th Jun 2011

Classification

Land use problems: Loss of surface water (runoff), problems of flooding, water erosion, soil degradation, drought

Land use		Climate	Degradation		Conservation measure
					
annual cropping (rainfed)	tree and shrub cropping (rainfed)	arid, subtropics	soil erosion by water: loss of topsoil / surface erosion	water degradation: aridification	structural: bunds / banks

extensive grazing land (before)
tree and shrub cropping (after)

Stage of intervention

▒	Prevention
■	Mitigation / Reduction
□	Rehabilitation

Origin

■	Land user's initiative: >50 years
□	Experiments / research
□	Externally introduced

Level of technical knowledge

▒	Agricultural advisor
▒	Land user

Main causes of land degradation:
Direct causes - Human induced: crop management (annual, perennial, tree/shrub)
Direct causes - Natural: change of seasonal rainfall, heavy / extreme rainfall
Indirect causes: poverty / wealth

Main technical functions:
- harvesting of runoff water / water trapping
- increase of infiltration
- sediment retention / trapping, sediment harvesting

Secondary technical functions:
- control of concentrated runoff: retain / trap
- increase / maintain water stored in soil
- increase of groundwater level, recharge of groundwater

Environment

Natural Environment

Average annual rainfall (mm)

□	> 4000
□	3000-4000
□	2000-3000
□	1500-2000
□	1000-1500
□	750-1000
□	500-750
□	250-500
■	< 250

Altitude (m a.s.l.)

□	> 4000
□	3000-4000
□	2500-3000
□	2000-2500
□	1500-2000
□	1000-1500
□	500-1000
■	100-500
▒	<100

Landform

□	plateau / plains
□	ridges
■	mountain slopes
□	hill slopes
▒	footslopes
□	valley floors

Slope (%)

□	flat
□	gentle
□	moderate
□	rolling
▒	hilly
■	steep
□	very steep

Soil depth (cm)

■	0-20
▒	20-50
□	50-80
□	80-120
□	>120

Growing season(s): 180 days (Oct - Mar)
Soil texture: medium (loam)
Soil fertility: very low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: medium

Soil water storage capacity: without Jessour: poor; with Jessour: medium to high
Ground water table: 5 - 50 m
Availability of surface water: poor only episodic streams
Water quality: poor drinking water
Biodiversity: medium

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount), wind storms / dust storms, droughts / dry spells, decreasing length of growing period
Sensitive to climatic extremes: floods

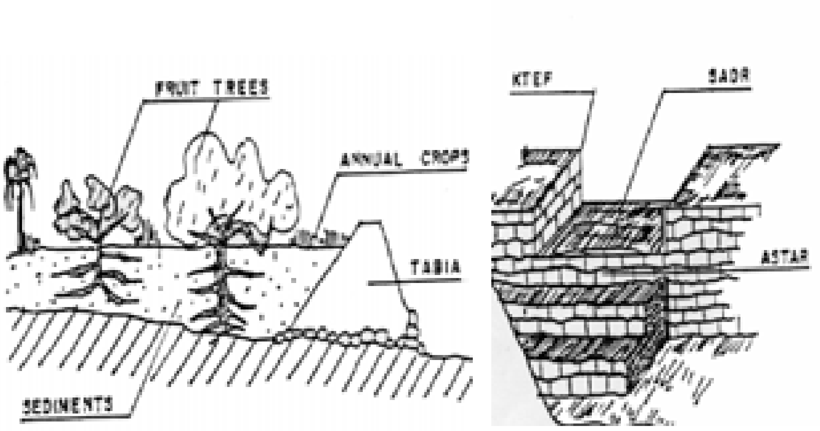
Human Environment

Mixed land per household (ha)

	<0.5
	0.5-1
■	1-2
	2-5
	5-15
	15-50
	50-100
	100-500
	500-1,000
	1,000-10,000
	>10,000

Land user: Individual and common small-scale land users, mainly men
Population density: 10-50 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, not titled
Land use rights: individual (the communal rule applies in this region: the farmer owns the terrace (the cropping area) and its impluvium from which the runoff is harvested).
Water use rights: individual
Relative level of wealth: average, which represents 80% of land users; 75% of the total land area is owned by average land users

Importance of off-farm income: > 50% of all income: the technology is very ancient and, therefore, all the farmers apply this technology. The only difference is the number of the owned Jessour. Off-farm incomes come from migration, construction works, commerce, tourism sector, administration or informal activities.
Access to service and infrastructure: low: financial services; moderate: health, technical assistance, employment, market, energy, roads & transport, drinking water and sanitation; high: education
Market orientation: subsistence (self-supply)



Technical drawing

Left: Cross-section of dyke (locally called tabia) and terrace (cropping area).
The Jessour ensure the collection of both runoff water and sediments allowing creating very deep ‘artificial’ soils (terrace) which form a very good reservoir for water and nutrients to be used by fruit trees and annual crops.
Right: The spillway allows the overflow to the other Jessour downstream. It also represents the symbol of water sharing equity between different farmers in the same watershed. (Drawing adapted from El Amami (1984)) (Ouessar M.)

Implementation activities, inputs and costs

Establishment activities

1. Dyke construction
2. Plantations
3. Spillway construction

Establishment inputs and costs per one Jessour per year

Inputs	Costs (US$)	% met by land user
Labour	1200	
Construction material	1000	
Agricultural	800	
TOTAL	**3000**	**100***

Maintenance/recurrent activities

1. Crop and trees maintenance
2. Dyke and spillway maintenance
3. Repairs
4. Tillage (against soil sealing)

Maintenance/recurrent inputs and costs per one Jessour per year

Inputs	Costs (US$)	% met by land user
Labour	400	
Construction material	300	
Agricultural	200	
TOTAL	**900**	**100***

Remarks:
Found in inaccessible and even remote areas, labour is the most determining factors affecting the costs of this system. The local wage rate is 10 US$/day.
* The technology establishment and maintenance costs met by the land users are 100% if executed on a private basis, but it can range from 10 to 50% when the site is subject to a publicly-funded programme.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ increased crop yield	++ reduced grazing lands
++ reduced risk of production failure	++ reduced available runoff for downstream users
++ increased farm income	
+ diversification of income sources	
Socio-cultural benefits	**Socio-cultural disadvantages**
++ improved conservation / erosion knowledge	+ socio cultural conflicts
++ improved situation of disadvantaged groups	
++ improved food security / self sufficiency	
Ecological benefits	**Ecological disadvantages**
+++ improved harvesting / collection of water	
++ reduced surface runoff	
++ reduced hazard towards adverse events	
++ reduced soil loss	
+ recharge of groundwater table aquifer	
Off-site benefits	**Off-site disadvantages**
++ increased water availability	++ reduced river flows (only during floods)
++ reduced downstream flooding	++ reduced sediment yields
++ reduced downstream siltation	
+ decreased damage on infrastructure	

Contribution to human well-being/livelihoods

++

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	very negative	very positive
Maintenance/recurrent	neutral	positive

Acceptance/adoption: Ten per cent of land user families have implemented the technology with external material support. Ninety per cent of land user families have implemented the technology voluntary. This technique is ancient and it is therefore already fully adopted / used in the region.

Concluding statements

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
This technique allowed a expansion of cropping lands in the mountain area → encourage maintenance of existing structure	Risks related to the climatic changes → it needs to be combined with supplemental irrigation
Allows crop production in very dry environments (with less than 200 mm of rainfall) → encourage maintenance of existing structure	Risk of local know-how disappearance → training of new generations
Collects and accumulates water, soil and nutrients behind the tabia and makes it available to crops → encourage maintenance of existing structure	Land ownership fragmentation → agrarian reform
Reduced damage by flooding → encourage maintenance of existing structure	Productivity of the land is very low → development of alternative income generation activities
Well adapted technology for the ecological environment → ensure maintenance works	Land ownership fragmentation → new land access
Well known technique by the local population →training of new generations	

Key reference(s): El Amami, S. 1984. Les aménagements hydrauliques traditionnels en Tunisie. Centre de Recherche en Génie Rural (CRGR), Tunis, Tunisia. 69 pp. / Ben Mechlia, N., Ouessar, M. 2004. Water harvesting systems in Tunisia. In: Oweis, T., Hachum, A., Bruggeman, A. (eds). Indigenous water harvesting in West Asia and North Africa, , ICARDA, Aleppo, Syria, pp: 21-41.

Contact person(s): Ouessar Mohamed (Med.Ouessar@ira.agrinet.tn), Sghaier Mongi (sghaier.mon@gmail.com), Institut des Régions Arides, 4119 Medenine, Tunisia


Tabia

Tunisia

Above left: Tabia on the piedmont area. Tree products (olive, almond, fig, palm) and annuals (barley) can be harvested. (Photo: Mongi Chniter)
Above right: Tabia earthen dam in the plain. Olive trees are generally grown along the dam, where the harvested water infiltrates better (Photo: Mohamed Ouessar)

The tabia earthen dyke is a water harvesting technique used in the foothill and piedmont areas.

The tabia technology is similar to the jessour system but is used in the gently-sloping foothill and piedmont areas. It is considered to be a relatively new technique, developed by mountain dwellers who migrated to the plains. Tabias, like jessour, comprise an earthen dyke (50-150 m in length, 1-2 m in height), a spillway (central and/or lateral) and an associated water harvesting area. The ratio between the area where water is applied (cropped area) and the total area from which water is collected varies from 1:6 to 1:20. The differences between the tabia and the jessour systems are that the former contains two additional lateral bunds (up to 30 m long) and sometimes a small flood diversion dyke (mgoud). Small tabia are constructed manually using shovels, pickles and carts. Larger constructions are done mechanically using tractors and bulldozers.

Tree products and annual crops are commonly grown using tabia. Besides their water harvesting qualities, tabias also have a positive effect on soil erosion and groundwater recharge.

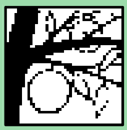
The tabia runoff-water harvesting technique is widely practised in central Tunisia. Tabias are usually installed on the piedmont, where the slope does not exceed 3% and where the soil is relatively deep. Ancient remnants of tabias have been found in the region of Gafsa (south west Tunisia). The system has been adopted by people living in the neighbouring foothills and plains of the central and southeastern regions (Jeffara) of the country, following the transformation of their pasture to cultivated fields.

Location: Medenine
Region: Medenine nord
Technology area: 10 - 100 km^2
Conservation measure: structural
Stage of intervention: prevention of land degradation
Origin: externally (10-50 years ago)
Land use: cropland, grazing land
Climate: arid, subtropics
WOCAT database reference: QT TUN12 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/zeuss-koutine-tunisia
Related approach: Dryland watershed management approach (QA TUN09)
Compiled by: Mohamed Ouessar, Mongi Chniter, Institut des Régions Arides (IRA), Tunisia
Date: 30th Jan 2009 updated 5th Jul 2011

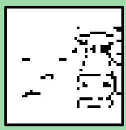
Classification

Land use problems: soil erosion by water, runoff and soil loss, overgrazing

Land use

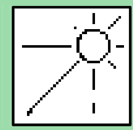


tree and shrub cropping (rainfed)



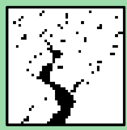
extensive grazing land

Climate



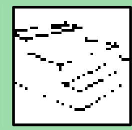
arid, subtropics

Degradation



soil erosion by water: loss of topsoil / surface erosion

Conservation measure



structural: bunds / banks

Stage of intervention

- ■ Prevention
- ▒ Mitigation / Reduction
- □ Rehabilitation

Origin

- ▒ Land user's initiative: traditional (> 50 years ago)
- □ Experiments / research
- ■ Externally introduced: 10-50 years ago

Level of technical knowledge

- ▒ Agricultural advisor
- ▒ Land user

Main causes of land degradation:
Direct causes - Natural: heavy / extreme rainfall
Indirect causes: land tenure

Main technical functions:
- control of concentrated runoff: retain / trap

Secondary technical functions:
- increase of infiltration
- water spreading

Environment

Natural Environment

Average annual rainfall (mm)

- □ > 4000
- □ 3000-4000
- □ 2000-3000
- □ 1500-2000
- □ 1000-1500
- □ 750-1000
- □ 500-750
- □ 250-500
- ■ < 250

Altitude (m a.s.l.)

- □ > 4000
- □ 3000-4000
- □ 2500-3000
- □ 2000-2500
- □ 1500-2000
- □ 1000-1500
- □ 500-1000
- ■ 100-500
- ▒ <100

Landform

- ■ plateau / plains
- □ ridges
- □ mountain slopes
- □ hill slopes
- ▒ footslopes
- □ valley floors

Slope (%)

- ■ flat
- ▒ gentle
- □ moderate
- □ rolling
- □ hilly
- □ steep
- □ very steep

Soil depth (cm)

- ▒ 0-20
- ■ 20-50
- □ 50-80
- □ 80-120
- □ >120

Growing season(s): 180 days (Oct - Apr)
Soil texture: medium (loam)
Soil fertility: very low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: medium

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: medium
Water quality: medium
Biodiversity: medium

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount), wind storms / dust storms, decreasing length of growing period
Sensitive to climatic extremes: floods and droughts / dry spells

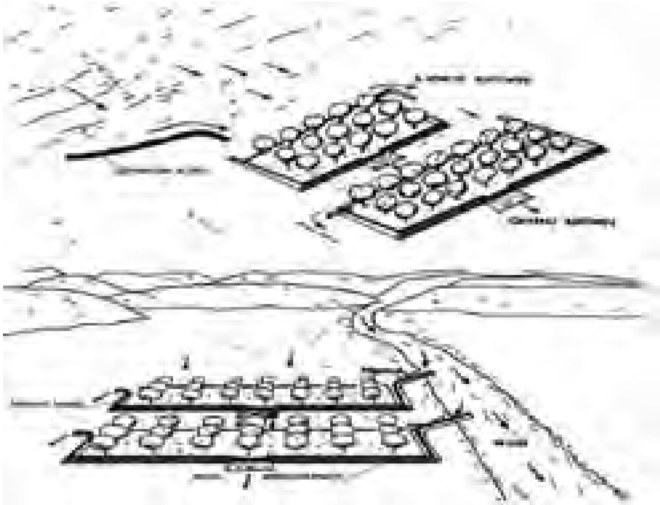
Human Environment

Mixed land per household (ha)

☐	<0.5
☐	0.5-1
■	1-2
☐	2-5
☐	5-15
☐	15-50
☐	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: individual and common small-scale land users, mainly men
Population density: 10-50 persons/km^2
Annual population growth: 0.5% - 1%
Land ownership: individual, titled
Land use rights: individual
Water use rights: individual
Relative level of wealth: average, which represents 70% of land users; 75% of the total land area is owned by average land users

Importance of off-farm income: > 50% of all income:
Access to service and infrastructure: low: financial services; moderate: health, technical assistance, employment, market, energy, roads and transport, drinking water and sanitation; high: education
Market orientation: mixed (subsistence and commercial)



Technical drawing

Tabia with natural water collection area (upper) and tabia on an expanded system with additional flood water diversions (lower). (Adapted from Alaya et al. 1993)
Found in flatter areas, tabia can accommodate more trees on the terrace especially when it can receive additional water from floods.

Implementation activities, inputs and costs

Establishment activities

1. Diversion channel
2. Plantation
3. Spillway construction
4. Terracing

Establishment inputs and costs per per medium-sized Tabia

Inputs	Costs (US$)	% met by land user
Labour	500	
Other	170	
TOTAL	**670**	**100***

Maintenance/recurrent activities

1. Dyke and spillway maintenance
2. Reconstruction

Maintenance/recurrent inputs and costs per per medium-sized Tabia

Inputs	Costs (US$)	% met by land user
Labour	150	
Other	50	
TOTAL	**200**	**100***

Remarks:
Labour is the most determining factor affecting the costs. The local wage rate is 10 US$/day.
* The technology establishment and maintenance costs met by the land users are 100% if executed on a private basis, but it can range from 10 to 50% when the site is part of a publicly-funded programme.

Assessment

Impacts of the Technology

Production and socio-economic benefits

- ++ increased crop yield
- ++ reduced risk of production failure
- ++ increased farm income
- ++ increased production area

Production and socio-economic disadvantages

- ++ loss of grazing land

Socio-cultural benefits

- ++ improved conservation / erosion knowledge
- + improved food security / self sufficiency

Socio-cultural disadvantages

Ecological benefits

- +++ improved harvesting / collection of water
- ++ reduced surface runoff
- ++ reduced hazard towards adverse events
- ++ reduced soil loss / erosion
- ++ recharge of groundwater table aquifer

Ecological disadvantages

- + increased evaporation

Off-site benefits

- ++ increased water availability
- + reduced downstream flooding
- + reduced downstream siltation
- + reduced damage on public / private infrastructure

Off-site disadvantages

- + reduced river flows (only during floods)
- + reduced sediment yields

Contribution to human well-being/livelihoods

+

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	very positive
Maintenance/recurrent	positive	very positive

Acceptance/adoption:

35% of land user families have implemented the technology with external material support.
65% of land user families have implemented the technology voluntary.
There is a strong trend towards (growing) spontaneous adoption of the technology.

Concluding statements

Strengths and → how to sustain/improve

This technique allows a rapid expansion of cropping lands in the piedmont and flat areas → encourage maintenance of existing structure

Allows crop production in very dry environments (with less than 200 mm of rainfall) → encourage maintenance of existing structure

Collects and accumulates water, soil and nutrients behind the tabia and makes it available to crops → encourage maintenance of existing structure

Reduced damage by flooding → encourage maintenance of existing structure

Weaknesses and → how to overcome

Risks related to the climatic changes → it needs to be combined with supplementary irrigation

Risk of local know-how disappearance → training of new generations

Land ownership fragmentation → agrarian reform

Productivity of the land is very low → development of alternative income generation activities

Drought spells → supplementary irrigation

Expansion is done at the expense of natural grazing land

Key reference(s): Alaya, K., Viertmann, W., Waibel, Th. 1993. Les tabias. Imprimerie Arabe de Tunisie, Tunis, Tunisia. 192 pp., Genin, D., Guillaume, H., Ouessar, M., Ouled Belgacem, A., Romagny, B., Sghaier, M., Taamallah, H. (eds) 2006. Entre la désertification et le développement: la Jeffara tunisienne. CERES, Tunis, 351 pp.

Contact person(s): Ouessar Mohamed (Med.Ouessar@ira.agrinet.tn), Chniter Mongi, Insitut des Régions Arides, 4119 Medenine, Tunisia

Above left: Water flowing through a traditional channel system (*acequia*) towards almond terraces (Photo: Joris de Vente)
Above right: Aerial view of a traditional water harvesting system (*boquera*) in SE-Spain (Photo: Google)

Water harvesting from concentrated runoff for irrigation purposes

Spain - *Boqueras (Spanish)*

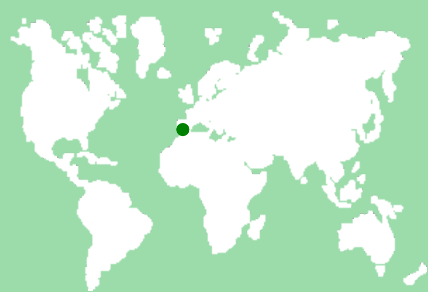
Water harvesting from intermittent streams to nearby fields and terraces during runoff events.

Water shortage is one of the most limiting factors for sustainable agriculture in large parts of SE-Spain. Part of the solution of this problem may come from the restoration of traditional water harvesting structures. Many of these structures were widely used in SE-Spain already during Arab and Roman times, and are also widespread in N-Africa and the Middle East. However, nowadays in Spain many of them are abandoned and forgotten. Here, we describe the technology of a small earthen- or stone- built bund that diverts flood water from intermittent streams towards cultivated fields with almond orchards and/or cereals. The diverted water will temporarily flood the fields and provide the crops with water. Depending on the slope gradient and the amount of water to be harvested, the fields are organised as single terraces, or as a staircase of terraces. On fields with gradients above ~3%, terraces are necessary to reduce the gradient and to retain the floodwater as long as possible. Water is diverted from one terrace to the next through small spillways in the terrace. The spillways can best be fortified with stones to prevent bank gully formation. The extra input of surface water can double the almond yield. The use of these water harvesting structures is only possible under certain environmental and topographic conditions. The cultivated fields should be at a relatively short distance from an intermittent stream (<~50m), and the stream should have a sufficiently large upstream contributing area to provide significant amounts of runoff water during rainfall events. With these systems, water can be harvested up to 8 times per year, mostly in spring and autumn during high intensity rainfall events. A well designed Boquera system may provide up to 550 mm of additional water, in areas with an average annual rainfall of 300 mm.

The goal of this technology is to increase crop yield. In addition, these structures help to reduce the intensity of floods and reduce the damage caused by them by reducing runoff volume in intermittent streams.

Water harvesting requires the identification of a suitable location for the construction of a diversion structure. This requires assessment of expected water inflow, which can usually be based on simple field observation during rainfall events and based on local knowledge of land users. It is, however, important to consider whether there are activities upstream that possibly affect the water quality (e.g. farm animals) and to assess the implications the water harvesting might have downstream. Permission is required from the water authorities to construct any type of water harvesting structure. Such structures are built by creating a small bund (<1m height) in the centre or to the side of a stream. Depending on the size, the bund can be built with a shovel or a tractor. The water harvesting structure will require control and some maintenance after each important runoff event. When strengthened with concrete, maintenance will be reduced to approximately once every 5 years.

Soils are mostly of shallow to medium depth (20-60 cm), and slopes are gentle to moderate (5-15%). The climate is semi-arid with a mean annual rainfall around 300 mm. Droughts, centred in summer commonly last for more than 4-5 months. Annual potential evapotranspiration rates larger than 1000 mm are common.

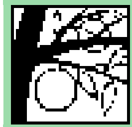


Region: Murcia, Guadalentin catchment
Technology area: < 0.1 km^2 (10 ha)
Conservation measure: structural
Stage of intervention: prevention of land degradation, mitigation / reduction of land degradation
Origin: traditional (>50 years ago)
Land use: cropland
Climate: semi-arid, subtropics
WOCAT database reference: QT SPA04 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/guadalentin-spain
Related approach: not documented
Compiled by: Joris de Vente, EEZA-CSIC
Date: 12th Jun 2008 updated 1st Jul 2011

Classification

Land use problems: There is a lack of water for irrigation of crops limiting the crop types that can be planted as well as the crop yield of dryland farming. A lack of water availability seriously limits the production potential of the soil and results in a low vegetation/crop cover. The relatively high soil erosion rates cause various off-site related problems (i.e. flooding, reservoir siltation) and on-site problems (i.e. gully formation and loss of soil depth).

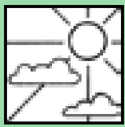
Land use



tree and shrub cropping (rainfed)

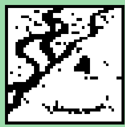
agroforestry

Climate



semi-arid, subtropics

Degradation



water degradation: aridification

Conservation measure

structural: bunds and bench terraces (slope of terrace bed <6%)

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative: > 50 years ago
Experiments / research
Externally introduced:

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - natural: droughts

Main technical functions:
- water harvesting / increase water supply
- control of concentrated runoff: retain / trap
- control of concentrated runoff: impede / retard
- control of concentrated runoff: drain / divert
- increase of infiltration

Secondary technical functions:
- water spreading

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 220 days (November until June)
Soil texture: medium (loam)
Soil fertility: low
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: poor (eg sealing /crusting)

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: for agricultural use only
Biodiversity: low

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase, wind storms / dust storms, droughts / dry spells, decreasing length of growing period
Sensitive to climatic extremes: seasonal rainfall decrease, heavy rainfall events (intensities and amount), floods
If sensitive, what modifications were made / are possible: The crop type is sensitive to changes in water availability under the semi-arid conditions.

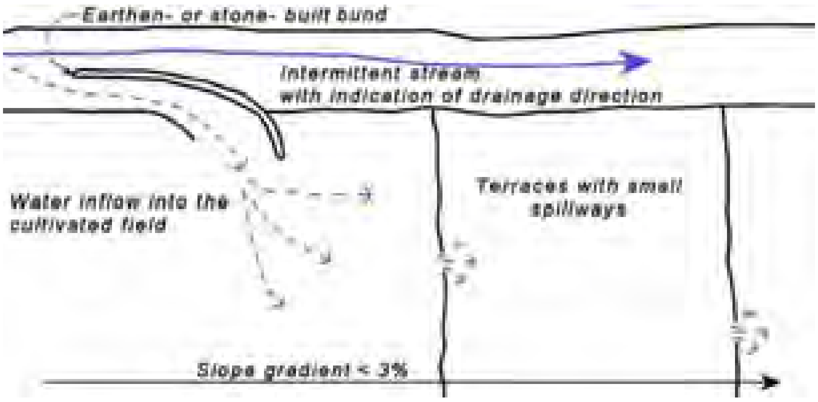
Human Environment

Cropland per household (ha)

	<0.5
	0.5-1
	1-2
	2-5
	5-15
	15-50
	50-100
	100-500
	500-1,000
	1,000-10,000
	>10,000

Land user: Individual and common small scale land users, mainly men
Population density: 10-50 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, titled
Land use rights: individual (most land is privately owned). The streams are not privately owned. Therefore permits are required to construct a water harvesting structure. Some shrubland or forest is state-owned.
Water use rights: individual. Water rights are provided and controlled by the water authority of the Segura river basin (CHS).)
Relative level of wealth average, which represents 80% of land users; 75% of the total land area is owned by average land users

Importance of off-farm income: > 50% of all income: there is no difference in the ones who apply the technology and those who do not. Most farmers do have an off-farm income for example from hunting, work in a factory or office.
Access to service and infrastructure: moderate: employment, energy;
high: health, education, technical assistance, market, roads & transport, drinking water and sanitation, financial services
Market orientation: commercial / market
Mechanization: mechanised
Livestock grazing on cropland: yes



Technical drawing

Sketch of a water harvesting structure consisting of an earthen- or stone- built bund that diverts water into cultivated fields. Several terraces are present in the fields in order to reduce slope gradient and retain water longer within the fields to allow maximum infiltration. Depending on the expected inflow of water several spillways can be made per terrace to prevent excessive concentration of flow in each spillway. (Joris de Vente)

Implementation activities, inputs and costs

Establishment activities

1. Construction of a bund (dam)

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	150	100
Equipment - machine use	350	100
Construction material - concrete	400	100
TOTAL	**900**	**100**

Maintenance/recurrent activities

1. Restoration of the bund

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	4	100
Equipment - machine use	12	100
Construction material - concrete	25	100
TOTAL	**41**	**100**

Remarks:
Labour costs and price of concrete are the most determinate factors affecting the costs.
The costs were indicated assuming a length of the bund dimensions of 5*1*1 metres. Maintenance is required once every 5 years, so yearly costs are the total costs divided by 5. The local wage rate is 79 US$/day (Prices are for spring 2008).

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ increased crop yield +++ increased farm income ++ increased irrigation water availability / quality + reduced risk of production failure	+ increased expenses on agricultural inputs
Socio-cultural benefits	**Socio-cultural disadvantages**
++ improved conservation / erosion knowledge	+ increased conflict over downstream effects
Ecological benefits	**Ecological disadvantages**
++ improved harvesting / collection of water + increased water quantity + increased soil moisture + reduced surface runoff + improved excess water drainage + recharge of groundwater table aquifer	
Off-site benefits	**Off-site disadvantages**
+ reduced downstream flooding + reduced damage on public / private infrastructure	

Contribution to human well-being/livelihoods

\+ during Roman and Arab times when most structures were operative they increased significantly the production. Nowadays, most of them are abandoned. However, those that are operational do cause increased crop yields.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	positive
Maintenance/recurrent	positive	positive

Implementation of the technology is relatively expensive. Once installed, maintenance is not expensive and pays off because of higher productivity.

Acceptance/adoption:
One hundred per cent of land user families have implemented the technology voluntarily.
There is no (growing) trend towards spontaneous adoption of the technology. Much of this knowledge is forgotten and not applied or maintained anymore

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
This technology is very effective at increasing water available for crop production and so increasing crop yield and farm income → Temporarily store the harvested water in a cistern to be used for irrigation using drip irrigation when most needed.	The implementation costs are relatively high when the bunds are made of concrete → Use of cheap materials that are freely available (stones from the fields). However, it is important to make the structure as resistant as possible against flood events.
The technology takes advantage of floodwater that is otherwise lost because of the erratic character and short duration of flow → Finding the optimal location for the water harvesting structures using a modelling approach	The water provided by these techniques is mostly interesting for small- and medium- scale rainfed farming. Intensively irrigated farming requires more water and a guarantee for water independently of flood events → Intensively irrigated farming might use this technology as an additional source of water and may store the harvested water in a cistern for use when needed.
	Farmers consider it relatively expensive to implement and there is no guarantee for water as this depends on the rainfall events. → Subsidies might help to install these structures where feasible. Therefore, good assessments of expected water inflow volumes are required before construction

Key reference(s): Frot, E., van Wesemael, B., Benet, A.S. and House, M.A., 2008. Water harvesting potential in function of hillslope characteristics: A case study from the Sierra de Gador (Almeria province, south-east Spain). Journal of Arid Environments, 72(7): 1213-1231

Contact person(s): Joris de Vente, EEZA-CSIC, Joris@sustainable-ecosystems.org

Above left: Irrigation canal that brings freshwater to arable land (Photo: Vasileios Diamantis)
Above right: Electric water pump that provides irrigation water directly from canal (Photo: Alexandros Pechtelidis)

Transport of freshwater from local streams

Greece - *Μεταφορά γλυκού από γειτονικά αρδευτικά κανάλια (Greek)*

Freshwater transport from local streams for irrigation purposes, in order to replace the traditional form of irrigation (by pumping saline groundwater from wells).

In low-lying regions suffering from overuse of the ground water for irrigation and seawater intrusion, pumping groundwater is detrimental and results in soil degradation (salinization) and reduced plant growth. For this reason, freshwater is transported over distances of up to 500 m (or more) from surface streams, for irrigation using water of better quality. In this way, overexploitation of the aquifer is being reduced.

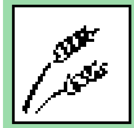
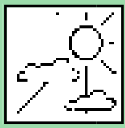
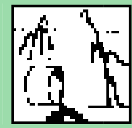
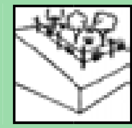
The pumps transfer water from canals or streams for irrigation purposes. A pumping station (10HP), pipes (PP-R, Ø 1100mm) for water transport and diesel or electricity for pump operation are the major items needed to replace groundwater with freshwater irrigation. However, annual maintenance of the pump and network is necessary.

The majority of families living in the research area make their living mostly from agricultural activities but also from livestock. Croplands are dominantly irrigated by wells (groundwater) and only those which are close to streams are irrigated with freshwater. Owing to over-pumping of the aquifer in order to irrigate the crop fields, there has been seawater intrusion over the past years. As a result, irrigation with groundwater led to saline soils. The group affected by this process comprises farmers who are now beginning to understand the extent of the desertification problem in the area. The degradation process significantly affects the quality of life of the local people. Saline soils lead to low productivity and thus to lower incomes (causing poverty) and thus an increase in social unrest. Although the farmers are totally aware of the on-going degradation problem that affects their fields and their livelihoods, they seem to be unwilling to change the way they irrigate their fields (with groundwater) as long as they do not have an alternative source of irrigation such as freshwater from local streams. The lack of information about how the salt-affected fields can be restored also makes the farmers believe that this situation is permanent and will extend over a wider area.

Location: Prefecture of Xanthi
Region: Eastern Macedonia and Thrace
Technology area: 9.59 km^2
Conservation measure: management
Stage of intervention: prevention of land degradation
Origin: experiments - recent (<10 years ago)
Land use: cropland
Climate: semi-arid, temperate
WOCAT database reference: QT GRE05 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/nestos-river-delta-greece
Related approach: Combating Soil Salinization (QA GRE05)
Compiled by: John Gkiougkis, Democritus University of Thrace, Greece
Date: 28th Nov 2008 updated 10th Jun 2011

Classification

Land use problems: Soil salinization and sodification.

Land use	Climate	Degradation	Conservation measure
			
annual cropping (full irrigation)	semi-arid, temperate	chemical soil deterioration: salinisation / alkalinisation	management: water transport

Stage of intervention

■	Prevention
▒	Mitigation / Reduction
▒	Rehabilitation

Origin

□	Land user's initiative
■	Experiments / research: <10 years ago
□	Externally introduced

Level of technical knowledge

■	Agricultural advisor
▒	Land user

Main causes of land degradation:
Human induced: disturbance of water cycle (infiltration / runoff), over abstraction / excessive withdrawal of water (for irrigation, industry, etc.)
Direct causes - Natural: seawater intrusion in coastal aquifers of the area, poor soil drainage
Indirect causes: increased pressure on groundwater for irrigation

Main technical functions:
- replacing saline groundwater with surface freshwater
- reduce pressure/overexploitation on aquifer

Secondary technical functions:
- increase of infiltration
- improvement of surface structure (crusting, sealing)
- improvement of topsoil structure (compaction)
- increase of groundwater level, recharge of groundwater

Environment

Natural Environment

Average annual rainfall (mm)

□	> 4000
□	3000-4000
□	2000-3000
□	1500-2000
□	1000-1500
□	750-1000
■	500-750
□	250-500
□	< 250

Altitude (m a.s.l.)

□	> 4000
□	3000-4000
□	2500-3000
□	2000-2500
□	1500-2000
□	1000-1500
□	500-1000
□	100-500
■	<100

Landform

■	plateau / plains
□	ridges
□	mountain slopes
□	hill slopes
□	footslopes
□	valley floors

Slope (%)

■	flat
□	gentle
□	moderate
□	rolling
□	hilly
□	steep
□	very steep

Soil depth (cm)

□	0-20
□	20-50
□	50-80
□	80-120
■	>120

Growing season(s): 100 days (April to August)
Soil texture: fine / heavy (clay)
Soil fertility: low
Topsoil organic matter: medium (1-3%), low (<1%)
Soil drainage/infiltration: poor (e.g. sealing /crusting)

Soil water storage capacity: medium
Ground water table: on surface, <5 m
Availability of surface water: good
Water quality: for agricultural use only
Biodiversity: high

Tolerant of climatic extremes: temperature increase
Sensitive to climatic extremes: seasonal rainfall increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount), floods, droughts / dry spells → not much can be done to reduce the sensitivity rather than increasing efficiencies of water use or adding storage capacity for irrigation water.

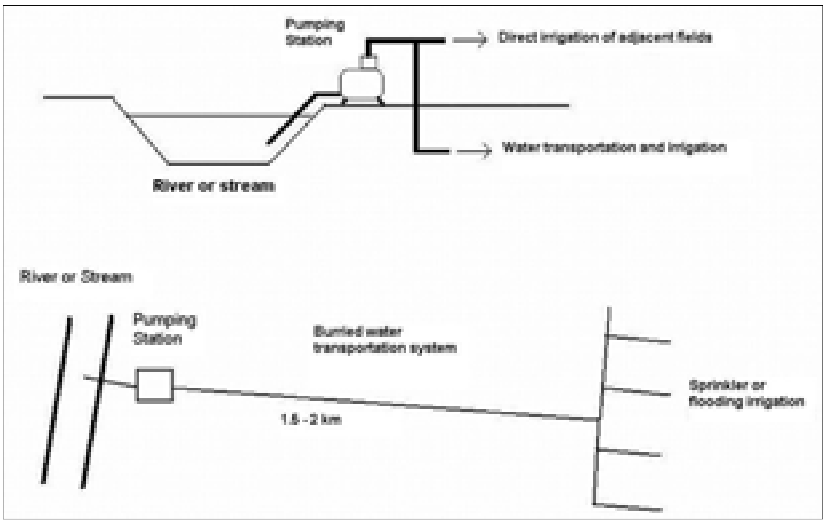
Human Environment

Cropland per household (ha)

- <0.5
- 0.5-1
- 1-2
- 2-5
- 5-15
- 15-50
- 50-100
- 100-500
- 500-1,000
- 1,000-10,000
- >10,000

Land user: groups / community of small and average scale land users, mixed
Population density: 10-50 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, titled
Land use rights: individual
Water use rights: communal (organised)
Relative level of wealth: average, which represent 70% of land users, 80% of the total land area is owned by average land users

Importance of off-farm income: 10-50% of all income: Animal breeders or/and factories workers.
Access to service and infrastructure: low: financial services; moderate: education, employment; high: health, technical assistance, market, energy, roads & transport, drinking water and sanitation
Market orientation: commercial / market
Mechanization: mechanised
Livestock grazing on cropland: yes little



Technical drawing

Scheme showing the SLM technology application (Alexandros Pechtelidis)

Implementation activities, inputs and costs

Establishment activities

1. Purchase of the materials: pump, pipes, etc.
2. Construction of irrigation network

Establishment inputs and costs per ha / one irrigation unit

Inputs	Costs (US$)	% met by land user
Labour	969	80
Equipment - hire of an excavator	1107	100
Construction material - water transport pipes	3598	100
Other - pumping station (10hp)	3460	100
TOTAL	**9129**	**97**

Maintenance/recurrent activities

1. Network maintenance

Maintenance inputs and costs per ha / one irrigation unit

Inputs	Costs (US$)	% met by land user
Labour	138	100
Other - pumping station spare parts - diesel fuel / electricity	 275 1512 / 824	 100 100
TOTAL	**1924 / 1237**	**100**

Remarks:
Diesel or electricity price affects the final cost.
The above costs are calculated on May 2011.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ decreased demand for groundwater ++ increased crop yield ++ reduced risk of production failure + increased farm income	++ decreased surface irrigation water quantity ++ increased demand for irrigation water
Socio-cultural benefits	**Socio-cultural disadvantages**
+++ improved conservation / erosion knowledge	
Ecological benefits	**Ecological disadvantages**
+++ increased water quality +++ reduced soil crusting / sealing +++ reduced salinity + recharge of groundwater table aquifer	
Off-site benefits	**Off-site disadvantages**
++ reduced groundwater / river pollution + reduced downstream flooding	++ reduced river flows
Contribution to human well-being/livelihoods	
++ income increase and thus well-being.	

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	positive	positive
Maintenance/recurrent	neutral / balanced	neutral / balanced

The benefits are obvious from the first year of application of the SLM technology and the maintenance cost is logical.

Acceptance/adoption:

100% of land user families (50 families; 50% of area) have implemented the technology voluntarily. The remaining area (50 %) is irrigated with groundwater.
There is a moderate and growing trend towards spontaneous adoption of the technology.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Increased irrigation water quality which result in a better soil quality → Construction of more irrigation canals	Installation cost → Financial aid from the government/EU
Remediation of soils → Better drainage systems	Applicable only for fields adjacent or very close to a freshwater source → Construction of canals
Groundwater recharge → Construction of more irrigation canals	Bureaucratic problems → Promotion of fast-track financial programmes
Improved quality/quantity of yield → Selection of the most suitable crop type	
Improved livelihood of the locals → Better local products promotion	
Better yield → Application of fertilizers	
More income due to improved crop quality → Selection of crop type	
Better future perspective for the area → Financial motives	

Key reference(s): Gkiougkis I. et. al. (2010) Proceedings of the 12th International Congress, Geological Society of Greece, Patras, May, 2010

Contact person(s): John Gkiougkis and Alexandros Pechtelidis, Democritus University of Thrace, Greece, jgiougis@civil.duth.gr

Above left: A recharge well reduces the length of time of standing water, and thus evaporation, by injecting flood water rapidly into the aquifer, where it is stored and recovered later to be used for different purposes. This is an example of a recharge well behind a gabion check dam after rain. (Photo: Ouessar M.)
Above right: A recharge well needs to be always combined with a gabion check dam which prevents floodwater movement downstream and creates a temporary pond (Photo: Temmerman S.)

Recharge well

Tunisia - *Puits filtrant (French)*

A recharge well comprises a drilled hole, up to 30-40 m deep that reaches the water table, and a surrounding filter used to allow the direct injection of floodwater into the aquifer.

The main worldwide used methods to enhance groundwater replenishment are through recharge basins or recharge wells. Though groundwater recharge aiming at storage of water in the periods of abundance for recovery in times of drought has a long history dating back millennia, the recharge wells began to be used only in the twentieth century, especially during the Second World War following concerns on attacks of the water supply facilities. Its use was extended later to sea intrusion control, treated waste water, water harvesting in the dry areas, and strategic water storage.

Recharge wells are used in combination with gabion check dams to enhance the infiltration of floodwater into the aquifer. In areas where the permeability of the underlying bedrock in front of a gabion is judged too low, recharge wells could be installed in wadi (ephemeral river) beds. Water is retained by the gabion check dam and it flows through the recharge well allowing accelerated percolation into the aquifer.

A recharge well consists of a long inner tube surrounded by an outer tube, the circumference of which ranges between 1 and 2 m. The area between the tubes is filled with river bed gravel which acts as a sediment filter. Water enters the well through rectangular-shaped openings (almost 20 cm long and a few mm in width) located in the outer tube, and it flows in the inner hole having passed through the gravel and the rectangular shaped openings of the drill hole. The above-ground height is around 2 to 3 m whereas the depth is linked to the depth of the water table (normally up to 40 m). The drill hole connects directly with the aquifer, where it is connected either directly with the water table or indirectly via cracks. Pond volume is dependent on the size of the gabion check dam but generally ranges between 500 and 3000 m^3. The filtered water can directly flow into the aquifer at a rate exceeding what would occur naturally through the soil and the underlying strata.

The design should be conducted primarily by a hydrogeologist and a soil and water conservation specialist in order to determine the potential sites and the required drilling equipment. Drilling needs to be carried out by a specialized company.

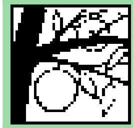
Depending on the geological setting, the overall cost is around 5000 to 10000 US$. The recharge wells are used to recharge the deep groundwater aquifers, which are mainly exploited by government agencies. However, private irrigated farms are benefiting indirectly by increased groundwater availability.

Location: Medenine
Region: Medenine nord
Technology area: 10 - 100 km^2
Conservation measure: structural
Stage of intervention: prevention of land degradation
Origin: externally - 10-50 years ago
Land use: cropland, grazing land
Climate: arid, subtropics
WOCAT database reference: QT TUN14 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/zeuss-koutine-tunisia
Related approach: Dryland watershed management approach (QA TUN09)
Compiled by: Mohamed Ouessar, Houcine Yahyaoui, Institut des Régions Arides (IRA), Tunisia
Date: 31st Jan 2009, updated 10th Jun 2011

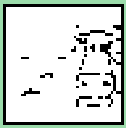
Classification

Land use problems: Runoff water loss, riverbank erosion, flooding risk, aridity

Land use

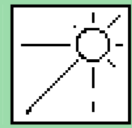


tree and shrub cropping



extensive grazing land

Climate

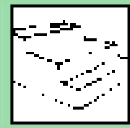


arid, subtropics

Degradation

water degradation: aridification

Conservation measure



structural: well

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative
Experiments / research: < 10 years ago
Externally introduced: 10-50 years ago

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - human induced: over abstraction / excessive withdrawal of water (for irrigation, industry, etc.)

Main technical functions:
- increase of groundwater level, recharge of groundwater

Secondary technical functions:
- water harvesting / increase water supply

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 180 days (Oct - Apr)
Soil texture: medium (loam)
Soil fertility: very low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: medium

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: poor, but with periods of excess (eg flood)
Water quality: medium
Biodiversity: medium

Tolerant of climatic extremes: all except extreme floods
Sensitive to climatic extremes: extreme floods

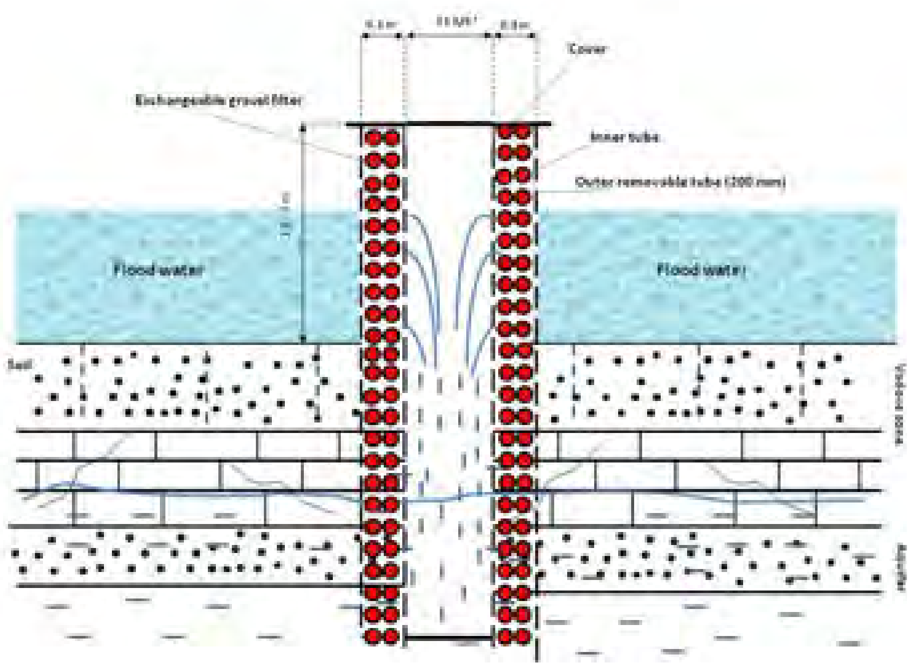
Human Environment

Mixed land per household (ha)

☐	<0.5
☐	0.5-1
■	1-2
☐	2-5
☐	5-15
☐	15-50
☐	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: employee (company, government)
Population density: 10-50 persons/km^2
Annual population growth: 0.5% - 1%
Land ownership: state
Land use rights: communal (organised)
Water use rights: communal (organised)
Relative level of wealth: average, which represents 70% of land users; 75% of the total land area is owned by average land users

Importance of off-farm income: > 50% of all income
Access to service and infrastructure: low: financial services; moderate: health, technical assistance, employment, market, energy, roads & transport, drinking water and sanitation; high: education
Market orientation: mixed (subsistence and commercial)



Technical drawing

Schematic representation of the main components of a recharge well. The flood water retained behind the gabion check dam flows through the outer tube and the gravel filter into the water table. Clogging of the filter is one of the major problems to be considered and solved. (Ouessar M.)

Implementation activities, inputs and costs

Establishment activities

1. Drilling
2. Installation

Establishment inputs and costs per unit

Inputs	Costs (US$)	% met by land user
Labour	7000	0
Construction material	1000	0
TOTAL	**8000**	**0**

Maintenance/recurrent activities

1. Desilting of the filter
2. Repairs

Maintenance/recurrent inputs and costs per unit per year

Inputs	Costs (US$)	% met by land user
Labour	500	0
Construction material	100	0
TOTAL	**600**	**0**

Remarks:
The costs per unit can be taken as per one hectare of land benefiting from the recharge well. Labour is the most determining factor affecting the costs. The local wage rate is 10 US$/day.

Assessment

Impacts of the Technology	
Production and socio-economic benefits	**Production and socio-economic disadvantages**
++ increased drinking water availability ++ increased water availability / quality for livestock ++ increased irrigation water availability / quality	
Socio-cultural benefits	**Socio-cultural disadvantages**
+ conflict mitigation + improved conservation / erosion knowledge	
Ecological benefits	**Ecological disadvantages**
+++ recharge of groundwater table / aquifer ++ improved harvesting / collection of water ++ reduced hazard towards adverse events (flooding, drought) ++ reduced salinity	++ risks of contamination of aquifers
Off-site benefits	**Off-site disadvantages**
++ increased water availability ++ reduced downstream flooding + reduced damage on public / private infrastructure	++ reduction of surface water to reach downstream areas
Contribution to human well-being/livelihoods	
++ increased availability of water for drinking, agriculture and livestock	

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	very positive	positive
Maintenance/recurrent	very positive	positive

Long-term benefits are slightly reduced due to silting problems.

Acceptance/adoption:

No land-user families have implemented the technology with external material support. It is solely constructed by the government agencies.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Replenishment of the aquifer → Good selection of the site and drilling methods	Silting up of the filter → Maintenance of the filters.
	Malfunction due to aquifer geometry and characteristics → Good selection of the sites
	Retain water for downstream users → Proper watershed management plan

Key reference(s): Yahyaoui, H., Ouessar, M. 2000. Abstraction and recharge impacts on the ground water in the arid regions of Tunisia: Case of Zeuss-Koutine water table. UNU Desertification Series, 2: 72-78.; Temmerman, S. 2004. Evaluation of the efficiency of recharge wells on the water supply to the water table in South Tunisia. Graduation dissertation, Ghent University, Belgium.

Contact person(s): Ouessar Mohamed, Institut des Régions Arides, 4119 Medenine, Tunisia, Yahyaoui Houcine, CRDA, 4100 Medenine, Tunisia, Med.ouessar@ira.agrinet.tn

Above left: Main and secondary pipe organization of a drip irrigation system (Photo: http://www.netafim.com.tr)
Above right: Drip irrigation of potato cropland within the Karapınar hotspot (Photo: Mehmet Zengin)

Drip irrigation

Turkey - *Damla Sulama (Turkish)*

Drip irrigation is a method designed for minimum use of water and labour for the optimum irrigation of plants in arid and semi-arid regions.

In drought–affected regions, fruit trees, vineyards, vegetables and other field crops such as maize, sugarbeet, potatoes, onion, etc. are watered by drip-irrigation using pipes with dripfeed points. This saves water and maximum benefit is achieved with a minimum of water. In this system, plant roots receive water at the right time and in sufficient quantities. Labour expenses with the system are low, but the first investment expenses are high. At current prices, it costs about 2000 US$ per ha, which varies with the density of the network required for the specific crop.

Depending on the size of the field to be watered, a main network of PVC pipes able to cope with the pressure necessary to convey water to secondary/lateral pipe systems. These pipes are mostly 2.5cm in diameter and have dripfeed points at their ends. The system is suitable for water conservation, because it enables watering to be focused where required, i.e. close to the root zone of the crops, but without wasting water. However, increased use in rainfed areas will increase the overall water demand. From the viewpoint of surface sealing of the soil, it has advantages since it causes wetting only in limited areas. Problems such as salinization and leaching of nutrients are also reduced by limiting the watering. At the same time, the method considerably increases farm income as excessive watering is avoided.

The basic land use types targeted with the technology are perennial tree crops (i.e. orchard and stony fruit crops) and annual crops with individual plant stems such as potato, maize and sunflower. Maize is used as fodder. It is particularly useful in arid and semi-arid regions where evapotranspiration is high, surface waters are scarce and groundwater is threatened due to high exploitation. It grows under all topographic conditions.

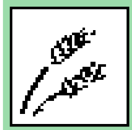
From the viewpoint of human environment, the technology is profitable for farmers who have a pressurized pumping system connected to a groundwater source. The basic costs are for the planning of the irrigation system, the hard PVC pipes and its set-up in the field. These services are provided by specialized companies, while the maintenance of the system can be done by the farmers themselves. The volume of the crops produced in this system is high and intended for commercial use.

Location: Konya
Region: Karapınar
Technology area: 1 km^2
Conservation measure: structural
Stage of intervention: prevention of land degradation
Origin: experiments - recent (<10 years ago)
Land use: cropland
Climate: semi-arid, temperate
WOCAT database reference: QT TUR03 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/karapinar-turkey
Related approach: Minimum Water Use (QA TUR03)
Compiled by: Mehmet Zengin, University of Selcuk, Faculty of Agriculture
Date: 1st Mar 2011, updated 7th Jul 2011

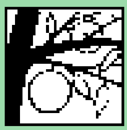
Classification

Land use problems: The main problem in the Konya closed basin is the rapidly dropping groundwater levels. For this reason electricity expenses for watering is intolerably increasing for the farmers and groundwater resources are irreversibly rapidly decreasing. Moreover, other types of watering (sprinkler and flowing) in the Karapınar area cause secondary degradation problems such as salinization and sealing.

Land use

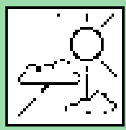


annual cropping (before)



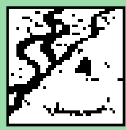
annual and tree cropping, full irrigation (after)

Climate



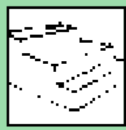
semi-arid, temperate

Degradation



water degradation: extreme exploitation of groundwater

Conservation measure



structural: irrigation network

Stage of intervention

- ■ Prevention
- ▒ Mitigation / Reduction
- □ Rehabilitation

Origin

- □ Land user's initiative
- ■ Experiments / research: <10 years
- □ Externally introduced

Level of technical knowledge

- ■ Agricultural advisor
- ▒ Land user

Main causes of land degradation:
Direct causes - Human induced: wrong crop management (annual, perennial, tree/shrub); over abstraction / excessive withdrawal of water (for irrigation)
Indirect causes: population pressure

Main technical functions:
- water harvesting / increase water supply

Secondary technical functions:
- increase of groundwater level, recharge of groundwater

Environment

Natural Environment

Average annual rainfall (mm)

- □ > 4000
- □ 3000-4000
- □ 2000-3000
- □ 1500-2000
- □ 1000-1500
- □ 750-1000
- □ 500-750
- ■ 250-500
- □ < 250

Altitude (m a.s.l.)

- □ > 4000
- □ 3000-4000
- □ 2500-3000
- □ 2000-2500
- □ 1500-2000
- ■ 1000-1500
- □ 500-1000
- □ 100-500
- □ <100

Landform

- ■ plateau / plains
- □ ridges
- □ mountain slopes
- □ hill slopes
- □ footslopes
- □ valley floors

Slope (%)

- ■ flat
- ▒ gentle
- □ moderate
- □ rolling
- □ hilly
- □ steep
- □ very steep

Soil depth (cm)

- ▒ 0-20
- ■ 20-50
- □ 50-80
- □ 80-120
- □ >120

Growing season(s): 210 days (Oct - Apr)
Soil texture: medium (loam)
Soil fertility: medium
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: good

Soil water storage capacity: medium
Ground water table: 50 m
Availability of surface water: poor / none
Water quality: poor drinking water
Biodiversity: low

Tolerant of climatic extremes: temperature increase and rainfall decrease
Sensitive to climatic extremes: very low temperatures

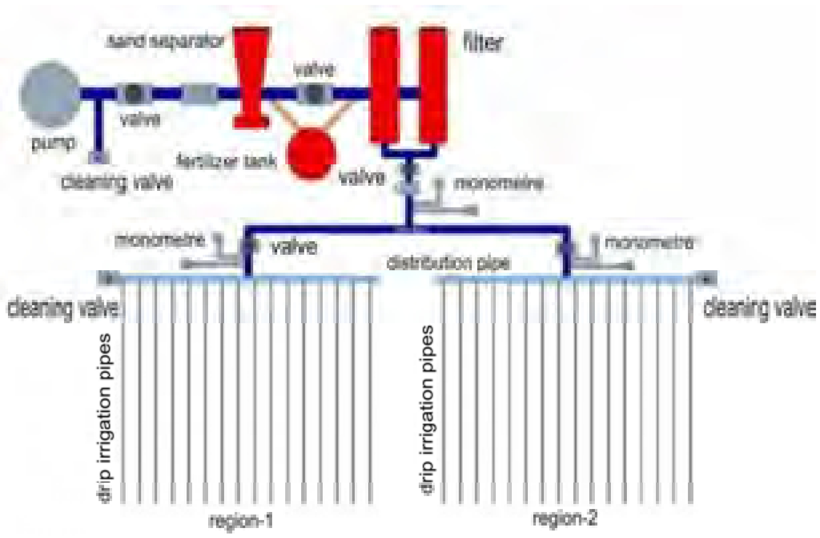
Human Environment

Cropland per household (ha)

	<0.5
	0.5-1
	1-2
	2-5
	5-15
■	15-50
▒	50-100
	100-500
	500-1,000
	1,000-10,000
	>10,000

Land user: individual and privileged medium scale land users
Population density: 10-50 persons/km^2
Annual population growth: 0.5% - 1%
Land ownership: individual, titled
Land use rights: individual
Water use rights: individual
Relative level of wealth: average, which represents 70% of land users; 10% of the total land area is owned by average land users

Importance of off-farm income: less than 10% of all income
Access to service and infrastructure: low: employment; moderate: health, technical assistance, market, energy, drinking water and sanitation, financial services; high: education
Market orientation: mixed (subsistence and commercial)



Technical drawing

A sufficiently powerful pump provides pressurized water into the system. Before entering the distribution pipes, the water is cleared of silt particles in the filters and fertilizers are added if needed (http://www.ziraialet.com/haber).

Implementation activities, inputs and costs

Establishment activities

1. Installation of drip irrigation system
2. Farmers training

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	100	90
Other - drip irrigation system: tools	2000	90
TOTAL	**2100**	**90**

Maintenance/recurrent activities

1. Change of drippers
2. Change of sediment filters
3. Overall cleaning of the system

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	100	100
Other - drip irrigation system: tools	200	100
TOTAL	**200**	**100**

Remarks:
The main network of hard PVC pipes, pressure indicators, main distributor, and labour force are the main costs. The local wage rate is 25 US$/day.
In the calculation, it is assumed that the crop is a legume with 50 cm regular row intervals and the distance between individual plants is of the order of 30 cm.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ increased fodder production ++ increased crop yield ++ increased fodder quality ++ increased irrigation water availability / quality ++ increased farm income ++ diversification of income sources	+ increased demand for irrigation water
Socio-cultural benefits	**Socio-cultural disadvantages**
++ improved conservation / erosion knowledge + community institution strengthening + conflict mitigation + improved health	
Ecological benefits	**Ecological disadvantages**
+++ reduced evaporation ++ increased water quantity ++ increased soil moisture + increased water quality + reduced surface runoff	
Off-site benefits	**Off-site disadvantages**
+++ increased water availability	

Contribution to human well-being/livelihoods

+++ Certainly the technology supplies richness, easiness and low water consumption. It supports high quality and quantity of production due to the fact that plants grow without no water or excessive water stress.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	very positive
Maintenance/recurrent	very positive	very positive

Short- and long-term benefits are very positive. But the technique is new and there is not enough knowledge of this system, especially in fertigation (watering + fertilizing). First investment costs are high and users do not believe drip water will feed the plants.

Acceptance/adoption:

The drip irrigation system is actively applied in 10% of the Apak Yayla area by 290 families, representing 30% of the population. In recent times, the area affected reached 20%, because the Turkish Government gives credit with no interest to farmers in dry regions. Seventy per cent of these land user families have implemented the technology with external material support; thirty per cent have implemented it voluntarily. Initially, only rich farmers used this system because it is expensive.
There is a general and growing trend towards spontaneous adoption of the technology amongst farmers. The government has responded positively to this situation by giving no-interest credit for 5 years.

Concluding statements

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
Minimum water use, easy using, low energy demand (fuel, electric, labour, etc.) → Subsidizing.	Users do not know how to use this new system exactly. In particular, farmers do not know "fertigation" methods for their different plants such as maize, sugar beet, potato, and orchards. → More education and demonstration of fertigation methods by state institutions.
Sufficient watering enables an increased crop yield → education regarding the watering frequency would be useful.	
Ease of watering with this system → Training and subsidies.	Drip irrigation system has a short life (1-5 years) → UV-tolerant plastic must be manufactured and used.

Key reference(s): Kara, M., 2005. Sulama ve Sulama Tesisleri. S.Ü. Ziraat Fak. Tarımsal Yapılar ve Sulama Böl., Konya, Turkiye.

Şahin, M. ve Kara, M., 2006. Konya İklim Koşullarında Farklı Sulama Uygulamalarının Çim Gelişimine Etkisi ve Su Kısıtına Yönelik Sulama Alternatifleri. S.Ü. Ziraat Fak. Derg., 20(39), 118-128, Konya.

Contact person(s): Assoc. Prof. Dr. Mehmet Zengin, University of Selcuk, Faculty of Agriculture; mzengin@selcuk.edu.tr

Above left: Stakeholders in the field (Photo: Zeiliguer Anatoly.)
Above right: Students managing water supply and controlling pipes of drip irrigation system at experimental parcel with drip irrigation of tomatoes (Photo: Zeiliguer Anatoly.)

Drip irrigation

Russian Federation - *Капельное орошение (Russian)*

Drip irrigation systems gradually apply water into the zone around the stem of the irrigated plant.

Drip irrigation experiments have been carried out on the left bank of the Volga River. Economic problems, regional reforms and shortage of investments in municipal water supply infrastructure led to problems of water quality and quantity of available water for industrial, agricultural and domestic uses. The situation is getting worse with the effects of regional climate change. Especially during summer, the study region has problems with shortage of water not just for irrigation of agricultural fields, or gardens, but also for domestic use. In such situations, more efficient water use is required through introducing water-saving technologies. One of these well-known irrigation technologies is drip irrigation. Small quantities of water are directly delivered to the plants by a pipe system. This technology is the most effective from the point of view of green water use efficiency. Correct application of drip irrigation technology drastically decreases water losses by runoff and evaporation as well as deep percolation to soil depths inaccessible to root uptake. Water can be provided to plants from surface water reservoirs, water tanks or groundwater wells through a network of plastic pipes (under low water pressure) and delivered through a water drip system. The flow rate can be adjusted to the needs of the particular stage of plant growth, to soil hydraulic properties and to the prevailing weather conditions. The low-pressure supply system can be operated using a header tank or directly by using a water pump to raise water from nearby surface water storage or a groundwater well. The aim of this technology is to show the effectiveness of freshwater usage in irrigating vegetables (tomatoes, peppers) at the scale of subsidiary plots or small irrigation systems (several ha in size) in a region with scarce water resources both as a water-saving measure and an eco-friendly alternative to furrow irrigation. Owing to the relative narrowness of the drip feeders, they are prone to blockages from organic matter, mineral particles or dissolved compounds. To prolong the lifetime of the drip irrigation equipment, it needs to be maintained using preventive and remedial measures such as visual inspection of pipes and water supply sources, filter installations as well as flushing the tubes and drip emitters to remove deposits.

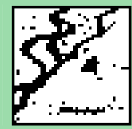
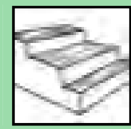
In general, a number of medium-scale farmers are using furrow irrigation of vegetables as their main agricultural activity. Drip-irrigation technology was tested with four families and compared to furrow irrigation in order to compare water consumption (water use efficiency as rate of yield and volume of water used for irrigation) as well as its impact on soil degradation and ground-water. The water use efficiency of drip irrigation is 3 - 10 times higher than that of furrow irrigation, depending on local conditions and qualification of furrow irrigators. Furthermore, this technology avoids water loss through soil surface evaporation, percolation to deep soil layers and ground water, and runoff into near water bodies (causing pollution by chemicals used for agricultural activities at irrigated fields like fertilizers and plant protectors). The negative impact of furrow irrigation on soil productivity is usually very high due to soil erosion.

Experimentations and demonstration of drip irrigation were done at two levels. The first level involved large-scale farms with the aim of demonstrating the considerable gains to be made through the efficient use of water, through the development of representative experimental plots on fields used for furrow irrigation by two farmers. During the growing season, we demonstrated these plots to local farmers as well as to farmers from other municipalities and locations in the region. The second level was developed for small-scale farmers and householders to demonstrate the efficiency of water saving in gardening.

Location: Saratov Region
Region: Marksovsky District
Technology area: < 0.1 km^2 (10 ha)
Conservation measure: structural
Stage of intervention: mitigation / reduction of land degradation
Origin: Externally - recent (<10 years ago)
Land use: cropland
Climate: semi-arid, temperate
WOCAT database reference: QT RUS01 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/novy-russia
Related approach: Living together- thinking on common (QA RUS01)
Compiled by: Anatoly Zeiliguer, Moscow State University of Environmental Engineering
Date: 20th Feb 2011 updated September 2011

Classification

Land use problems: Scarcity of fresh water resources, change of local seasonal climate patterns related to change in rainfall, scarcity of freshwater resources, soil salinization, disappearance of some species of flora and fauna.

Land use	Climate	Degradation	Conservation measure
			
annual cropping (irrigated)	semi-arid, temperate	water degradation: decline of surface water quality and quantity (soil and water bodies) s	structural: irrigation network

Stage of intervention

- □ Prevention
- ■ Mitigation / Reduction
- □ Rehabilitation

Origin

- □ Land user's initiative: >50 years ago
- □ Experiments / research
- ■ Externally introduced

Level of technical knowledge

- ▒ Agricultural advisor
- ▒ Land user

Main causes of land degradation:
Direct causes - human induced: disturbance of water cycle (infiltration / runoff)
Indirect causes: inputs and infrastructure

Main technical functions:
- saving water resources

Secondary technical functions:
- increase in organic matter

Environment

Natural Environment

Average annual rainfall (mm)

- □ > 4000
- □ 3000-4000
- □ 2000-3000
- □ 1500-2000
- □ 1000-1500
- □ 750-1000
- □ 500-750
- ■ 250-500
- □ < 250

Altitude (m a.s.l.)

- □ > 4000
- □ 3000-4000
- □ 2500-3000
- □ 2000-2500
- □ 1500-2000
- □ 1000-1500
- □ 500-1000
- □ 100-500
- ■ <100

Landform

- ■ plateau / plains
- □ ridges
- □ mountain slopes
- □ hill slopes
- □ footslopes
- □ valley floors

Slope (%)

- ■ flat
- □ gentle
- □ moderate
- □ rolling
- □ hilly
- □ steep
- □ very steep

Soil depth (cm)

- □ 0-20
- ▒ 20-50
- ■ 50-80
- □ 80-120
- □ >120

Growing season(s): 120 days (May - Sept)
Soil texture: medium (loam)
Soil fertility: very low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: poor (e.g. sealing /crusting)

Soil water storage capacity: high
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: for agricultural use only
Biodiversity: low

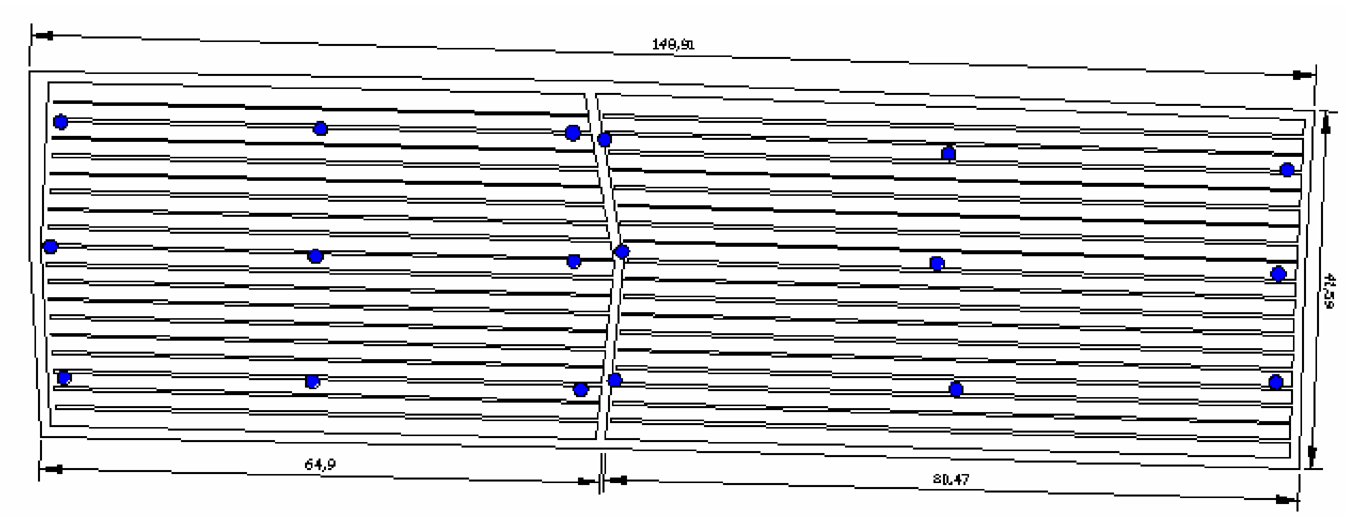
Tolerant of climatic extremes: -
Sensitive to climatic extremes: droughts / dry spells
If sensitive, what modifications were made / are possible: input of organic matter

Human Environment

Cropland per household (ha)		
<0.5 **0.5-1** (selected) 1-2 2-5 5-15 15-50 50-100 100-500 500-1,000 1,000-10,000 >10,000	**Land user:** Individual small-scale land users **Population density:** < 10 persons/km^2 **Annual population growth:** < 0.5% **Land ownership:** communal / village **Land use rights:** individual **Water use rights:** communal (organised) **Relative level of wealth:** poor (70% of all land users). In all, 80% of the total land area is owned by poor land users	**Importance of off-farm income:** less than 10% of all income **Access to service and infrastructure:** low: drinking water and sanitation, technical assistance, employment, market, financial services; moderate: health, education, energy, roads & transport **Market orientation:** subsistence (self-supply) **Mechanization:** mechanised **Livestock grazing on cropland:** yes

Technical drawing

Schematic diagram of an experimental plot with drip irrigation at the large-scale farm level, showing the location of access tubes for soil moisture monitoring (Semenov V.)



Implementation activities, inputs and costs

Establishment activities

1. installation of pipe network
2. tapping the source of water supply

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	60	100
Equipment - tools	3000	0
TOTAL	**3060**	**100**

Maintenance/recurrent activities

1. Reinstallation of pipe network every year.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	60	100
TOTAL	**60**	**100**

Remarks:

The pipe system is the most determining factor affecting the costs. Costs are given for 1 ha of land.

Assessment

Impacts of the Technology	
Production and socio-economic benefits	**Production and socio-economic disadvantages**
+++ reduced demand for irrigation water ++ increased product diversification ++ increased crop yield	+ relatively high costs for purchasing, installation and maintenance.
Socio-cultural benefits	**Socio-cultural disadvantages**
++ improved food security / self sufficiency	
Ecological benefits	**Ecological disadvantages**
++ increased soil moisture ++ reduced evaporation	
Off-site benefits	**Off-site disadvantages**
+++ no runoff, no water erosion, no ground water rising	
Contribution to human well-being/livelihoods	
++ this technology will help people to receive more diverse food.	

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	neutral / balanced	positive
Maintenance/recurrent	positive	positive

Even in the first year the labour time is much less compare to the labour needed for irrigation by furrows.

Acceptance/adoption:

In all, 100% of land user families (4 families; 100% of area) have implemented the technology with external support in terms of materials. The system is at an experimental phase.
There is a moderate (growing) trend towards spontaneous adoption of the technology. People are interested in the technology and are watching their benefits on the experimental plots

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Saving water → By implementing water saving technologies, not only in irrigation, but in other fields of water application like gardening, greenhouses etc.	Requires preventive and regular maintenance → monitoring and independent control of water use efficiency as well as through financial instruments (pressure on inefficient users)
Diversification of crop production → Land-users can grow vegetables, which were not possible with the application of large amounts of water during the drought season.	High investment costs due to expensive pipe system → provide subsidies for drip irrigation user.
Savings of soil fertility → topsoil is not washed away with runoff during irrigation applied to the furrows.	

Key reference(s): Zeiliguer, A., G. Sokolova, V. Semeonv, O. Ermolaeva. Results of field experimentations at 2008 to grow tomatoes under drip irrigation at Pallasovsky District of Volgograd Region. Proceeding of conference at MSUEE. 2008, p. 45-56.

Contact person(s): Anatoly Zeiliguer, MSUEE – Moscow State University for Environmental Engineering, 19, Prjanishnikov Street, 127550 Moscow, Russia. Tel/fax : +7499 9764907, e-mail: azeiliguer@hotmail.ru

Above left: View of roof rainwater system at the *lands* in Mokoboxhane (Photo: L. Magole)
Above right: Taking dimensions for a rainwater system in Mopipi *lands* (Photo: M. Moemedi)

Roof rainwater harvesting system

Botswana – *Lekidi (Setswana)*

Roof rainwater catchment system using galvanised iron roof material, feeding an underground water tank.

A roof of galvanised iron (corrugated iron) with the dimensions 7 x 6m is constructed on a support of gum poles (see photos). The roof catches the rain. The rain water flows over the roof into pipes at the rear end of the roof (sloping side) into an underground conical water tank. The tank is made of bricks and mortar. The underground tank serves two key roles: i) it stores water for use during the dry spells or times of no rain; and ii) the tank keeps the water cool in this hot environment. The technology is most preferred for so-called '*lands*' areas, to provide household drinking water. On average, these *lands* are distant from water sources (e.g. 2-15 km). Other benefits of storing rainwater include less pressure on natural water ponds, but this would be a secondary concern.

Water is critical for human consumption and needed around the home. The cool water is effective in quenching the thirst; it reduces labour time to collect water thus freeing time to concentrate on other farm activities. The water is mainly for household drinking and household chores like washing. Some is used as drinking water for chickens and for the animals used for draught power (e.g. donkeys during ploughing). The units are for use by individual farmers and thus restricted to individual households. The owner or the farmer has exclusive rights to the use of the water. Some farmers indicated that, in times of no rain, or before the first rains, they collect water from the village in drums, and pour it into this underground water tank, thus using it as a reservoir. They especially like the persistent coolness of water stored in the underground tank.

The technology is for rainwater collection in four villages. Rainwater that flows over the roof is collected, for example, on galvanised iron roofs. The water then runs through gutters and a pipe to the underground water tank. To build the underground tank, the ground is excavated, to about 2m deep and about 3m wide. Within this hole, a drum-like feature is built with concrete bricks and mortar. After the wall of the tank is complete, it is then lined with mortar from the inside, and the base is also lined to form the completed tank. It is then sealed at over most of the surface leaving an opening with a lid. This opening is large enough for a man to enter for occasional cleaning of the groundwater tank. Thus the system comprises a roof, for collecting rainwater, and an underground tank for storing it.

The environment is semi-arid and seasonal rainfall dominates during the summer months of October to April. People depend on nearby boreholes for water in the *lands* areas or have to travel to the village (about 2-5km away on average, but can be up to 15km) to fetch water. Most boreholes are either privately owned or communal and water is rationed to about two drums per week or even fortnightly. Most of the borehole water in the area is brackish. Thus roof rainwater (which is fresh) acts as the preferred alternative source of water. The underground tank, once full, is equivalent to 110 drums. Most normal rain events fill the tank, and the water remains in use till the next rainy season, which was found to be the case at all four pilot sites visited. Thus the rainwater catchments systems offer water security in the lands areas; water of very good drinking quality (sweet taste, cooler).

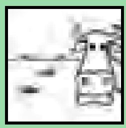
Location: Boteti area, in the Central District of Botswana
Region: Central District
Technology area: 0.01 km^2
Conservation measure: structural
Stage of intervention: mitigation / reduction of land degradation
Origin: Externally - 10-50 years ago
Land use: Cropland, grazing land
Climate: semi-arid, subtropics
WOCAT database reference: QT BOT04 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/boteti-botswana
Related approach: not documented
Compiled by: Julius Atlhopheng, University of Botswana
Date: 18th Mar 2009 updated 3rd Jun 2011

Classification

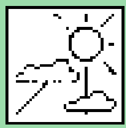
Land use problems: Water shortage and poor water quality. The water harvesting system is critical in a semi-arid environment, where water shortages are common. To augment water supplies, storage is needed especially in arable land areas where there are no coordinated water distributions like standpipes, as is the case in villages. People at the lands eke a living out of the arable fields, and assured water availability enables families to remain longer close to the fields for essential crop management, hence increased yields.

Land use

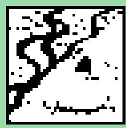

annual cropping


extensive grazing land

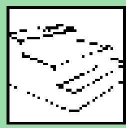
Climate


semi-arid, subtropics

Degradation


water degradation: change in groundwater / aquifer level

Conservation measure


structural: dams / pans: store excessive water

Stage of intervention

□	Prevention
■	Mitigation / Reduction
□	Rehabilitation

Origin

□	Land user's initiative: 10-50 years ago
▒	Experiments / research
■	Externally introduced

Level of technical knowledge

▒	Agricultural advisor
□	Land user

Main causes of land degradation:
Direct causes - Natural: droughts
Indirect causes: land tenure

Main technical functions:
- water harvesting / increase water supply

Secondary technical functions:
- is used as open storage for farm equipment
- offers shade against the heat, as well as temporary shelter

Environment

Natural Environment

Average annual rainfall (mm)

□	> 4000
□	3000-4000
□	2000-3000
□	1500-2000
□	1000-1500
□	750-1000
□	500-750
■	250-500
□	< 250

Altitude (m a.s.l.)

□	> 4000
□	3000-4000
□	2500-3000
□	2000-2500
□	1500-2000
□	1000-1500
■	500-1000
□	100-500
□	<100

Landform

■	plateau / plains
□	ridges
□	mountain slopes
□	hill slopes
□	footslopes
□	valley floors

Slope (%)

□	flat
■	gentle
□	moderate
□	rolling
□	hilly
□	steep
□	very steep

Soil depth (cm)

□	0-20
■	20-50
□	50-80
▒	80-120
□	>120

Growing season(s): 197 days (Oct - Mar)
Soil texture: coarse / light (sandy)
Soil fertility: very low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: good

Soil water storage capacity: very low
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: poor drinking water
Biodiversity: high medium

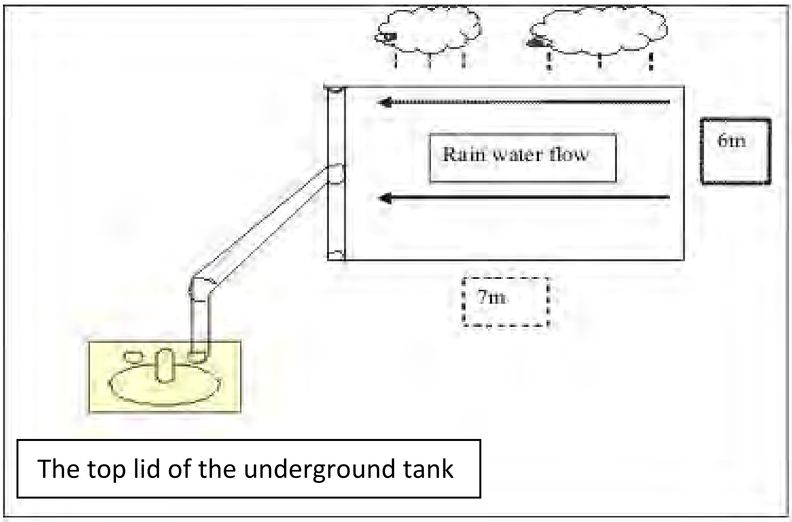
Tolerant of climatic extremes: Temperature increase, seasonal rainfall increase, heavy rainfall (intensities and amount), floods, decreasing length of growing season.
Sensitive to climatic extremes: seasonal rainfall decrease, droughts / dry spells
If sensitive, what modifications were made / are possible: The roof area is such that, some limited amounts of rain do fill or add some water into the storage tank

Human Environment

Cropland per household (ha)

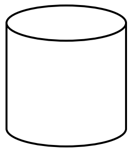
☐	<0.5
☐	0.5-1
☐	1-2
■	2-5
☐	5-15
☐	15-50
☐	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: Individual small scale land users and disadvantaged land users
Population density: < 10 persons/km^2
Annual population growth: 2% - 3%
Land ownership: communal / village
Land use rights: open access (unorganised) (Communal grazing and individual land ownership for ploughing. Water availed through communal boreholes in lands and cattle posts, but with individual standpipes in villages. Open access to surface water resources for livestock e.g. pans after rains. Dual grazing rights problem, whereby private ranchers graze in the commons, but the opposite not possible.)
Water use rights: communal (organised) (Communal grazing and individual land ownership for ploughing. Water availed through communal boreholes in *lands* and cattle posts, but with individual standpipes in villages. Open access to surface water resources for livestock e.g. pans after rains. Dual grazing rights problem, whereby private ranchers graze in the commons, but the opposite not possible.)
Relative level of wealth: very poor, which represent 30%; 20% of the total land area is owned by very poor land users
Importance of off-farm income: less than 10% of all income: Saves labour time to fetch water. Very limited off-farm income opportunities for everyone, including non-adopters of the technology
Access to service and infrastructure: low: employment, energy, financial services; moderate: health, education, technical assistance, market, roads & transport, drinking water and sanitation
Market orientation: subsistence (self-supply)



Technical drawing

Rain water falls onto the corrugated roof surface, which usually measures 7 x 6m. This water flows down into the gutters, then down through the pipe into an underground water storage tank (built from concrete blocks which are lined with a coating of mortar, or mortar is applied to wire mesh. Most storage tanks, when full, have a capacity of about 110 drums (a drum holds 200 litres). Without this system, a farmer usually only has about 2 drums per week. (Atlhopheng Julius).



Circular underground tank

Implementation activities, inputs and costs

Establishment activities

1. Digging pit
2. Transporting sand, cement and concrete blocks
3. Construction

Establishment inputs and costs per unit

Inputs	Costs (US$ / local currency)	% met by land user
Labour	12.5	100
Construction material - sand, cement, concrete block	1500	100
Other - labour by government person (8 person days)	500	0
TOTAL	**2012.5**	**75**

Maintenance/recurrent activities

1. Cleaning roof
2. Cleaning storage tank

Maintenance/recurrent inputs and costs per unit per year

Inputs	Costs (US$ / local currency)	% met by land user
Labour	12.5	100
TOTAL	**12.5**	**100**

Remarks:
Cost of building materials, specifically iron sheets, timber, concrete blocks, cement and the professional builder from the government. Prices of construction material for the roof rainwater system, fitted with the underground water storage system. All prices and exchange rates were calculated for 29 September 2008. The government subsidy was such that, men pay 30% of all costs, while women pay 20%. The 20-30% could be paid through labour (i.e. digging the pit, transporting sand and cement and serving as a labour hand during construction. Thus if the farmer offers labour, then he does not pay anything. The costs are calculated with labour input and its price or the local wage, which is 5 US$ per day. Each roof catchment unit is supposed to benefit one household, so it serves on average 4 people, who farm a 2-3 ha area (5-15km away from the main village).

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ reduced risk of production failure +++ increased drinking water availability ++ increased crop yield ++ diversification of income sources ++ decreased workload + increased animal production	+++ increased expenses on agricultural inputs +++ increased economic inequity

Socio-cultural benefits	Socio-cultural disadvantages
+++ improved health +++ conflict mitigation ++ community institution strengthening ++ improved situation of disadvantaged groups ++ improved food security / self-sufficiency	+++ worsen situation of disadvantaged groups

Ecological benefits	Ecological disadvantages
+++ increased water quantity and quality +++ improved harvesting / collection of water +++ reduced evaporation +++ reduced emission of carbon and greenhouse gases	++ decreased water quality (if roof not cleaned)

Off-site benefits	Off-site disadvantages
+ increased water availability	

Contribution to human well-being/livelihoods

++ Many educational tours made on these demonstration sites. Fresh rainwater is good for health compared to borehole (salty) water.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	very negative	very positive
Maintenance/recurrent	very negative	very positive

Very costly to set up, if no government aid. It is however, very good for long term water provision.

Acceptance/adoption: The technology is generally deemed to be too expensive by the less wealthy farmers; and inadequate for the rich farmers (need to water many cattle) who drill their own boreholes. Thus only about 1% of land user families (1 families; 1% of area) have implemented the technology with external material support. There is one such structure per village in Boteti sub-district - and they are all demonstration schemes. There was no public uptake following demonstration, as government subsidy changed and was later stopped. It is too costly e.g. building materials, hiring of professional builder and cement to set up in *lands* areas. There is no trend towards (growing) spontaneous adoption of the technology. High capital or start-up costs. The area has low income groups who get water from communal boreholes, while rich cattle owners obtain water from their private boreholes, and hence desalination is favoured rather than rainwater systems.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Provides cool water in hot summers → keep it working	Costly to set up → subsidies by government, NGOs, private sector
Provides water in *lands* areas, where it is most needed → maintain the structure, or increase tank capacity	Seen as dependent on rains, thus fails during droughts → research, information dissemination to stakeholders
Farmers appreciate the good water quality and clean system annually → keep it working	Water quality issues (concerns) → Education on keeping storage clean and boiling water for human consumption
It has low maintenance costs, it is easy to use → keep it working	Costly to set up, due to the price of building materials → Government subsidies, private sector, NGOs
Useful as shelter or storage → keep it working	Fear that their land would be taken away by the government after financial assistance → Education on subsidies to allay fears

Key reference(s): Ministry of Agriculture Headquarters, Department of Crop Production, Engineering Division, Water Development Section, P/Bag 003, Gaborone, Botswana. dcp@gov.bw [department of crop production] or kmphokedi@gov.bw [for director] and [blaolalng@gov.bw] for technical officer

Contact person(s): Julius Atlhopheng, ATLHOPHE@mopipi.ub.bw

Above left: Young apple trees in small pits, the traditional method (Photo: Wang Fei)
Above right: The progressive bench terraces with apple trees (Photo: Wang Fei)

Progressive bench terrace

China - *树盘，逐年扩盘 (Chinese)*

Bench terraces are progressively expanded to form a fully developed terrace system in order to reduce runoff and soil erosion on medium- to high- angled loess slopes

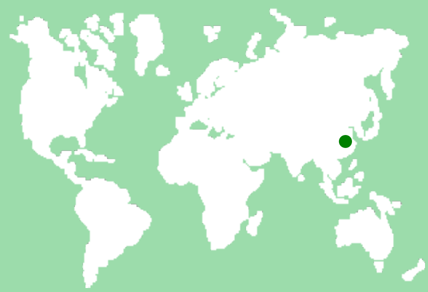
In Miaowan Village, the technology is mainly applied to apple tree plantations. Tree seedlings are planted in rows every 4 m along the contour with a spacing of 2.5-3.5 m between rows. Trees are planted in pits 40 cm diameter and 30-40 cm deep. Manure and/or fertilizer are applied and the seedlings are watered.

Around each tree, soil from the upper parts of the slope is removed and deposited below in order to extend the flat terrain. Over 5-10 years, the terraces become enlarged around each tree and form a terrace with the neighbouring trees along the contour, such that the slopes are transformed into level bench terraces. The fruit trees are located in the middle of the terrace. All the work is done manually using shovels.

The establishment phase thus takes 5-10 years. Afterwards maintenance inputs are restricted to repairing the terrace walls.

The main purpose of this technology is to reduce runoff and soil erosion on the slope and to improve soil quality and soil moisture retention. It is a sustainable land use technology for small farmers because farmers can use their spare time to improve the land's condition during the growth of the trees.

A major aim is to conserve water and reduce runoff. Soil erosion in this village is very severe and the soil erosion rate before amounted to 60-100 tonnes per hectare per year and was reduced practically to zero as a result of building the terraces. Slope gradients are very steep (around 20-35 degrees). The main income of local farmers is from orchards.

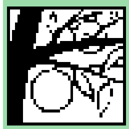


Location: Shaanxi
Region: Miaowan village, Xuejiagou watershed
Technology area: 2.55 km^2
Conservation measure: structural
Stage of intervention: prevention of land degradation
Origin: through land user's initiative 10-50 years ago
Land use: cropland
Climate: semi-arid, temperate
WOCAT database reference: QT CHN53 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/yan-river-basin-china
Related approach: year-after-year terraced land (QA CHN53)
Compiled by: Wang Fei, Institute of Soil and Water Conservation, CAS and MWR, China
Date: 23rd Dec 2008 updated 14th Jun 2011

Classification

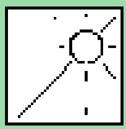
Land use problems: On moderate- to high-angled slopes, water loss and soil erosion are very high. Outside the protected canopy of the trees rainsplash impact during heavy storms is very severe. The local farmers clear all the wild grasses and shrubs, such as Korshinsk Peashrub, *Artemisia scoparia*, *Leymus secalinus*, *Stipa bungeana*, *Lespedeza davurica* etc. to reduce competition with the fruit trees. Consequently, the soil is bare and unprotected

Land use



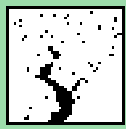
tree and shrub cropping, (rainfed)

Climate



semi-arid, temperate

Degradation



soil erosion by water: loss of topsoil, surface erosion, water loss

Conservation measure

structural: reshaping surface (reducing slope)

Stage of intervention

- Prevention (black)
- Mitigation / Reduction (grey)
- Rehabilitation

Origin

- Land user's initiative: 10-50 years ago (black)
- Experiments / research
- Externally introduced

Level of technical knowledge

- Agricultural advisor
- Land user (grey)

Main causes of land degradation:
Direct causes - Natural: Heavy / extreme rainfall, orchards on steep slopes without conservation measures.
Indirect causes: poverty / wealth

Main technical functions:
- control of concentrated runoff: retain / trap
- reduced soil loss

Secondary technical functions:
- reduction of slope angle

Environment

Natural Environment

Average annual rainfall (mm)		Altitude (m a.s.l.)		Landform		Slope (%)	
> 4000		> 4000		plateau / plains		flat	
3000-4000		3000-4000		ridges		gentle	
2000-3000		2500-3000		mountain slopes		moderate	
1500-2000		2000-2500		hill slopes	black	rolling	grey
1000-1500		1500-2000		footslopes	grey	hilly	
750-1000		1000-1500	grey	valley floors		steep	grey
500-750	black	500-1000	black			very steep	black
250-500		100-500					
< 250		<100					

Soil depth (cm)

Soil depth (cm)	
0-20	
20-50	
50-80	
80-120	black
>120	

Growing season(s): 300 days (Mar - Nov)
Soil texture: medium (loam)
Soil fertility: very low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: good

Soil water storage capacity: low
Ground water table: 5 - 50 m
Availability of surface water: medium, poor / none
Water quality: good drinking water
Biodiversity: medium

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount), droughts / dry spells
Sensitive to climatic extremes: wind storms / dust storms
If sensitive, what modifications were made / are possible: The technology increases infiltration, reduces soil erosion by water and improves soil moisture retention to reduce the negative impact of extreme drought. However, it does not protect the soil well from wind erosion. Soil cover could be increased to protect against strong winds and reduce water loss by evaporation. However, the resulting increased competition with the trees for water and nutrients needs to be solved.

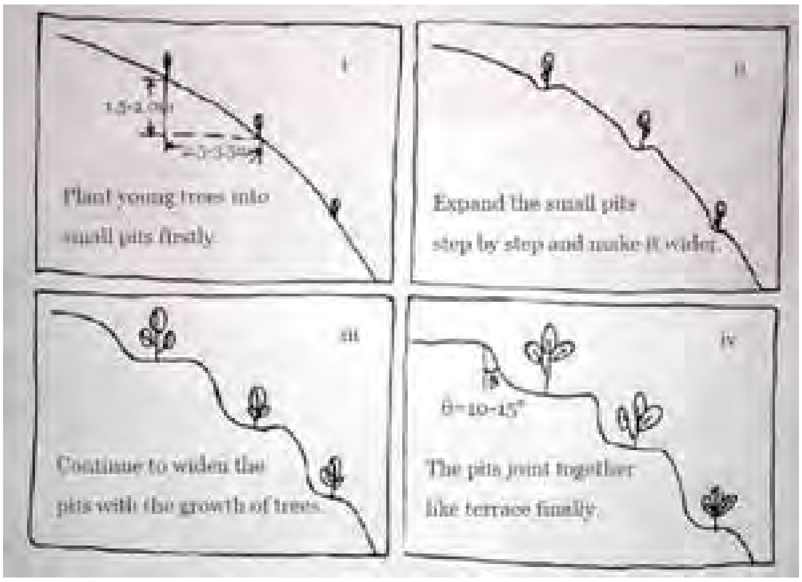
Human Environment

Cropland per household (ha)

☐	<0.5
☐	0.5-1
☐	1-2
■	2-5
☐	5-15
☐	15-50
☐	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: individual / household, small scale land users, common / average land users, women and men
Population density: 50-100 persons/km^2
Annual population growth: < 0.5%
Land ownership: state
Land use rights: individual
Water use rights: open access (no organisation)
Relative level of wealth: rich, which represents 30% of land users; 30 % of the total land area is owned by rich land users

Importance of off-farm income: 10-50% of all income: Only a few land users have implemented this measure because there are other market based activities that bring higher returns. Sometimes farmers have enough money to buy more fertilizer for the orchard.
Access to service and infrastructure: low: drinking water and sanitation; moderate: health, employment, financial services; high: education, roads & transport
Market orientation: commercial / market
Mechanization: manual labour
Livestock grazing on cropland: no



Technical drawing

i: first year: planting of fruit trees along the contour in small pits
ii: after 3-4 years: a small terrace is built up around each tree (as the tree grows it needs more water, which is collected from the platform around the trees.
iii: after 5-8 years: terraces develop
iv: final stage: fully developed level bench terraces

Owing to the soil properties of loess, there is no need to separate surface and subsoil as there is little difference between them. Therefore, soil can be moved directly from upper to lower parts of the terrace without changing soil fertility.

(Wang Fei)

Implementation activities, inputs and costs

Establishment activities

1. Plant the young trees with small pits.
2. The soils from the upper parts of the slope is shovelled away and deposited on the lower side of the trees
3. Expand the pits into a large platform year by year.
4. 3.4 years after planning the trees a level platform of 2 to 3 square meters around the trees is build.
5. The platforms increase and the space between trees is change into terrace.

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour (450 days)	6398	100
TOTAL	**6398**	**100**

Maintenance/recurrent activities

1. Repair the bank of progressive bench terraces

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (15 days)	219.6	100
TOTAL	**219.6**	**100**

Remarks:
Slope is the most important factor. The steeper it is, the higher the cost. Labour was not considered as a cost before, but now it is expensive so that some local farmers do not use this technology. The costs are calculated assuming a local wage rate of 14.2 US$/day.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ increased crop yield (fruits) ++ increased farm income	+ increased labour constraints

Socio-cultural benefits	Socio-cultural disadvantages
+ improved situation of social and economic disadvantaged groups	

Ecological benefits	Ecological disadvantages
+++ reduced surface runoff +++ reduced soil loss	

Off-site benefits	Off-site disadvantages
+++ reduced downstream flooding	+++ reduced river flows

Contribution to human well-being/livelihoods

++ The stable income from orchards improves the standard of living, and people can buy enough food and meat. The nine-year compulsory education in China, which once had to be paid for, is now free.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	slightly positive	positive
Maintenance/recurrent	positive	positive

It is very cheap to maintain this measure. More trees could be planted on degraded land in future.

Acceptance/adoption: All land user families (65 families; covering 15% of their area) have implemented the technology voluntarily without any external support or inputs. In this area, there are many other practices, such as reforestation, enclosure (to prevent grazing) and terrace construction.
There is a moderate (growing) trend towards spontaneous adoption of the technology. Even the local farmers know the benefits of progressive bench terraces, but with the increased labour costs, fewer people apply this technology.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Establishing the technology over a long time. Local farmers have enough time to do it. → Show to land users that they have time and can spread to work over many years and fit the labour into the time they have available.	It takes considerable time to establish and labour is more and more expensive so that farmers are looking for paid work → Subsidy for farmers using this measure.
It can reduce water loss and soil erosion and prevent the degradation of land → Give subsidy to the local farmers to reduce the sediment delivery into the downstream river.	
It can increase soil moisture → Makes people understand the importance of conserving water with such a technology.	
Higher yield and income → Share ideas through meeting in the field. Present this measure to more people and show them how to apply it and promote the technology to more farmers.	

Key reference(s): Soil and water conservation records of Shaanxi Province. 2000. Shaanxi People's Press, Xi'an City, China Library of ISWC, CAS

Contact person(s): Wang Fei, Institute of Soil and Water Conservation, CAS and MWR, China. wafe@ms.iswc.ac.cn. wang.fei.cas@gmial.com

Woven wood fences

Turkey – *Odundan Örme Çitler (Turkish)*

Above left: A series of woven wooden fences set up on hillslopes of the Eskişehir area (Photo: Faruk Ocakoğlu)
Above right: Close-up view of a fence prepared for a dry-farmed barley crop (Photo: Faruk Ocakoğlu)

Wooden fences are an effective and relatively cheap way of conserving soil from water erosion by decreasing overland flow. They also increase crop yield by encouraging better infiltration.

Dry croplands in semi-arid regions are generally subjected to intense soil erosion in hillslopes due to sudden heavy rainfalls. In these areas, conserving soil and water by cheap technologies that could be installed by the farmers with available resources and knowledge becomes important.

Woven wood fences represent a technology applied and demonstrated successful in semi-arid mountainous dry croplands in Eskişehir, central Anatolia. They consist of wooden posts 150 cm height inserted into the ground and branches woven between these posts. Eroded soil from upslope becomes trapped on the upslope side of the fence and overland flow is decreased. The distance between the fences is determined with respect to soil texture and field gradient. It is 30 m in hillslopes of 10% gradient covered by sandy loams in the Eskişehir region.

The basic costs are for the materials, its transportation and the labour involved in installation. The posts and branches are derived either from trees on the farmers' fields or from nearby state-owned forests. For 2009, the cost of installation was about 1350 US$/ha. The maintenance costs of this medium-term (20 years) technology are only the labour needed to repair the damaged fences/terraces after extreme rainfalls. Technological change includes contour (rather than downslope) tillage between the fences, which causes a minor increase (10%) in the expenses of tillage operations.

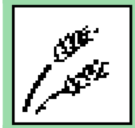
The technology can be applied both by small- and large-scale farmers in quite different soil and slope gradient conditions. Results indicate that crop yield doubles (1300 kg/ha of barley) and soil loss apparently diminishes using this technology.

Location: Eğriöz village, Eskişehir
Region: Central Anatolia
Technology area: 1.15 ha
Conservation measure: structural
Stage of intervention: prevention of land degradation
Origin: experiments - recent (<10 years ago)
Land use: cropland
Climate: semi-arid, temperate
WOCAT database reference: QT TUR05 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/eskiehir-turkey
Related approach: not documented
Compiled by: Faruk Ocakoğlu, Eskişehir Osmangazi University, Faculty of Engineering and Architecture
Date: 10th Oct 2011, updated 15th Oct 2011

Classification

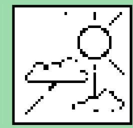
Land use problems: The current dry cropland use requires the fields to be fallow every second year due to insufficient water in the soil. For this reason drought radically decreases crop yield. Owing to heavy rainfall, removal of both topsoil and subsoil occurs in places causing increased stoniness in the soil, which decreases its fertility and makes the tillage operations difficult.

Land use



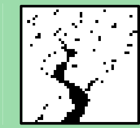
annual cropping
rainfed irrigation

Climate



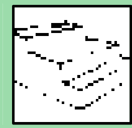
semi-arid,
temperate

Degradation



soil erosion by water:
removal of top soil by water

Conservation measure



structural:
protective fences

Stage of intervention

- ■ Prevention
- □ Mitigation / Reduction
- □ Rehabilitation

Origin

- □ Land user's initiative
- ■ Experiments / research: <10 years ago
- ■ Externally introduced

Level of technical knowledge

- ■ Agricultural advisor
- ▒ Land user

Main causes of land degradation:
Direct causes - Human induced: soil and crop management; natural: drought
Indirect causes: lack of knowledge, poverty

Main technical functions:
- reduction of slope length
- control of dispersed runoff (retain / trap)

Secondary technical functions:
- increase of infiltration
- increase / maintain water stored in soil
- increase in organic matter

Environment

Natural Environment

Average annual rainfall (mm)

- □ > 4000
- □ 3000-4000
- □ 2000-3000
- □ 1500-2000
- □ 1000-1500
- □ 750-1000
- □ 500-750
- ■ 250-500
- □ < 250

Altitude (m a.s.l.)

- □ > 4000
- □ 3000-4000
- □ 2500-3000
- □ 2000-2500
- □ 1500-2000
- □ 1000-1500
- ■ 500-1000
- □ 100-500
- □ <100

Landform

- □ plateau / plains
- □ ridges
- ■ mountain slopes
- ■ hill slopes
- □ footslopes
- □ valley floors

Slope (%)

- □ flat
- ■ gentle
- ■ moderate
- □ rolling
- □ hilly
- □ steep
- □ very steep

Soil depth (cm)

- ▒ 0-20
- ■ 20-50
- □ 50-80
- □ 80-120
- □ >120

Growing season(s): 220 days (Nov - June)
Soil texture: medium (loam)
Soil fertility: low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: good

Soil water storage capacity: medium
Ground water table: 50 m
Availability of surface water: poor / none
Water quality: good water
Biodiversity: medium

Tolerant of climatic extremes: medium to low intensity rainfall
Sensitive to climatic extremes: very high intensity rainfall

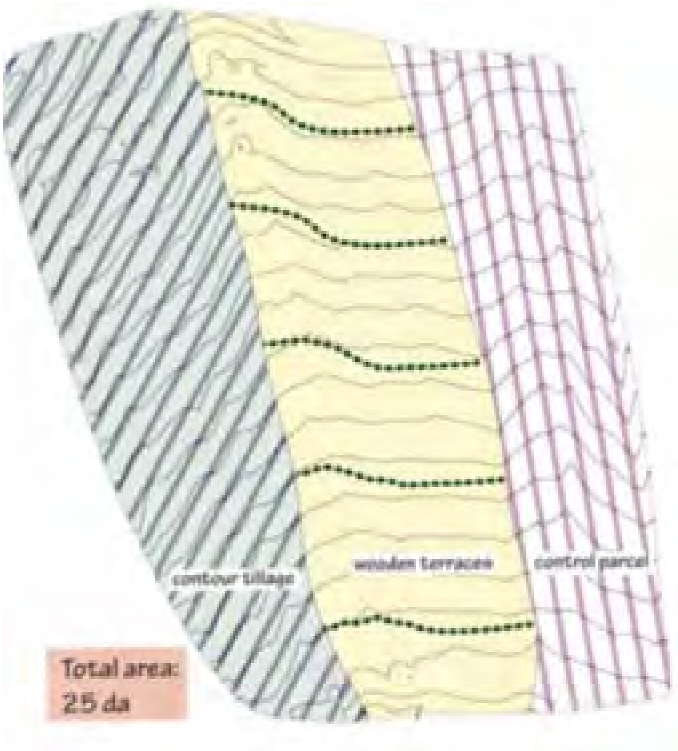
Human Environment

Cropland per household (ha)

<0.5	
0.5-1	
1-2	
2-5	■ (black)
5-15	■ (grey)
15-50	
50-100	
100-500	
500-1,000	
1,000-10,000	
>10,000	

Land user: individual, small- to medium-scale, disadvantaged land users
Population density: 10-50 persons/km^2
Annual population growth: 0.5% - 1%
Land ownership: individual, titled
Land use rights: individual
Water use rights: individual
Relative level of wealth: poor – 50% of poor land users own 20% of the total land area

Importance of off-farm income: as high as 30% of all income
Access to service and infrastructure: low: employment, health, technical assistance; moderate: market, energy, drinking water and sanitation, financial services; education
Market orientation: mixed (subsistence and commercial)



Technical details

Plan of the site implementation in Eskişehir. Solid lines depict contours at 1 m intervals.
The implementation area (at the centre of the Figure on the left) has a gradient of 10 %. Fence spacing is 30 m and each fence is 60 m long. Posts provide the strength of the structure and are inserted up to 30 cm into the ground. Branches are woven between the posts. Eroded soil trapped on the upslope side produces an earth bank.

Implementation activities, inputs and costs

Establishment activities

1. Building the fences (providing wooden material, excavations, terracing)

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	550	10
Construction material (wood)	600	0
Other - transportation, oil	200	90
TOTAL	**1350**	**17**

Maintenance/recurrent activities

1. Repair of fences

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	100	100
Construction material	10	100
TOTAL	**110**	**100**

Remarks:
In the account above, we do not consider regular cropping activities (ploughing, tillage, fertilization etc.) but only the basic costs of the new technology.

Assessment

Impacts of the Technology

Production and socio-economic benefits

- +++ increased crop yield
- +++ increased animal production
- +++ increased farm income
- \+ reduced demand for irrigation water

Production and socio-economic disadvantages

- \+ loss of land
- \+ increased labour constraints

Socio-cultural benefits

- +++ improved conservation / erosion knowledge
- \+ improved food security / self-sufficiency

Socio-cultural disadvantages

Ecological benefits

- ++ improved harvesting / collection of water

Ecological disadvantages

Off-site benefits

- +++ reduced damage on neighbouring fields
- ++ reduced downstream siltation

Off-site disadvantages

Contribution to human well-being/livelihoods

\+ The technology produces a large crop yield increase and also conserves soil and water. As a result it increases farm income considerably.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	neutral/slightly negative	very positive
Maintenance/recurrent	very positive	very positive

The long-term benefits are very positive while short-term ones are neutral to slightly negative due to the high investment rates. The technique is new and there is not enough knowledge of it. Initial investment costs are relatively high compared to farmers' incomes.

Acceptance/adoption:

All land user families (1 family; 100% of area) have implemented the technology with external material support.
Farmers expect state subsidies for further adoption of technology.

Concluding statements

Strengths and → how to sustain/improve

Increase in crop yield → Rotational cropping may further increase the yield

Increase in farm income → Cropping new species tolerant to drought

Weaknesses and → how to overcome

Small parcels left in the very borders of the terraces cause a loss of field → Smaller tractors with more manoeuvre capability

Key reference(s): Gates J. B., Scanlon B. R., Mu, X., Zhang, L., 2011. Impacts of soil conservation on groundwater recharge in the semi-arid Loess Plateau, China. Hydrogeology Journal, 19: 865–875.

Ağaçlandırma ve Erozyon Kontrolü Genel Müdürlüğü, 2011. Su Erzoyonu ile Mücadele. http://www.agm.gov.tr/AGM/AnaSayfa/faliyetler/erozyon

Contact person(s): Prof. Dr. Faruk Ocakoğlu, Eskişehir Osmangazi University, Faculty of Engineering and Architecture, focak@ogu.edu.tr; Assis. Prof. Dr. İnci Tolay, itolay@akdeniz.edu.tr

Above left: Vegetated earth-banked terraces in an almond orchard (Photo: Joris de Vente)
Above right: Vegetated earth-banked terraces in a cereal field with almonds on the terrace ridge (Photo: Joris de Vente)

Vegetated earth-banked terraces

Spain - *Terrazas de tierra vegetadas (Spanish)*

Earth-banked terraces in cereal and almond cropland covered with drought-resistant shrubs.

Earth-banked terraces are constructed by carefully removing a superficial soil layer (~10-20 cm) from one part of a field, concentrating it on the lower end of that field in order to reduce slope gradient and length. Another terrace is created directly downslope to form a cascade of terraces. Terrace risers have to be of restricted height (~50-150 cm) to prevent steep and unstable terraces. Stones from the fields can be used to reinforce the terrace ridge. After terrace construction, fields should be gently sloping (<3%) in the direction of the main slope. The distance between terraces must be enough to allow tractor movement during normal cultivation activities and it depends also on the slope gradient. The steeper the slope, the shorter is the distance between terraces. Terraces reduce the formation of gullies and retain water from upslope. The terraces are made with locally available machinery (tractor, small bulldozer). The terrace ridges are optimal locations to plant olives, almonds or fruit trees. Moreover, to be most effective, the terrace ridges are vegetated with shrubs and grasses adapted to semi-arid conditions and with a good surface cover (>~30%) throughout the year (e.g. *Stipa tenacisima, Rosmarinus officinalis, Thymus vulgaris, Ulex parviflorus, Rhamnus lycioides, Pistacia lentiscus*). Natural regeneration of vegetation is allowed without limitation on the terrace ridges, so no herbicide application or burning are carried out to remove weeds. Where possible, regeneration should be stimulated by planting the same adapted species in at least 25% of the terrace ridge. Optionally, in the other 75% of the terrace ridge, cereals or other leguminous species can be sown, but should not be harvested or used for grazing.

This technology reduces flooding, damage to infrastructure and siltation of water reservoirs, while maintaining (or slightly increasing) crop productivity. This is achieved by reducing runoff, soil erosion and hydraulic connectivity through a decreased slope gradient and an increased vegetation cover. The terrace ridge functions as a sink for runoff within fields and reduces runoff velocity. The vegetation leads to increased soil organic matter content below plants, producing an improved soil structure and a higher infiltration capacity. The use of stones from the fields to reinforce the terraces is optional, but facilitates crop production in the fields and makes the ridges more resistant to higher runoff velocities. The technology requires an initial investment in the construction of the terraces. Terraces can best be located on thalwegs and on areas where gully formation is often observed. Maintenance consists of filling up possible bank gullies developed in the terraces after important rainfall events and, if needed, substitute decayed shrubs with new ones.

The technology is generally applied on soils of shallow to medium depth (20 – 60 cm), and slopes are gentle to moderate (5-15%). The climate is semi-arid with a mean annual rainfall around 300 mm. Droughts, peaking in summer commonly last for more than 4-5 months. Annual potential evapotranspiration rates larger than 1000 mm are common. The production system is highly mechanized and market-oriented but depends strongly on agricultural subsidies. All cropland is privately-owned.

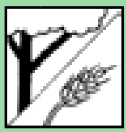
Location: Murcia
Region: Guadalentin catchment
Technology area: 10 - 100 km^2
Conservation measure: vegetative, structural
Stage of intervention: prevention of land degradation, mitigation / reduction of land degradation
Origin: Developed through land user`s initiative, traditional (>50 years ago); externally / introduced through project, recent (<10 years ago)
Land use: cropland and mixed land
Climate: semi-arid, subtropics
WOCAT database reference: QT SPA02 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/guadalentin-spain
Related approach: Regional rural development programme (QA SPA01)
Compiled by: Joris de Vente, EEZA-CSIC
Date: 5th April 2011

Classification

Land use problems: Lack of water for irrigation of crops limiting the crop types that can be planted as well as the crop yield of dryland farming. A lack of water availability seriously limits the production potential of the soil and results in a low vegetation/crop cover. The relatively high soil erosion rates cause various off-site related problems (i.e. flooding, reservoir siltation) and on-site problems (i.e. gully formation and loss of soil depth).

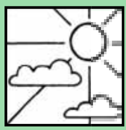
Land use

annual cropping (rainfed)



agroforesty

Climate

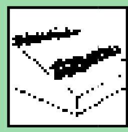


semi-arid, subtropics

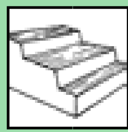
Degradation

soil erosion by water: loss of topsoil/surface erosion, gully erosion/gullying, offsite degradation effects

Conservation measure



vegetative: tree and shrub cover, grasses and perennial herba-ceous plants



structural: bench terraces (slope of terrace bed <6%)

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative: > 50 years ago
Experiments / research
Externally introduced: < 10 years ago

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - human induced: crop management (annual, tree), disturbance of water cycle (infiltration / runoff), other human induced causes: cropping of relatively steep slopes sensitive to erosion because of slope gradient
Indirect causes: governance / institutional (spatial planning of land use results in formation of too large fields without field boundaries)

Main technical functions:
- control of concentrated runoff: retain / trap
- control of concentrated runoff: impede / retard
- control of dispersed runoff: retain / trap
- control of dispersed runoff: impede / retard
- reduction of slope angle
- increase of infiltration
- increase / maintain water stored in soil

Secondary technical functions:
- reduction of slope length
- water harvesting / increase water supply
- sediment retention / trapping, sediment harvesting
- spatial arrangement and diversification of land use

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 220 days (November to June)
Soil texture: medium (loam)
Soil fertility: low
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: poor (e.g. sealing /crusting)

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: for agricultural use only
Biodiversity: low

Tolerant of climatic extremes: seasonal rainfall increase
Sensitive to climatic extremes: temperature increase, seasonal rainfall decrease
If sensitive, what modifications were made / are possible: The crop type is sensitive to changes in water availability under the semi-arid conditions

Human Environment

Cropland per household (ha)

	<0.5
	0.5-1
	1-2
	2-5
	5-15
■	15-50
■	50-100
	100-500
	500-1,000
	1,000-10,000
	>10,000

Land user: individual / household, medium scale land users, common / average land users, mainly men
Population density: 10-50 persons/km2
Annual population growth: < 0.5%
Land ownership: individual, titled
Land use rights: individual (all cropland is privately owned, some shrubland or forest is state property)
Water use rights: individual. Water use is organised by permits to water extraction from aquifers on individual basis. Water rights are provided and controlled by the water authority of the Segura river basin.
Relative level of wealth: average, which represents 80% of land users; 75% of the total land area is owned by average land users

Importance of off-farm income: > 50% of all income: There is no difference in the ones who apply the technology and those who do not. Most farmers do have an off-farm income for example from hunting, work in a factory, or office.
Access to service and infrastructure: moderate: employment (e.g. off-farm), energy; high: health, education, technical assistance, market, roads & transport, drinking water and sanitation, financial services
Market orientation: commercial / market
Mechanization: mechanised
Livestock grazing on cropland: yes

Technical drawing

Quickbird satellite image showing the concentration of terraces along natural drainage lines (thalwegs) where runoff concentrates. Drainage lines are indicated with dotted lines.

Implementation activities, inputs and costs

Establishment activities

1. Construction of terraces
2. Plantation of shrubs and cereals or leguminous species (optional)

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	270	10
Equipment - machine use	428	10
Other - shrub seedlings and seeds	218	10
TOTAL	**916**	**10**

Maintenance/recurrent activities

1. Filling up bank gullies in terraces
2. Replace died shrubs (optional)

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	28	10
Equipment - machine use	24	10
Other - shrub seedlings and seeds	22	10
TOTAL	**74**	**10**

Remarks:
Price of fuel and labour are the most important determinants of the costs. The local wage rate is 79 US$/day.
The costs were indicated assuming a distance between terraces of 50 meter, meaning two terraces of 100 meter long per hectare. Prices are for spring 2008. Subsidies are foreseen for the installation of the vegetated terraces and for maintenance during at least 4 years if all requirements are fulfilled that are described in the regional development programme.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+ decreased workload (less damage to fields due to less gully formation)	+ increased expenses on agricultural inputs + hindered farm operations

Socio-cultural benefits	Socio-cultural disadvantages
++ improved conservation / erosion knowledge + conflict mitigation (less damage to neighbours' fields)	

Ecological benefits	Ecological disadvantages
++ reduced soil loss ++ reduced hazard towards adverse events ++ reduced surface runoff + improved harvesting / collection of water + increased soil moisture + improved soil cover + increased soil organic matter / below ground C + increased animal diversity (terraces provide corridors connecting fields and provide shelter) + increased plant diversity + increased beneficial species + increased / maintained habitat diversity	

Off-site benefits	Off-site disadvantages
+++ reduced downstream flooding +++ reduced downstream siltation +++ reduced damage on neighbours fields +++ reduced damage on public / private infrastructure + improved buffering / filtering capacity	

Contribution to human well-being/livelihoods

++ There is less damage to fields and to infrastructure due to gully formation and flooding.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	neutral / balanced
Maintenance/recurrent	neutral / balanced	slightly positive

Implementation of the terraces is relatively expensive. Additionally planting of shrubs is also relatively expensive and requires a subsidy. Once installed, maintenance is not expensive and pays off because of less damage to fields and infrastructure.

Acceptance/adoption:
Eighty per cent of land user families have implemented the technology with external material support. Terraces are traditionally widespread in the region. Most of them were installed without external support. Nowadays there are subsidies for construction and maintenance of vegetated strips and terraces. Twenty per cent of land user families have implemented the technology voluntary.
There is no trend towards (growing) spontaneous adoption of the technology. There is acceptance, but it is not growing. In some parts terraces are removed to make larger fields, and some new ones are also constructed. Recently installed subsidies may change this

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
This technology is very effective at reducing surface runoff and erosion by reducing slope gradients and connectivity. In addition, it has a water harvesting effect. So it reduces on-site and off-site erosion problems and potentially increases water retention in the fields. → The technology can be enhanced by providing more information and publicity so that existing terraces are maintained.	The technology does not improve farm income and has a significant implementation cost → Provide information on all the advantages that include many costs for society (including floods, reservoir siltation etc.). The subsidy for implementation already solves the problem of implementation costs.
The terraces prevent gully formation and damage to the fields and to their neighbours → maintenance is needed and should be promoted.	It is considered relatively expensive to implement and particularly the optional planting of woody species is considered complicated in dry years → Subsidies for terrace construction and planting of woody species as well as cooperation between farmers to reduce costs of maintenance when subsidies stop.

Key reference(s): CARM 2008. Programa de Desarrollo Rural de la Región de Murcia 2007-2013 Tomo I. 508pp, http://www.carm.es/neweb2/servlet/integra.servlets.ControlPublico?IDCONTENIDO=4689&IDTIPO=100&RASTRO=c431$m1219

Contact person: Joris de Vente, EEZA-CSIC, Joris@sustainable-ecosystems.com

Above left: Olive tree plantation, part of the Sehoul Project of farming development (Photo: Nadia Machouri)
Above right: View of the olive tree plantation with intercropping technology, in autumn, immediately following contour tillage activities (Photo: Antari Elmostafa)

Olive tree plantations with intercropping

Morocco - *Plantations d'oliviers avec cultures intercalaires (French), Jnane Zitoune (Arabic)*

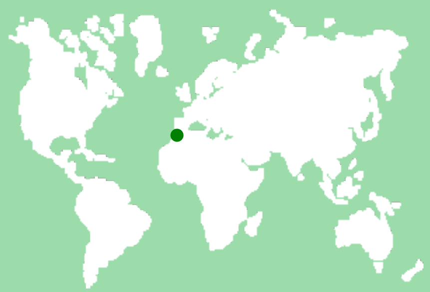
Contour planting of olive trees with crops, legumes and vegetables intercropping

On gentle slopes of the Sehoul municipality, heavy or prolonged rainfall causes runoff and erosion on cultivated lands cleared at the beginning of the 20th century. In the last 10 years, in some plots, land users have started to implement contour plantations separated by intercropping strips with annual crops. Only the immediate tree surroundings involve harvesting and storing rainwater and runoff. No additional water harvesting structure has been built. A fence around the plot prevents livestock from entering.

The economic objective of the technology is to improve income, because cultivation of cereals only gives low yields (500-600 kg/ha). Olive trees can provide an attractive yield and can be an alternative to crops especially during drought. As the olive tree is considered a revered tree, the technology is also beneficial from a social viewpoint. Environmental objectives include surface protection against erosion as well as the maintenance and improvement of soil fertility.

To implement the change, a boundary of barbed wire (Chabkka) or cactus to form a natural hedge is installed in order to prevent livestock intrusion. Plantation work includes breaking up the soil, digging holes along the contour and planting the trees. Animal manure and chemical fertilizers are used as inputs. Weeding, pesticide application and manual watering are required regularly to support tree growth. As a drip-irrigation technique, watering cans with perforations are left to drop water continuously until the cans are empty.

The plantations are on a fragile substrate of marl underlying Plio-Quaternary and loamy-stony deposits with more than 40 cm of fersialitic and sandy soil on low-angled slopes (<10 %). The climate is Mediterranean with a semi-arid trend. The socio-economic environment is characterised by a medium-density population (10-50 persons/km^2) and scattered homesteads. The traditional production system (cultivation of cereals and extensive breeding) is dominant, as well as the use of traditional techniques and practices. Tillage is performed using animal traction.

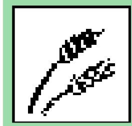


Location: Sehoul
Region: Salé province
Technology area: 0.4 km^2
Conservation measure: vegetative and agronomic
Stage of intervention: prevention of land degradation
Origin: developed externally / introduced through project, recent (<10 years ago)
Land use: cropland, mixed (agroforestry)
Climate: subhumid, subtropics
WOCAT database reference: QT MOR14e on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/sehoul-morocco
Related approach: Development of rainfed agriculture (QA MOR14e)
Compiled by: Rachida Nafaa, Université Mohammed V Agdal, Faculté des Lettres, Rabat
Date: 15th Sep 2008, updated September 2011 by Nadia Machouri

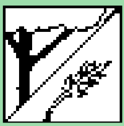
Classification

Land use problems: Irregular rainfall and drought, lack of surface water and depth of the groundwater table are major environmental problems. Excessive runoff causes gullying in the event of exceptional heavy rainfall. All fields on slopes are subject to soil loss because of sheet erosion, especially in early autumn, when lands are bare and without a plant cover due to summer grazing. Gully erosion also results from concentrated runoff from bare ground upslope, especially on steep slopes. There is a lack of support from the authorities and agricultural services and insufficient knowledge about water conservation. Technologies for surface water harvesting do not exist.

Land use

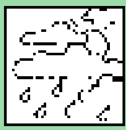


annual cropping (rainfed) (before)



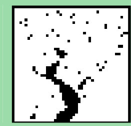
agroforestry (after)

Climate



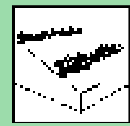
subhumid, subtropics

Degradation

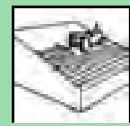


soil erosion by water: loss of topsoil/ surface erosion:

Conservation measure



vegetative: tree and shrub cover



agronomic: contour ploughing

Stage of intervention

■ (black)	Prevention
▒ (grey)	Mitigation / Reduction
□	Rehabilitation

Origin

□	Land user's initiative
□	Experiments / research
■ (black)	Externally introduced: < 10 years ago

Level of technical knowledge

▒ (grey)	Agricultural advisor
■ (black)	Land user

Main causes of land degradation:
Direct causes - human induced: crop management

Main technical functions:
- improvement of ground cover

Secondary technical functions:
- increase of infiltration

Environment

Natural Environment

Average annual rainfall (mm)

□	> 4000
□	3000-4000
□	2000-3000
□	1500-2000
□	1000-1500
□	750-1000
■	500-750
□	250-500
□	< 250

Altitude (m a.s.l.)

□	> 4000
□	3000-4000
□	2500-3000
□	2000-2500
□	1500-2000
□	1000-1500
□	500-1000
■	100-500
□	<100

Landform

■	plateau / plains
□	ridges
□	mountain slopes
□	hill slopes
□	footslopes
□	valley floors

Slope (%)

□	flat
▒ (light grey)	gentle
▒ (grey)	moderate
■	rolling
□	hilly
□	steep
□	very steep

Soil depth (cm)

□	0-20
□	20-50
■	50-80
▒ (grey)	80-120
□	>120

Growing season(s): 270 days (October to June)
Soil texture: medium (loam)
Soil fertility: medium
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: poor

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: medium **Water quality:** good drinking water
Biodiversity: low

Tolerant of climatic extremes: Olive trees are tolerant of variations typical of the Mediterranean, but the yield differs from one year to the next; extremely low temperatures in some winters can make the yield very poor; the low amount of rain in spring can also be very detrimental.

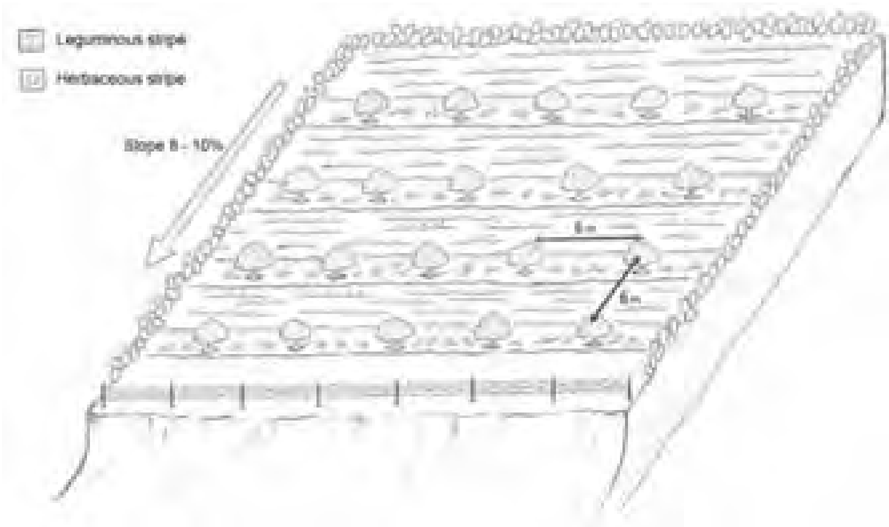
Human Environment

Cropland per household (ha)

☐	<0.5
☐	0.5-1
☐	1-2
■	2-5
☐	5-15
☐	15-50
☐	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: Individual / household, small scale land users, common / average land users, men and women
Population density: 10-50 persons/km^2
Annual population growth: negative
Land ownership: individual, titled
Land use rights: individual (small properties due to heritage)
Water use rights: open access (unorganised)
Relative level of wealth: average, which represents 12% of the land users; 25 % of the total land area is owned by average land users

Importance of off-farm income: less than 10% of all income
Access to service and infrastructure:
health : low
education : moderate
technical assistance : low
roads and transport: moderate
drinking water and sanitation: low
Market orientation: mixed (subsistence and commercial)
Mechanization: manual labour, animal traction
Livestock grazing on cropland: no



Technical drawing

The spatial arrangement of olive trees plante symmetrically (at 6m intervals) with intercropping. The beans grow in the stripes, and there is a barbed wire fence and cactus hedge to prevent livestock intrusion. (Larbi Elktaibi)

Implementation activities, inputs and costs

Establishment activities

1. Holes dug for tree plantation
2. Manure application
3. Plantation
4. Soil preparation by tillage

Establishment inputs and costs per ha

Inputs	Costs (US$ / local currency)	% met by land user
Labour	568	52
Equipment - machine use - animal traction - tools	 25 15 96	2 1 9
Other Agricultural - seedlings - compost/manure	307 80	28 8
TOTAL	**1091**	**36**

Maintenance/recurrent activities

Olive tree strips:
1. Early tillage for soil preparation (September)
2. Manure spreading around the olive tree plants (autumn)
3. Pruning of olive trees (January)
4. Treatment of olive tree against disease (if necessary)
5. Olive harvest (October – November)

Cropping strips:
1. Early tillage for breaking up the soil
2. Sowing of beans
3. Harrowing for aeration of the soil and weeding
4. Treatment against bean parasites
5. Harvest and collection of grains

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$ / local currency)	% met by land user
Labour	64	22
Equipment - machine use - animal traction	 50 35	 17 12
Agricultural - seedlings - biocides - compost/manure	 40 18 80	 14 6 28
TOTAL	**287**	**19**

Remarks:
Labour and seedlings are the most determining factors affecting the costs. The local wage rate is 5 US$/day.
Costs are calculated on the basis of initial expenses for buying tillage tools and seedlings, and maintenance expenses for tillage, seedlings buying and fertilizers.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ increased crop yield	++ reduced fodder production
++ increased farm income	+ grazing land reduction

Socio-cultural benefits	Socio-cultural disadvantages
+++ improved conservation / erosion knowledge	+ socio cultural conflicts

Ecological benefits	Ecological disadvantages
+++ reduced surface runoff	Increase habitat for birds that invade crops (negligible)
+++ reduced wind velocity	
+++ increased soil organic matter / below ground C	
+++ reduced soil loss	
+++ higher soil fertility	
++ increased soil moisture	
+ reduced soil crusting / sealing	

Off-site benefits	Off-site disadvantages
+ reduction of overland flow and flooding	
+ reduction of siltation in the dam reservoir	

Contribution to human well-being/livelihoods

+ Incomes from the implemented technology are still low because of the low olive and oil production. They are expected to increase 7 years after plantation.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	positive
Maintenance/recurrent	slightly negative	positive

Over the long term, increase in olive production creates great financial resources

Acceptance/adoption:

Seventy per cent of land user families have implemented the technology with external material support. Thirty per cent of land user families have implemented the technology voluntarily. This technology is a new agricultural practice which becomes more and more interesting for land users. There is a strong (growing) trend towards spontaneous adoption of the technology. This technology is rapidly growing because it is a promising alternative to combat climatic irregularities and rural poverty.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Ecological balance: olive tree plantations allow soil conservation through reduction of the erosion risks. It also provides benefits on water resources due to infiltration improvement. → Intensification of olive tree plantations and support of individual plantation projects, manure and fertilizers buying and technical supervision	Decrease in breeding activities because of protected areas and grazing land reduction → Additional fodder supply and promotion of fodder cultivation and stalling
Improvement in socio-economic conditions: olive tree plantations provide more financial resources for land users, and provide high added value activities. → By promoting awareness-raising and technical supervision	Insignificant economic benefits and low profitability provided by the technology over the short term → Promotion of intercropping to overcome the period before production begins, and give land users subsidies for fodder, seeds and fertilizers
Over the long term, this cultivation activity is more profitable than cereals → Promotion of olive tree plantation by subsidies	Owing to limited water resources, irrigation can be difficult during a dry year → Support in localized irrigation implementation (drip system)
Olive tree plantations are a less sensitive to irregular rainfalls than other cultivations → search for drought-resistant species	Conflicts occur because of protected areas → Allowing access for livestock

Key reference(s): DPA (2001): Projet de mise en valeur des terres en bour de Sehoul. Direction Provinciale de l'Agriculture, Rabat

Contact person(s): Abdellah Elhazziti, Centre des travaux agricoles Bouknadel, Route de Kénetra Bouknadel (CT221) Salé, Tél +212041274340

Above left: *Aloe vera* living barriers are often combined with stone walls to enhance the erosion control on steep slopes (Photo: Hanspeter Liniger)
Above right: *Aloe vera* in an agroforestry farming system (Photo: M. Moemedi)

Aloe Vera living barriers

Cape Verde - *Barreiras Vivas de Aloe vera (Portuguese)*

It is a technique which uses the structure of a cross-slope barrier of *Aloe vera* to combat soil erosion by decreasing surface wash and increasing infiltration.

Aloe vera is a durable herbaceous plant which is planted in the form of living barriers to recover degraded slopes on the Cape Verde Islands.

The plants are closely planted along the contour to build an efficient barrier for retention of eroded sediments and superficial runoff. The living hedges of *Aloe vera* stabilize the soil, increase soil humidity by improving infiltration and soil structure. Groundwater is recharged indirectly. Soil cover is improved, and thus evaporation and erosion reduced.

Implementation is relatively simple. The contour lines are demarcated using a water level. Seedlings are planted along one line at a distance of 30-50 cm between plants; spacing between the rows varies between 3-5 m according to the slope. The technology is applied in subhumid and semi-arid areas, on steep slopes with shallow soils, a poor vegetation cover and high soil erosion rates. These areas are generally used by poor subsistence farmers for rainfed agriculture with crops such as maize and beans, which are considered inappropriate for such slope angles. On slopes steeper than 30% the living barriers are often combined with stone walls (width 40-50 cm; height 80-90 cm). The plants stabilize the stone risers, making this combined technology one of the most efficient measures for soil erosion control on the Cape Verde Islands.

The herbaceous plant is well adapted to the local biophysical conditions and to the land use system: it can be grown with any crop, is available for any farmer, establishment and transport are simple, its green leaves are not palatable for livestock, the plant is extremely resistant to water stress and grows on any bioclimatic zone on the island. Furthermore, Aloe is known for its multiple uses in traditional medicine.

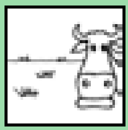
Location: Ribeira Seca catchment
Region: Santiago Island, Cape Verde
Technology area: 71.5 km^2
Conservation measure: vegetative, sometimes in combination with structural: contour furrows and stone walls
Stage of intervention: rehabilitation / reclamation of denuded land
Origin: North Africa during slavery in the 15^{th} century, externally / introduced through project (10-50 years ago)
Land use: cropland and grazing land
Climate: semi-arid, tropics
WOCAT database reference: QT CPV06e on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/ribeira-seca-cape-verde
Related approach: Training, Information and Awareness-raising (QA CPV01)
Compiled by: Jacques Tavares, Instituto Nacional de Investigação e Desenvolvimento Agrário (INIDA)
Date: 5^{th} Mar 2009, updated 31^{th} Aug 2011

Classification

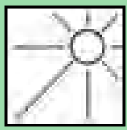
Land use problems: Low productive land, shallow soil depth, loss of soil by runoff water, reducing its thickness and fertility

Land use


annual cropping (rainfed)


extensive grazing land

Climate


semi-arid, tropics

Degradation


soil erosion by water: gully erosion/gullying, loss of topsoil, surface erosion

Conservation measure


vegetative: grasses and perennial herbaceous plants

optional structural: stone walls and ditches

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative
Experiments / research
Externally introduced

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - Human induced: soil management, overgrazing, weeding
Direct causes - Natural: droughts, heavy rainfalls , Steep slopes: Low vegetation cover accelerates the runoff
Indirect causes: poverty / wealth, education, access to knowledge and support services

Main technical functions:
- reduction of slope length
- improvement of ground cover
- improvement of topsoil structure (compaction)
- stabilization of soil (e.g. by tree roots against landslides)
- increase of groundwater level, recharge of groundwater (expected)
- sediment retention / trapping, sediment harvesting
- increase of biomass (quantity)

Secondary technical functions:
- control of raindrop splash
- reduction of slope angle
- increase of surface roughness

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 90 days (August to October)
Soil texture: medium (loam)
Soil fertility: medium
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: medium

Soil water storage capacity: low but high on barriers
Ground water table: 5 - 50 m
Availability of surface water: limited
Water quality: poor drinking water
Biodiversity: low

Tolerant of climatic extremes: seasonal rainfall decrease, wind storms / dust storms, floods, decreasing length of growing period
Sensitive to climatic extremes: seasonal rainfall increase, droughts / dry spells
If sensitive, what modifications were made / are possible: *Aloe vera* is resistant to dry conditions because of its physiognomy and anatomy, but cannot resist a prolonged drought

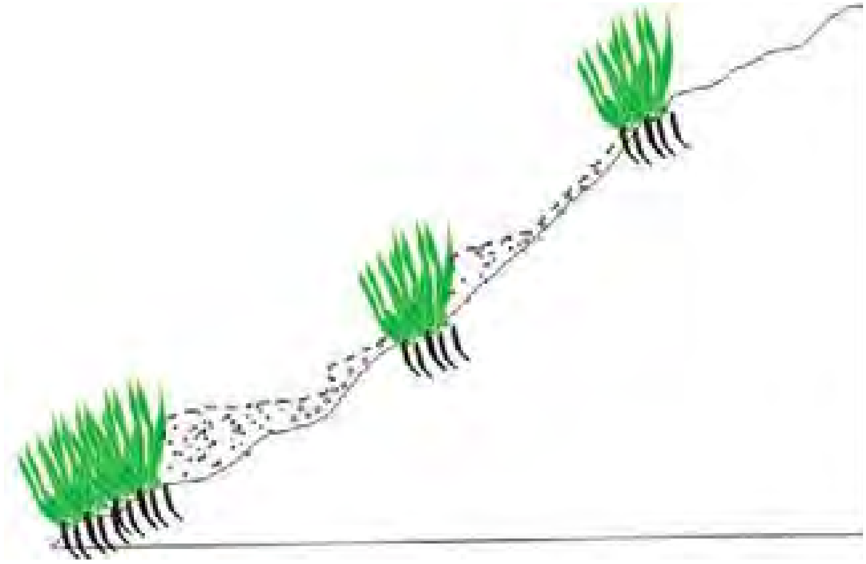
Human Environment

Cropland per household (ha)

- <0.5
- 0.5-1
- 1-2
- 2-5
- 5-15
- 15-50
- 50-100
- 100-500
- 500-1,000
- 1,000-10,000
- >10,000

Land user: individual / household, medium scale land users, leaders / no gender bias
Population density: 100-200 persons/km^2
Annual population growth: > 4%
Land ownership: individual, titled, Diocese
Land use rights: leased
Water use rights: communal (organized)
Relative level of wealth: among 125 land users contacted, 40 % own their land

Importance of off-farm income: if rainfed then > 50%, if also irrigated land:30-40%
Access to service and infrastructure: moderate: health, technical assistance, employment, market, drinking water and sanitation, financial services; high: education, energy, roads & transport
Market orientation: subsistence (self-supply)
Mechanization: manual labour
Livestock grazing on cropland: yes



Technical drawing

Aloe Vera Living Barriers on slope of more than 60%. The soil accumulated behind the barrier can reach depths of 55 cm (Jacques Tavares)

Implementation activities, inputs and costs

Establishment activities

1. Demarcation of contour lines, using water levels
2. Collection of Aloe Vera plants (*Aloe vera* grows naturally on upper slopes and in depressions)
3. Planting
   Not including collecting stones and building stone barriers

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	215	100
Equipment - tools	13	100
TOTAL	**228**	**100**

Maintenance/recurrent activities

1. Vegetative control: removal of *Aloe vera* plants that are invading cropland (maize, peas) between the living barriers.
2. Replanting of *Aloe vera* to fill gaps in living barriers (very rare, survival rate is over 95%)

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	33	100
TOTAL	**33**	**100**

Remarks:
The labour used in this technique consists of individuals from poor or very poor rural communities who come to work in search of an income with a payment of 250 Escudos per day. Labour inputs for implementation are rewarded by project: individuals of poor communities receive a salary of 3.3 US$ per day. Plants are collected locally; their value on the market would be around 3-4 US$ per plant. Establishment costs do not include labour-intensive construction of stone risers (supportive measure). Maintenance costs are borne by land users.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
++ reduced risk of production failure + increased crop yield	++ loss of land (about 8% if the production area is 1 ha)

Socio-cultural benefits	Socio-cultural disadvantages
+ improved cultural opportunities (additional crops possible) + improved conservation / erosion knowledge + improved food security / self sufficiency	

Ecological benefits	Ecological disadvantages
+++ improved harvesting / collection of water +++ reduced surface runoff and suspended sediment ++ reduced soil loss ++ improved soil cover ++ increased biomass / above ground C + increased water quantity + increased soil moisture	

Off-site benefits	Off-site disadvantages
+ increased water availability	

Contribution to human well-being/livelihoods

\+ *Aloe vera* is used in traditional medicine, and is also used in personal hygiene.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	slightly negative	very positive
Maintenance/recurrent	neutral / balanced	very positive

The structure does not require costly maintenance, it is simply controlling the spacing of the barrier (vegetative control) and punctual replanting.

Acceptance/adoption:

95% of land user families (380 families; 9% of area) have implemented the technology with external material support. 5% of land user families (20 families; 1% of area) have implemented the technology voluntary. There is little trend towards (growing) spontaneous adoption of the technology.

Concluding statements

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
Recover the degraded land and increase the production area → The vegetation of the area between the barriers will make the recovery and protection of the soil layer is stronger	Reduction of the production area, which is occupied by bands of *Aloe vera* → Annual vegetative control within cultivated area and by cutting *Aloe vera* plants growing outside the living barriers, using it more economically
Stabilizes the soil making it more resistant to the impact of the rain water → Sedimentation behind the barriers is favored along the time due to the continued growth of the plant *Aloe vera*	
Improves the thickness of the soil leaving it stronger and more productive → The mineral and organic matter retained behind the lines of *Aloe vera* will promote an increase in the thickness of the soil, improving also the volume of water retained in the soil, resulting in better root development. Therefore, the process of soil formation is best done.	

Key reference(s): Field Trip Guide, INIDA - Cabo Verde, 2008 / Técnicas de Conservação de Solos e Água em Cabo Verde, MPAR &CILSS, 1994 / Consercação de Solos e Água (Teoria e Prática), Sabino, António Adnino, 1991

Contact person(s): Jacques Tavares, Instituto Nacional de Investigação e Desenvolvimento Agrário (INIDA), Cape Verde, jacques.tavares@gmail.com

Above left: Native agave (*A. inaequidens*; *"maguey bruto"*) freshly planted on eroded soil (Acrisol type) in the Cointzio basin, Michoacán de Ocampo state (Photo: C. Prat, IRD)
Above right: Example of a plantation (2002) of *Agave cupreata ("maguey papalote")* with and without a tree cover. Titzio project, Michoacán de Ocampo state (Photo: A. Martínez, UMSNH)

Land reclamation by agave forestry with native species

Mexico - *Recuperación de tierras degradadas por agaveforestería con especies locales de agaves, arboles y herbaceas (Spanish)*

Agave forestry land reclamation system with native agaves, trees, shrubs and grasses planted through participatory action for a sustainable production of mezcal and other products in order to generate high incomes for farmers.

Rehabilitation of degraded land is achieved using native agave (*Agave inaequidens*), trees and/or fruit trees, shrubs and grasses to create, over the medium-term (7-10 years), sustainable production of a traditional alcoholic drink (*mezcal*) made from agave and/or cosmetic and medicinal products, and/or fibres and/or fodder for cattle and/or wood. Between the agave plants, native vegetation is managed or planted for use as food, fodder and/or medicinal products. Depending on the slope and the level of land degradation, continuous planted rows of agave provide a 'green' barrier that controls soil erosion and runoff.

The main purpose is to achieve sustainable land rehabilitation while generating a high income for the farmer. This allows reducing the amount of livestock and overgrazing, which is the main cause of soil erosion in this region. The production of *mezcal* gives local farmers high incomes. Trees, shrubs and grasses for medicinal uses, food, and fodder are complements of agave production and are processed mainly by women, while agave harvesting is a male activity. As it is very attractive financially, farmers stay in the communities instead of emigrating to cities or abroad. Biodiversity is preserved and increased using native plants (agaves, trees, shrubs, grasses). These plant associations are effective at controlling plant pests and diseases. Turning eroded into productive soil sequesters carbon and increases water availability as a result of the new soil cover.
Unlike most agave, *Agave inaequidens* reproduces from seed, which requires harvesting the seeds from native plants in the fields. One plant generates 80,000 seeds with a 90% success rate of germination, which is enough to cover 25 ha of agave forestry plantations set up to control soil erosion. After harvesting seeds from native agaves, trees and shrubs, seedlings and small plants are raised in a greenhouse and nursery managed by the owners and tenants of the land in the first year. At the beginning of the rainy season, these are planted in plots protected from cattle grazing for at least the first two years after planting. The harvesting activity for trees, shrubs and grasses is done annually, but for the agaves only once every 7 to 12 years depending on the degree of soil degradation. Some months before harvesting, the flower from the stem has to be cut. The leaves are then cut and left in the plot while the 50 kg heart of the agave (*"piña"*) is removed. Mezcal is produced from the heart and requires an average of three weeks and at least two men to process 25 agave plants (1.5 tonnes), which produces about 300 litres of mezcal.
Poverty levels in the area are medium to high and the income from agriculture accounts for only 10 to 20% of the total family budget. People, therefore, do not have time to install soil erosion protection systems in the fields. Cattle graze freely everywhere and the number of animals is increasing annually, which also increases soil erosion. Locals know how to produce *mezcal*, but they prefer to buy it from other people who take wild plants from their lands to process them. The proximity of the site to the Michoacán of Ocampo state capital and the recognition of the designation of origin for *mezcal* by the authorities will enhance its value for future production.

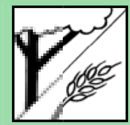
Location: Morelia municipality
Region: Cointzio watershed, Michoacán state
Technology area: 0.1 - 1 km^2
Conservation measure: vegetative
Stage of intervention: rehabilitation / reclamation of denuded land
Origin: Developed through experiments / research, recent (<10 years ago); externally / introduced through project, recent (<10 years ago)
Land use: Grazing land: Extensive grazing land (before), Mixed: Agroforestry (after)
Climate: semi-arid, temperate
WOCAT database reference: QT MEX002 on cdewocat.unibe.ch/wocatQT
DESIRE site information: http://www.desire-his.eu/en/cointzio-mexico
Related approach: Participative actions for economic benefits of agave forestry (Mex002)
Compiled by: Christian Prat, Institut de Recherche pour le Développement (IRD), France and Alejandro Martínez Palacios, Universidad Michoacana San Nicolas de Hidalgo (UMSNH), Mexico
Date: 1st Oct 2010, updated Nov 2011

Classification

Land use problems: Soil erosion by water due to storms and improper land use, mainly overgrazing due to uncontrolled grazing by cattle.

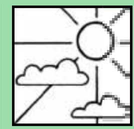
Land use

extensive grazing land (before)



agroforestry (after)

Climate



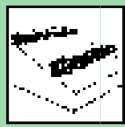
semi-arid, subtropics

Degradation

soil erosion by water: loss of topsoil / surface erosion, gully erosion,

biological degradation: reduction of vegetation cover, quality and species composition / diversity decline

Conservation measure



vegetative: tree and shrub cover

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative: traditional (< 50 years ago)
Experiments / research: < 10 years ago
Externally introduced: < 10years ago

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - human induced: soil management, overgrazing.
Indirect causes: poverty / wealth

Main technical functions:
- improvement of ground cover
- increase of biomass (quantity)
- promotion of vegetation species and varieties (quality, eg palatable fodder)
- control of concentrated runoff: retain / trap
- sediment retention / trapping, sediment harvesting

Secondary technical functions:
- improvement of surface structure (crusting, sealing)
- improvement of topsoil structure (compaction)
- increase of infiltration
- control of raindrop splash
- control of dispersed runoff: impede / retard
- control of concentrated runoff: impede / retard; drain / divert
- water harvesting / increase water supply
- improvement of water quality, buffering / filtering water

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 190 days (June to November)
Soil texture: medium (loam), fine / heavy (clay)
Soil fertility: medium, low, very low
Topsoil organic matter: medium (1-3%), low (<1%)
Soil drainage/infiltration: medium

Soil water storage capacity: medium, low, very low
Ground water table: 5 - 50 m, > 50 m
Availability of surface water: medium, poor / none
Water quality: for agricultural use only or not usable
Biodiversity: high

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount), wind storms / dust storms, floods, droughts / dry spells, decreasing length of growing period
Sensitive to climatic extremes: The native plants used with this technology are adapted to the local climate and they are therefore not sensitive to the climatic extremes and are used to living in these extreme conditions.

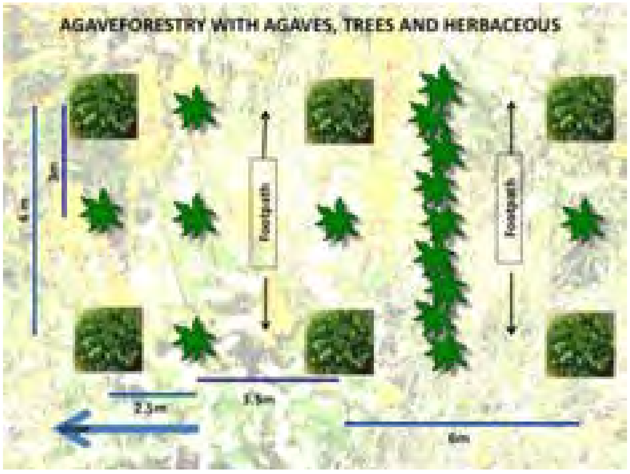
Human Environment

Mixed land per household (ha)

- <0.5
- 0.5-1
- 1-2
- 2-5
- 5-15
- 15-50
- 50-100
- 100-500
- 500-1,000
- 1,000-10,000
- >10,000

Land user: groups / community, small scale land users, common / average land users, men and women
Population density: 10-50 persons/km^2
Annual population growth: 1 - 2%
Land ownership: communal / village, *"ejido"*
Land use rights: communal (organised): *"ejido"* is the community organisation in Mexico: land belongs to the state but it is managed by the community. Some areas can be used by everybody; others are assigned to the land user families.
Water use rights: water concession given by National Water Authority to the *"ejido"*
Relative level of wealth: average (owning 34% of the land); poor (owning 33%), very poor (owning 33%)

Importance of off-farm income: Off-farm incomes represent between 80-90% of the annual incomes: "external" job, business, trade, or by money sent by family members from the USA
Access to service and infrastructure: moderate: technical assistance, employment (e.g. off-farm), financial services; high: health, education, market, energy, roads & transport, drinking water and sanitation
Market orientation: mixed (subsistence and commercial)



Technical drawing

Agave production is based on planting them with trees along the contour. Herbaceous plants are maintained / planted or sown between the plants. Depending on the slope, one or more dense lines of agaves (1 plant every 25 cm) is planted for control of soil erosion and runoff, including a lateral gradient to the gully which will evacuate the excessive runoff. Footpaths are planned for the maintenance of the plantation (Design of Alejandro Martinez).

Implementation activities, inputs and costs

Establishment activities

1. Selection and collection of agave and tree seeds
2. Building of greenhouses incl. soil and organic matter
3. Fencing of greenhouses with barbed wire, poles and nails (0.5 ha)
4. Sowing & maintaining seedlings in greenhouses (3 months)
5. Installation of a nursery for agaves and trees and transplantation of seedlings into plastic bags
6. Plant care and maintaining in nursery (9 months)
7. Transportation of plants in plastic bags
8. Planting of plants (agaves and trees)

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	153	10
Equipment		
- greenhouse (10 years life)	18	10
- transport (trucks)	16	10
Construction material		
- earth	23	10
- plastic bag for plants	12	10
- barbed wire (10 years life)	11	10
Agricultural - seedlings	100	10
TOTAL	**333**	**10**

Maintenance/recurrent activities

1. Weeding around plants to give them space during the first 3 years (10 person days/ha)
2. Cutting the stalks before the harvest (15 person days/ha)
3. Replanting of agaves after 7 to 14 years (restarting of a new cycle of production, see establishment activities)

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Agricultural		
- cleaning around plants	37	10
- cutting scape	17	10
TOTAL	**54**	**10**

Remarks:
The most important factors determining the costs are: 1) the materials to build a greenhouse and the personnel to take care of young plants; 2) the difficulties of making holes in the indurated soils, which takes time and efforts; and 3) the distance between the nursery and the field requires time and efforts (truck carrying the plants).
Calculations are for the plantation of 200,000 plants (agaves and trees) which correspond to the numbers of plants for 100 ha in the agave forestry example presented here. The main portion of these plants is planted by the community on their own land; the rest is given or sold to other communities or private people. The lifetime of the greenhouse, nursery and fencing installations is around 10 years. The local wage rate is 12 US$/day.

Assessment

Impacts of the Technology

Production and socio-economic benefits

+++ increased farm income, diversification of income sources
+++ increased production area and diversification
+++ increased crop yield
++ increased wood and fodder production and quality

Production and socio-economic disadvantages

+++ reduced animal production
+++ anticipated impact on the community due to the huge benefits which may induce corruption, violence, etc.

Socio-cultural benefits

+++ improved conservation / erosion knowledge
+++ improved situation of disadvantaged groups
+++ improved food security / self-sufficiency
++ conflict mitigation
++ improved health (through medicinal plants and income)

Socio-cultural disadvantages

+++ socio cultural conflicts
++ increased health problems (due to alcohol)

Ecological benefits

+++ improved harvesting of water, increased soil moisture
+++ reduced surface runoff and soil loss
+++ improved soil cover
+++ increased animal, plant and habitat diversity
++ increased biomass and nutrient cycling

Ecological disadvantages

+ increased fire risk

Off-site benefits

+++ reduced downstream flooding and siltation
+++ reduced damage on neighbours fields and on public / private infrastructure
+++ increased biodiversity
++ increased water availability

Off-site disadvantages

Contribution to human well-being/livelihoods

+++ the production of the mezcal drink (with designation of origin) from agaves, and/or medicinal products, will generate very high incomes for stakeholders which change their life and allow farmer's sons to stay in the community and work in their fields.

Benefits/costs according to land user
That is why state institutions fund the installations of this system, although the production has not started yet. After that, benefits generated will be enough to motivate people to increase the surface to remediate by themselves, without economical helps.

Benefits compared with costs	short-term:	long-term:
Establishment	negative	very positive
Maintenance/recurrent	negative	very positive

Acceptance/adoption:
All the land user families (50 families; 10% of area) who implemented the technology received an external material support. As the programme only started in 2010, it is impossible to have an exact overview of the results (end of 2011). As the land users belong to the same community ("ejido"), formally, all the inhabitants are involved in some way. It is too early to identify an adoption trend.

Concluding statements

Strengths and → how to sustain/improve

Remediation of degraded land turning it to a sustainable production generating very high incomes in the medium term → life will change drastically and not necessarily for the better. Transparency and communication regarding benefits and land use are necessary

Low-cost project but it needs to be funded and supported with technical and institutional advice to initiate the first cycle of the project → Farmers can start to produce their *mezcal* from the wild agaves to sell them to wholesalers and use this money to pay for the project.

As a result of the economic benefits, young people will stay in the communities → Involve the young to guarantee the future: develop the marketing, the diversification of the products, the quality of production, etc.

It will hopefully reduce the number of cattle, which are the main cause of soil erosion, as farmers lose interest in cattle raising → Authorities need to monitor this and inform the farmers about the ecological impact of too much free cattle grazing

Weaknesses and → how to overcome

Obligation to find external funds to pay the first steps of the system (greenhouse, planting etc.) due to the lack of incomes amongst farmers → Involvement of all stakeholders in the project

Ensuring that alcohol production will not be consumed in excess in the community → control of the volume of the production, and the sufficiently high selling price should avoid "losing" the production at local scale

Risk that the benefits will be captured by few people → transparency and stakeholder communication in accounting for the benefits

Marketing and selling the products → authorities help the farmers to contact sellers. The formation of communities of producers, leading to products conforming to regulations that maintain good quality and provide certification.

Owing to the high incomes, life will change drastically and not necessarily for the better.

Key reference(s): Colunga-García Marín P., D. Zizumbo-Villareal, J.T. Martínez. 2007. Tradiciones en el aprovechamiento de los agaves mexicanos: una aportación a la protección legal y conservación de su diversidad biológica y cultural. In: En lo Ancestral hay Futuro: del Tequila, los Mezcales y otros Agaves. P. Colunga-GarcíaMarín, L. Eguiarte, A. Larqué, D. Zizumbo-Villarreal (eds). CICY-CONACYT-CONABIO-SEMARNAT-INE. México D.F., pp. 85-112.

Contact person(s): Alejandro Martínez Palacios, UMSNH-Universidad Michoacana San Nicolas de Hidalgo, Morelia, Mexico, apalacios56@gmail.com
Christian Prat, IRD-Institut de Recherche pour le Développement, France, christian.prat@ird.fr

Above left: The field during *Atriplex* planting in April 2009 (Photo: Gudrun Schwilch)
Above right: The vegetation cover 2 years after *Atriplex* planting, showing the boundary fence (Photo: Gudrun Schwilch)

Gully control by plantation of *Atriplex*

Morocco

Rehabilitation of a gullied slope and gully control, by plantation of *Atriplex halimus* fodder shrubs.

The experimental plot, with a size of 5000m², corresponds to an old fallow field and strongly gullied slope. The gullies are parallel and start around the middle of the slope. They extend by retreat of the gully heads upslope. Each gully is 2 to 4 m large and 1 to 2 m deep and up to 120 m long. Downslope, the gullies lose their depth and deposit fans composed of material eroded upstream, before they join the channel of Hannanet, which has the tendency to incise its bed (more than 4 m deep) inside colluvial deposits made of sand, clay and beds of pebbles. The plot was planted with shrubs of *Atriplex halimus*, and enclosed with a fence since April 2009. Planting was organised in strips 6 m apart, with the objective of stabilizing the gullies and restoring biodiversity. Planting density is about 760 shrubs/ha, with a rate of success of about 89.5%. Owing to late plantation in spring it was irrigated every 20 days during the summer months. It is planned to open it again to grazing 2.5 years after its plantation.

The objective of the fencing to prevent encroachment of animals is to improve the vegetation cover through reduction of loss through grazing and reduced compaction of the soil. This improves biodiversity and also provides richer and more varied grass fodder in addition to the fodder from the shrubs. The improved cover density retains water in the soil and reduces runoff. The aim is to reduce the catchment area of the gullies, and the amount of water collected in order to progressively diminish the gullies.

Several phases were undertaken in the establishment of this experimental plot: The plants were obtained from a nursery in the Beni Mellal region (from the Forest authority). The second activity was the preparation of holes (760 holes of 40x40x40cm) and the establishment of a wire fence around the plot, in order to ensure no grazing during the first 2 years. After planting the shrubs, irrigation was necessary for the first few months during the dry season.

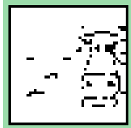
The climate is semi-arid with around 450 mm of rain annually. The topography consists of a plateau, incised by channels, with short tributaries extending into the Grou valley. The slope angle is between 10 and 50 %. The soils on the slope are often not developed. The thick colluvium, which is made of erodible reddish sand and clay, explains the depth and width of the gullies. The economy relies on a system based on cereals and grazing. The income of this system is low because of the extensive character and the reduction of yield due to degradation. Many changes are occurring, such as changes in land cover and in emigration, land abandonment and increased links to urban activities.

Location: Sehoul
Region: Salé province
Technology area: 0.005 km^2
Conservation measure: vegetative
Stage of intervention: rehabilitation / reclamation of denuded land
Origin: developed through experiments / research and externally / introduced through project, recent (<10 years ago)
Land use: grazing land
Climate: semi-arid, subtropics
WOCAT database reference: QT MOR15e on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/sehoul-morocco
Related approach: not documented
Compiled by: Laouina Abdellah, Chaire Unesco-GN, Faculté des Lettres et des Sciences Humaines, Rabat, Morocco
Date: 09th Sep 2011

Classification

Land use problems: Decrease in yield, decrease in the availability of water and of its level in wells. Retreat and degradation of the vegetation cover, degradation of soil quality, development of signs of water erosion, namely rills and on some slopes gullies with rapid extension. Progressive expansion of abandoned lands not recolonized by vegetation, which create patches of desertified land in the area.

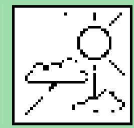
Land use



extensive grazing land (before)

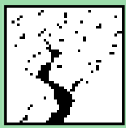
intensive grazing/fodder production (rainfed) (after)

Climate



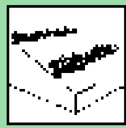
semi-arid, subtropics

Degradation



soil erosion by water: gully erosion/gullying

Conservation measure



vegetative: tree and shrub cover

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative:
Experiments / research: <10 years
Externally introduced: <10 years

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - human induced: overgrazing, disturbance of water cycle (infiltration / runoff). The degraded lands are abandoned and this leads to the continuous extension and deeper incisions of gullies
Direct causes - natural: heavy / extreme rainfall (intensity/amounts), irregularity of rainfall
Indirect causes: land tenure (free grazing), education, access to knowledge and support services, attractiveness of cities, poverty / wealth.

Main technical functions:
- control of concentrated runoff: retain / trap
- control of dispersed runoff: impede / retard
- improvement of ground cover and biomass
- increase of surface roughness
- stabilisation of soil
- increase of infiltration
- promotion of vegetation species and varieties (quality, eg palatable fodder)

Secondary technical functions:
- control of raindrop splash
- increase / maintain water stored in soil
- improvement of surface structure (crusting, sealing)
- improvement of topsoil structure (compaction)
- increase in organic matter
- reduction in wind speed

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 210 days (September to April)
Soil texture: medium (loam)
Soil fertility: low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: poor (e.g. sealing /crusting)

Soil water storage capacity: medium
Ground water table: 20-60 m
Availability of surface water: poor / none
Water quality: good drinking water
Biodiversity: low

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase, heavy rainfall events (intensities and amount), wind storms / dust storms, floods
Sensitive to climatic extremes: seasonal rainfall decrease, droughts / dry spells

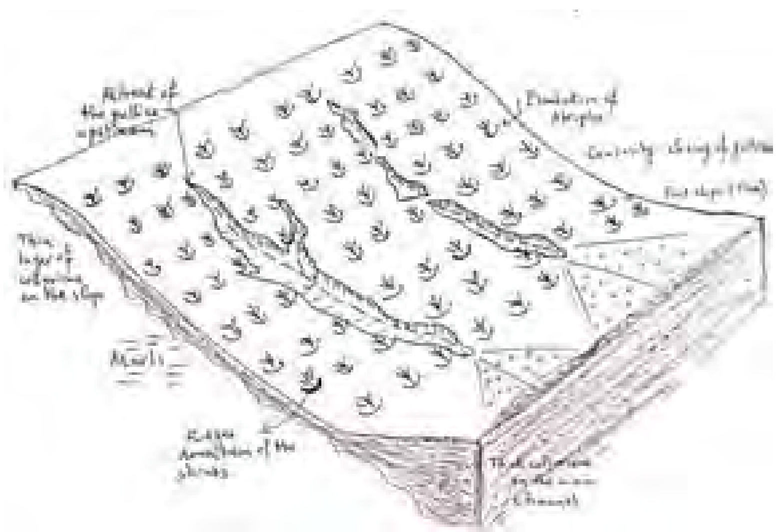
Human Environment

Grazing land per household (ha)

	<0.5
	0.5-1
	1-2
■	2-5
	5-15
	15-50
	50-100
	100-500
	500-1,000
	1,000-10,000
	>10,000

Land user: individual, medium to large scale, privileged land user, mainly men
Population density: 10-50 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, not titled
Land use rights: open access
Water use rights: open access
Relative level of wealth: average, which represent 25% of land users; 12% of the total land area is owned by average land

Importance of off-farm income: 10-50% of all income
Access to service and infrastructure: low: health, education, market, energy, drinking water and sanitation, financial services; moderate: technical assistance, employment (eg off-farm), roads & transport
Market orientation: mixed (subsistence and commercial)
Livestock density: 25-50 LU /km^2



Technical drawing

The drawing shows a slope eroded by parallel gullies. The incision develops in colluvial red material. Downstream, the gullies deposit the transported material and deposit it in the form of large fans made of pebbles washed by water which transports the fine elements to the main channel and to the Grou valley. The technology consists in the plantation of *Atriplex* shrubs planted along the contours. The small ridges on the downstream side of the shrubs and the shrubs themselves retain water and improve infiltration, which creates better conditions for growing grass. (Abdellah Laouina)

Implementation activities, inputs and costs

Establishment activities

1. Digging Holes: 40 * 40 * 40 cm
2. Wood stakes and fencing
3. Plantation
4. Irrigation 4 times

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	2344	0
Equipment - plants - water	 563 500	 0 0
Construction material - wood - metallic fence	 205 650	 0 0
TOTAL	**4262**	**0**

Maintenance/recurrent activities

1. No maintenance activities yet, but maybe a temporal enclosure will be necessary again to protect the atriplex

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
TOTAL	**0**	**0**

Remarks:
The cost is determined by the amount of work necessary for plantation and fencing the plots. The local wage rate is 31 US$/day

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ increased fodder production ++ increased fodder quality	++ hindered farm operations ++ the free displacement of flocks is blocked + loss of land + increased labour constraints

Socio-cultural benefits	Socio-cultural disadvantages
++ improved conservation / erosion knowledge + national forest institution strengthening by better regulation (in the long term) + improved situation of disadvantaged groups	

Ecological benefits	Ecological disadvantages
+++ improved soil cover +++ increased biomass above ground C ++ increased soil moisture ++ increased plant diversity + reduced soil compaction	

Off-site benefits	Off-site disadvantages
++ reduced downstream flooding (if implemented more widely) ++ reduced damage on neighbours fields (if implemented more widely) + reduced downstream siltation (if implemented more widely)	

Contribution to human well-being/livelihoods

+ The implementation of *Atriplex* planting and fencing have an effect in the long-term while in the short-term, the effects are still not apparent

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	slightly negative	positive
Maintenance/recurrent	neutral / balanced	positive

The outputs could be really positive after at least 7 years

Acceptance/adoption:

Only one family has implemented the technology with incentives within this framework of experimentation. No trend in adaptation yet.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Rehabilitation of degraded land → engagement of the government in subsidizing part of the inputs and in creating awareness among the people to maintain the technology	High costs of implementation → government to subsidize part of the inputs
Change in land cover by vegetation → temporary fencing when necessary	Non-grazing due to fences during a 2 year period → rotation between grazing plots
Change in hydrological behaviour of the surface and improved water balance on- and off-site → maintain vegetation cover	
Improvement of the fodder quality and quantity → temporary fencing when necessary, enrichment of herbs by controlling the grazing period and number of animals	
Less loss of land (due to gullies) and reduced risk of erosion →expand technology and maintain vegetation cover, planting of other shrubs, such as *Cactus opuntia* to control gully incision	
Availability of fodder when the plots are opened to grazing → temporary fencing when necessary	

Key reference(s): Laouina A., Aderghal M., Al Karkouri J., Chaker M., Machmachi I., Machouri N., Sfa M. (2010) : Utilisation des sols, ruissellement et dégradation des terres, le cas du secteur Sehoul, région atlantique, Maroc. Sécheresse, 21, 4, 309-316.

Contact person(s): Abdellah Laouina, Chaire Unesco-GN, Faculté des Lettres et des Sciences Humaines, Rabat, Morocco; laouina.abdellah@gmail.com

Above left: The rangelands need only to be protected from grazing to produce an improved plant cover. (Photo: Ouled Belgacem A.)
Above right: Without protection from grazing the land is overgrazed and vegetation cover is heavily reduced (Photo: Ouled Belgacem A.)

Rangeland resting

Tunisia - *G'del (Arabic)*

This technique is based on the principle of leaving the rangeland protected (by excluding grazing during 2-3 years) to allow the plant cover to recover.

To tackle degradation and the negative effects of drought on rangelands, leaving the rangeland protected for rehabilitation is one of the common practices used for many decades by local people in arid areas of Tunisia. This technique is based on the principle of not allowing grazing for a period and thus resting the rangeland so that the plant cover can recover. The grazing-free period lasts commonly from 2 to 3 years depending on the ecosystem resilience (its capacity to recover) and climatic conditions. Owing to the high cost of fencing, an agreement between the administration and users is achieved regarding the boundaries (generally making use of natural ones such as a mountain chain, wadi, etc.). Users are totally committed to respect the protection of the site during the fixed period. In return, they receive a subsidy to compensate for the loss of production during this period. It is estimated at a quantity of barley equivalent to 70 US $ per hectare per year.

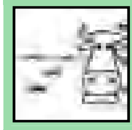
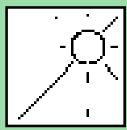
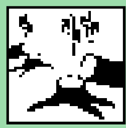
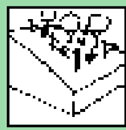
Applied in several types of improved land managements (rangeland improvement, dunes stabilization, national parks, etc.), this technique gives good results in terms of regeneration of vegetation in arid and even desert areas of Tunisia. However, the effectiveness of this technique varies according to several factors which determine the potential for regeneration of the treated area (rainfall, soil properties, level of degradation reached, etc.).

The resting period is recommended even in heavily overgrazed sites, but only if the vegetation still has its resilience capacity (indicated by the presence of some remnants of key and good range species) so that regeneration is possible. To have a fast, substantial and convincing impact, this technique should be applied in those rangelands that still contain relics of good pastoral species and where soil is more or less covered by sediments which allow good infiltration. These wind deposits are used as seed bed and act as mulch. In situations of extreme degradation, there is no point in applying this technique, since in these situations the soil seed stocks are often lacking and/or the soil has reached a very degraded and shallow state.

Location: Medenine
Region: Béni Khédache - El Athmane
Technology area: 1 - 10 km^2
Conservation measure: management
Stage of intervention: mitigation / reduction of land degradation
Origin: land users - traditional (> 50 years ago)
Land use: grazing land
Climate: arid, subtropics
WOCAT database reference: QT TUN11 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/zeuss-koutine-tunisia
Related approach: Dryland watershed management approach (QA TUN09)
Compiled by: Azaiez Ouled Belgacem, Institut des Régions Arides (IRA), Tunisia
Date: 3rd Oct 2008 updated, 23rd Jun 2011

Classification

Land use problems: low potential of rangelands, increase in feed costs, degradation of plant cover, loss of plant diversity (mainly perennial species), abundance of unpalatable species, soil erosion.

Land use	Climate	Degradation	Conservation measure
			
extensive grazing land (rainfed)	arid, subtropics	biological degradation: quality and species composition/ diversity decline	management: change of management/ intensity level

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative: >50 years ago
Experiments / research
Externally introduced: 10-50 years ago

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Overgrazing, tree and cereal crop expansion, fuel wood collection

Main technical functions:
- improvement of ground cover

Secondary technical functions:
- increase of biomass (quantity)
- increase of species richness (quality)

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 240 days (Oct - May)
Soil texture: coarse / light (sandy), medium (loam)
Soil fertility: very low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: medium

Soil water storage capacity: low
Ground water table: 50 m
Availability of surface water: poor / none
Water quality: medium
Biodiversity: medium

Tolerant of climatic extremes: wind storms / dust storms, floods, droughts / dry spells
Sensitive to climatic extremes: seasonal rainfall increase, seasonal rainfall decrease
If sensitive, what modifications were made / are possible: Without human disturbance, natural vegetation is well adapted to drought

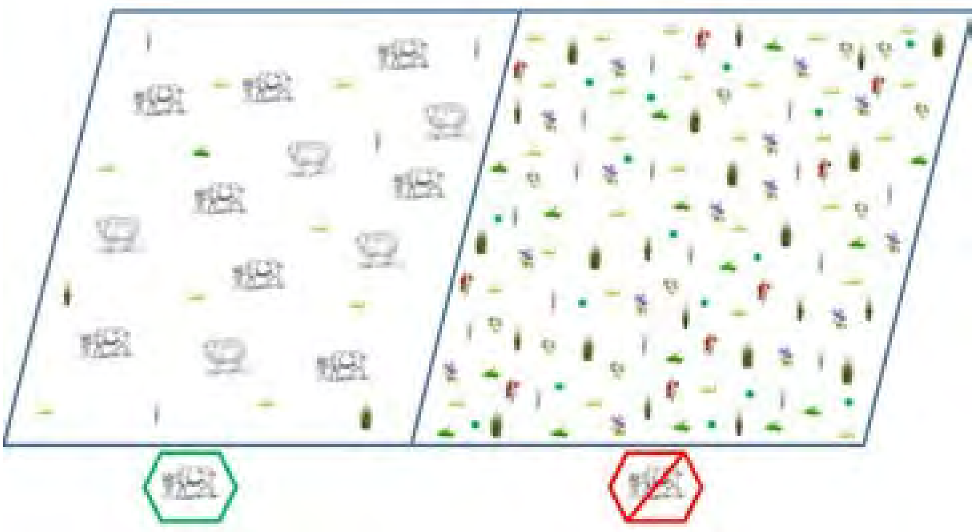
Human Environment

Mixed land per household (ha)

☐	<0.5
☐	0.5-1
■	1-2
☐	2-5
☐	5-15
☐	15-50
☐	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: Individual and common small scale land users, mainly men
Population density: < 10 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, titled
Land use rights: individual / communal (unorganised)
Water use rights: individual / communal (unorganised)
Relative level of wealth: poor, which represents 20% of the total land users; 20% of the total land area is owned by poor land users

Importance of off-farm income: > 50% of all income: off-farm incomes come from migration, construction works, commerce, tourism sector, administration or informal activities.
Access to service and infrastructure: low: employment, market; moderate: health, education, technical assistance, energy, roads & transport, drinking water and sanitation, financial services
Market orientation: subsistence (self-supply)



Technical drawing

Overgrazed (left) and rested (right) rangelands (M. Ouessar, 2011)

Implementation activities, inputs and costs

Establishment activities

1. Agreement between the rangelands users and the National Office of Livestock and Pasture (OEP)
2. Identification and delimitation of the rangelands to be left fallow.

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Other		
- social delimitation of rested rangelands	50	50
- subsidies (animal feed barely)	30	0
TOTAL	**80**	**31.25**

Maintenance/recurrent activities

1. Provide subsidies for the owners
2. The owner has to guard the rested rangelands (otherwise subsidies can be suspended)

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Other		
- subsidies (animal feed barely)	70	0
TOTAL	**70**	**0**

Remarks:
The subsidies (barely) are fully provided by the government in the framework of the national strategy. The local wage rate is 10 US$/day.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ increased fodder production	++ loss of land
++ increased fodder quality	
++ increased animal production	
++ increased farm income	

Socio-cultural benefits	Socio-cultural disadvantages
+ national institution strengthening	
+ conflict mitigation	
+ improved conservation / erosion knowledge	
+ improved food security / self sufficiency	

Ecological benefits	Ecological disadvantages
+++ improved soil cover	
+++ increased biomass / above ground C	
+++ increased plant diversity	
++ reduced soil loss	
+ increased soil organic matter / below ground C	

Off-site benefits	Off-site disadvantages
++ reduced downstream flooding	
+ reduced wind transported sediments	
+ reduced damage on public / private infrastructure	

Contribution to human well-being/livelihoods

++ combat the rural exodus and improve the income of agriculture (20%)

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	positive	very positive
Maintenance/recurrent	positive	very positive

Acceptance/adoption:

In all, 98% of land user families have implemented the technology with external material support.
Only 2% of land user families have implemented the technology voluntary.
There is a moderate trend towards (growing) spontaneous adoption of the technology.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Traditional technology - not expensive → by the participation of the land user's	Limitation of the grazing area → subsidies from the government and/or reduce animal numbers.
Reduce the costs of supplementation of livestock → subsidies of the government	Heavily based on government subsidies → alternative feed, rangeland seeding, etc.

Key reference(s): Ouled Belgacem A., Chaieb M., Neffati M., Tiedeman J. 2006. Response of Stipa lagascae R. & Sch. to protection under arid condition of southern Tunisia. Pakistan Journal of Biological Science. 9(3):465-469., Ouled Belgacem, A., Ben Salem H., Bouaicha A., El Mourid Mohamed. 2008. Communal rangeland rest in arid area, a tool for facing animal feed costs and drought mitigation: the case of Chenini community, southern Tunisia. J. Bio. Sc., 8(4): 822-825.,
Contact person(s): A. Ouled Belgacem Institut des Régions Arides, 4119 Medenine – Tunisia, Azaiez.OuledBelgacem@ira.rnrt.tn
Mliki Salem, OEP - 4100 Medenine - Tunisia

Above left: Controlled grazing - goats (Photo: Dino Torri)
Above right: Controlled grazing in deciduous oak forest (Photo: Dino Torri)

Controlled grazing in deciduous woods as an alternative to grazing on rangeland

Italy – *Pascolo controllato (Italian)*

Controlled grazing in deciduous woods seasonally limited in summer when grass cover in rangeland suffers water stress.

During the driest season, farmers shifts grazing to deciduous forest. Grazing in forest is controlled because it is limited to specific areas and with a controlled number of animals (cows and goats). In deciduous forest, the animals can still find green grass in the dry season. This action prevents excessive stress in the surrounding rangelands, which are suffering from a seasonal summer water deficit, as is typical of areas with a Mediterranean climate.

One purpose of this management technology is to allow grazing in environments that still preserve grasses in the summer dry season. Moreover, this technology can prevent overgrazing (and its consequences in rangeland and pastures). Controlled grazing is typical in the Rendina watershed (Basilicata, Italy). The upper part of the watershed is located above 800 m a.s.l. and is characterized by deciduous oak forest, which every 20 years is subject to selective cutting. Selective cutting involves cutting a high percentage of a limited range of tree species. Within about 10 years, regeneration of the whole wooded area is possible. This allows for a constant regeneration of the woodland and reduces the probability of a progressive degradation as well as of wildfires due to an excessive build-up of the fuel load. The surrounding areas are either cultivated or rangeland and suffer from the soil erosion and landslides that give rise to degradation and hence to the loss of arable lands.

Annual rainfall is 500 mm with two rainy seasons (October-November and March-May). Potential evapotranspiration is up to 1100 mm annually. The Rendina catchment ranges from humid-subhumid to subhumid-semiarid conditions. The surrounding area ranges from (subhumid)-semiarid to semiarid-arid.

Forests are either government-owned or privately-owned, but controlled grazing woodland areas are mostly government-owned. Based on the number of grazing animals admitted, the farmers need to pay a tax to the municipalities or regions. Each farmer has a specific number of animals admitted to the woodland area and there is a overall maximum of animals especially during summer, when a risk of overgrazing exists. Access to private forest, on the other hand, is arranged directly with the owners. Grazing is organized on a daily basis by the herdsman. The controlled grazing areas are always located in the woodlands where selective cutting is carried out. In such areas livestock during summer can enter and move more easily in the relatively cool conditions.

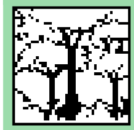
When controlled grazing is adopted as the conventional management technology, selective cutting of trees every 20 years is also used to provide additional earnings from the sale of firewood.

Location: Rendina Basin
Region: Potenza / Regione Basilicata
Technology area: 10 km^2
Conservation measure: management
Stage of intervention: prevention of land degradation
Origin: through land user's initiative 10-50 years ago
Land use: forests / woodlands and mixed
Climate: subhumid, temperate
WOCAT database reference: QT ITA01 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/rendina-italy
Related approach: not documented
Compiled by: Lorenzo Borselli, CNR
Date: 3rd Nov 2008, updated 5th Jun 2011

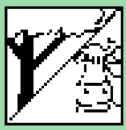
Classification

Land use problems: The land users claim about reduction of vegetation cover. This impacts water and tillage erosion and landslides but is not considered as main issue by land user, yet.

Land use

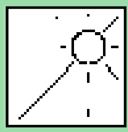


selective cutting of (semi-) natural forest (before)



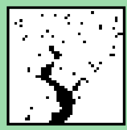
mixed: silvo-pastoralism (after)

Climate



subhumid, temperate

Degradation



biological degradation: reduction of vegetation cover

Conservation measure

management: displacement of livestock during the dry season

Stage of intervention

- □ Prevention
- ■ Mitigation / Reduction
- □ Rehabilitation

Origin

- ■ Land user's initiative: 10-50 years ago
- □ Experiments / research
- □ Externally introduced

Level of technical knowledge

- ▨ Agricultural advisor
- ▨ Land user

Main causes of land degradation:
Direct causes - human induced: overgrazing
Indirect causes: land tenure

Main technical functions:
- improvement of ground cover

Secondary technical functions:
- stabilisation of soil (e.g. tree roots against landslides)

Environment

Natural Environment

Average annual rainfall (mm)

- □ > 4000
- □ 3000-4000
- □ 2000-3000
- □ 1500-2000
- □ 1000-1500
- □ 750-1000
- ■ 500-750
- □ 250-500
- □ < 250

Altitude (m a.s.l.)

- □ > 4000
- □ 3000-4000
- □ 2500-3000
- □ 2000-2500
- □ 1500-2000
- □ 1000-1500
- ■ 500-1000
- □ 100-500
- □ <100

Landform

- □ plateau / plains
- □ ridges
- ▨ mountain slopes
- ■ hill slopes
- □ footslopes
- □ valley floors

Slope (%)

- □ flat
- □ gentle
- □ moderate
- ■ rolling
- ▨ hilly
- □ steep
- □ very steep

Soil depth (cm)

- □ 0-20
- ▨ 20-50
- ■ 50-80
- □ 80-120
- □ >120

Growing season(s): 90 days (Apr - Jun)
Soil texture: medium (loam)
Soil fertility: medium
Topsoil organic matter: high (>3%)
Soil drainage/infiltration: good

Soil water storage capacity: high
Ground water table: 5 - 50 m
Availability of surface water: medium
Water quality: good drinking water
Biodiversity: medium

Tolerant of climatic extremes: temperature increase
Sensitive to climatic extremes: seasonal rainfall decrease, decreasing length of growing period
If sensitive, what modifications were made / are possible: increase the number or the extension of the areas within the basin where controlled grazing can be established and performed.

Human Environment

Mixed land per household (ha)

	<0.5
	0.5-1
	1-2
	2-5
	5-15
■	15-50
	50-100
	100-500
	500-1,000
	1,000-10,000
	>10,000

Land user: Individual, medium scale, averaged land users, mainly men
Population density: 10-50 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, not titled
Land use rights: individual
Water use rights: individual
Relative level of wealth: average, which represents 60% of land users; 80 % of the total land area is owned by average land users

Importance of off-farm income: less than 10% of all income
Access to service and infrastructure: low: employment; moderate: education, technical assistance, market, roads & transport, financial services; high: health, energy, drinking water and sanitation
Market orientation: mixed (subsistence and commercial), commercial / market

Implementation activities, inputs and costs

Establishment activities

1. Selective cutting of woodland

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	100	100
TOTAL	**100**	**100**

Maintenance/recurrent activities

1. Selective cutting of woodland every 20 years
2. Shifting animals in closed woodland areas

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	75	100
TOTAL	**75**	**100**

Remarks:
Labour costs are the most important determining factor affecting the costs. The local wage rate is 100 US$/day.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
++ reduced risk of production failure + increased farm income	++ increased labour constraints

Socio-cultural benefits	Socio-cultural disadvantages
++ improved conservation / erosion knowledge	

Ecological benefits	Ecological disadvantages
++ reduced hazard towards adverse events ++ improved soil cover ++ increased biomass above ground C ++ reduced soil loss	++ risk of overgrazing in the woodland if grazing is not well controlled

Off-site benefits	Off-site disadvantages
++ reduced damage on public / private infrastructure ++ reduced downstream flooding ++ reduced downstream siltation	

Contribution to human well-being/livelihoods

The technology can contribute to education of young farmers.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	slightly positive	positive
Maintenance/recurrent	positive	positive

It is very cheap to maintain the measure. In the surrounding areas, where land should be less degraded due to reduced grazing, more trees can be planted and allowed to grow in future.

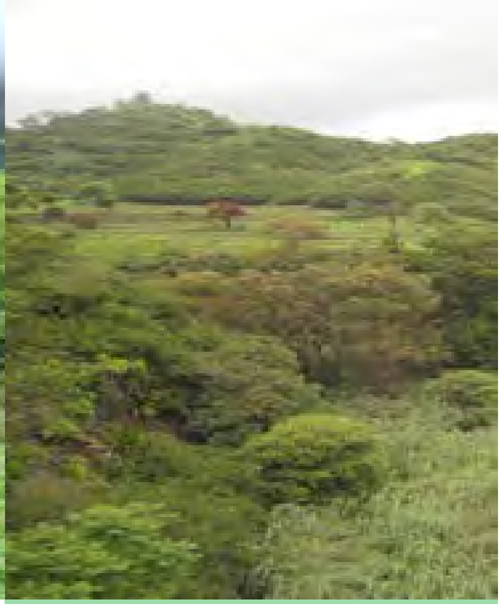
Acceptance/adoption:

50% of land user families have implemented the technology with external material support.
50% of land user families have implemented the technology voluntarily.
There is no trend towards any increase in spontaneous adoption of the technology.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Good impact with low cost → facilitate access to public forest land	Limited wooded areas are available for public access → creation of managed enclosures in order to increase natural reforestation or afforestation.
Good animal production → the general quality of the products of the grazing (milk, beef and cheese) is improved due to the availability of more grass and water in the driest periods of the year.	Rights of access to public lands and forest management rules → the regional legislative process should define better the management of the access of farmers to public lands and in general the whole controlled grazing process.
	Risk of overgrazing of the woodland area, if the area is not well controlled → ensure control mechanisms

Key reference(s): Official Bulletin of the Basilicata region (Italy): N. 29 – 29/04/2002; N. 22 – 16/06/2008.
Cocca C. & Campanile G. (2005). Pascolo in bosco solo se controllato. Agrifoglio, N. 7, pages 20-21.
Contact person(s): Lorenzo Borselli, Instituto de Geologia / Fac. De Ingegneria, Universitad Autonoma de San Luis Potosì (UASLP), Mexico. borselli@gmail.com



Above left: Forest area in the mountains with several species: *Eucalyptus spp*., *Dichrostachys cinerea* and *Lantana camara* on steep slopes. (Photo: Jacques Tavares)
Above right: Summit area invaded by *Dichrostachys cinerea* and *Lantana camara* towards the bottom. In the middle and foot slope areas there is an association of rainfed agriculture with fruit trees (mangoes) on land protected with stone terraces. (Photo: Jacques Tavares).

Afforestation

Cape Verde - *Arborização / floresta (Portuguese)*

Afforestation is one of the key technologies to address the fragility of ecosystems: it provides better protection against erosion and makes better use of rainfall in order to maintain the sustainability of agricultural systems.

Mountain forest areas are considered protective due to their role in regulating water (infiltration of storm water, regulation of surface runoff, and groundwater recharge) within the watershed. The main species used are *Prosopis juliflora, Parkinsonia aculeata, Jatropha curcas, Atriplex spp, Acacia holosericea, Acacia victoriae*, Lantana camara and others, in arid areas and *Eucalyptus camaldulensis, Grevillea robusta, Pinus and Cupressus ssp.* in highland and humid areas.

The climatic conditions are characterized by high spatial and temporal variability of the rainfall. The rains are concentrated in two or three months (August and September or October); the highlands and the N-NE parts are wetter compared to the low lands or coastal areas, which are very dry. The average annual rainfall is about 225 mm over the whole island; it has declined since the 1960s, with negative effects on farming conditions, and water supply. However, in areas located more than 500 m above sea level and exposed to trade winds, rainfall can exceed 700 mm. About 20% of the precipitation is lost through runoff, 13% infiltrates the soil and recharges aquifers and 67% evaporates. The evaporation loss is a limiting factor for any agriculture or forestry. Therefore, it is necessary to adapt the afforestation implementation to the specific local conditions (slope, stone cover, climate, etc). To overcome and minimize the problem of water scarcity, several measures are applied: (a) *caldeira* or half-moon structures achieved with earth or stone; (b) contour furrows or level bench terraces with stone walls arranged along the contour; (c). small dams to protect gullies. The aim is to maximize retention of water and control surface runoff. This not only allows better infiltration of water for the tree plantations, but also protects against soil erosion and facilitates groundwater recharge.

The success of the reforestation may be indicated not only by the area covered but also by the number of introduced plants. In 1975, there were about 3,000 ha of afforested land. By 2011, there are over 90,000 ha of afforested land with almost 50 million trees. Afforestation has focused mainly on the island of Santiago and Santo Antão, (13% of the total area reforested). Nowadays, more than 20% of the country is afforested. The forest has had a great importance in the context of combating desertification, rehabilitation of vegetation cover, in meeting energy needs and forage production and in developing agrosilvopastoral systems, as well as having undoubtedly contributed to a significant modification of the landscape in Cape Verde. The afforestation activities also contributed to increase biodiversity of some species of birds, including “Galinha di mato” (*Numida meleagris*), “Codorniz” (*Coturnix coturnix*), “Passarinha” (*Halcyon leucocephala*) and others.

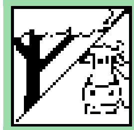
The forest species are mainly used for land protection and for production of fuel wood and coal. Because of the poor growing conditions, the forest species are not well suited to the construction industry or wood processing.

Location: Ribeira Seca
Region: Santiago Island / Cape Verde
Technology area: 71.5 km^2
Conservation measure: vegetative
Stage of intervention: rehabilitation of land degradation
Origin: developed externally / introduced through project, 10-50 years ago
Land use: forest land and mixed
Climate: arid, tropical
WOCAT database reference QT CPV03 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/ribeira-seca-cape-verde
Related approach: Training, information and awareness-raising (QA CPV01)
Compiled by Jacques Tavares, INIDA, Cape Verde
Date: 4th Mar 2009, updated 10th October 2011

Classification

Land use problems: Soil erosion by runoff, low productive soils, low organic matter, low soil cover, fertility and depth particularly in the agro-systems with rainfed agriculture.

Land use

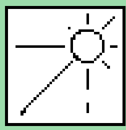


silvo-pastoralism (in arid and semi-arid areas),

agro forestry (in semi-arid and sub humid areas).

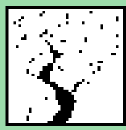
forestry (in highlands)

Climate

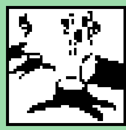


semi-arid, tropical

Degradation



biological degradation: loss of habitat, reduction of vegetation cover



soil erosion by water: gully erosion, gullying, loss of topsoil, surface erosion

Conservation measure

vegetative: tree and shrub cover

Stage of intervention

- Prevention
- Mitigation / Reduction
- Rehabilitation

Origin

- Land user's initiative
- Experiments / research
- Externally introduced: 10-50 years ago

Level of technical knowledge

- Agricultural advisor
- Land user

Main causes of land degradation:
Direct causes - human induced: soil management, crop management (annual, perennial, tree/shrub)
Indirect causes: poverty / wealth, education, access to knowledge and support services

Main technical functions:
- improvement of soil cover
- control of raindrop splash
- stabilisation of soil (e.g. by tree roots against landslides)
- increase of infiltration
- increase of groundwater level, recharge of groundwater

Secondary technical functions:
- increase in organic matter
- increase / maintain water stored in soil
- reduction in wind speed

Environment

Natural Environment

Average annual rainfall (mm)

- > 4000
- 3000-4000
- 2000-3000
- 1500-2000
- 1000-1500
- 750-1000
- 500-750
- 250-500
- < 250

Altitude (m a.s.l.)

- > 4000
- 3000-4000
- 2500-3000
- 2000-2500
- 1500-2000
- 1000-1500
- 500-1000
- 100-500
- <100

Landform

- plateau / plains
- ridges
- mountain slopes
- hill slopes
- footslopes
- valley floors

Slope (%)

- flat
- gentle
- moderate
- rolling
- hilly
- steep
- very steep

Soil depth (cm)

- 0-20
- 20-50
- 50-80
- 80-120
- >120

Growing season(s): 90 days (Aug – Oct)
Soil texture: medium (loam)
Soil fertility: medium
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: good

Soil water storage capacity: low to medium
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: poor drinking water
Biodiversity: medium

Tolerant of climatic extremes: temperature increase, seasonal rainfall decrease, decreasing length of growing period
Sensitive to climatic extremes: wind storms / dust storms, droughts / dry spells
If sensitive, what modifications were made / are possible: Tree species more tolerant of the climatic factors can be used, whilst retaining all the benefits that the existing species provide

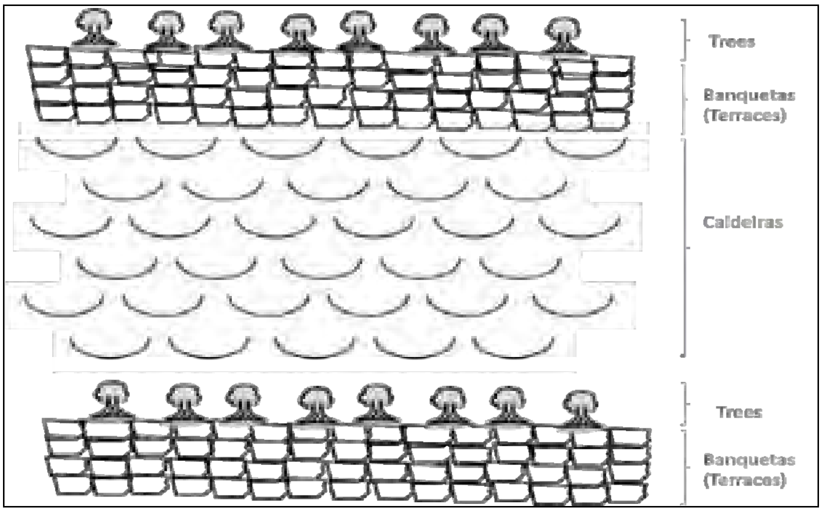
Human Environment

Mixed land per household (ha)

	<0.5
	0.5-1
	1-2
	2-5
	5-15
	15-50
	50-100
	100-500
	500-1,000
	1,000-10,000
	>10,000

Land user: employee (company, government), large scale land users
Population density: 100-200 persons/km^2
Annual population growth: > 4%
Land ownership: individual, state
Land use rights: individual, communal (organised),
Water use rights: communal (organised)
Relative level of wealth poor, which represents 75 % of land users (rainfed agriculture). 1% of the total area is owned by poor land users

Importance of off-farm income: less than 10% of all income: forest production (mainly grass and wood) generate an annual income of approximately $2,500
Access to service and infrastructure: low: employment (e.g. off-farm), market, drinking water and sanitation, financial services; moderate: education, technical assistance, energy, roads & transport
Market orientation: Mixed (subsistence and commercial). Forest products are quite limited: lumber, firewood, charcoal and fodder from the pods. Firewood is the most important product but marketing is quite limited in time and space.



Technical drawing

Treatment of slope before afforestation
(Author: Jacques Tavares)

Implementation activities, inputs and costs

Establishment activities

1. Quantification of the area to be afforested
2. Production of plants in nursery (500 - 1300 plants)
3. Treatment of area (slope) with:
3.1 Building terraces (15 m / person / day) or
3.2 Making half-moons "*Caldeiras*" (3 / person / day)
4. Excavating the pits (10 / person / day): 60x60x60 cm
5. Planting (50 /person / day): 5 to 5 metres
6. Initial maintenance (8 /persons / day)

Materials: To set out the terraces along the contour requires the following materials:
1. Measuring tape
2. 30 cm wooden stakes
3. Flags
4. Spirit level
5. Square timber beams

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	28,218	0
Equipment & material - tools - wood	410	10
Agricultural -seeds	942	0
TOTAL	**29570**	**0.1**

Maintenance/recurrent activities

1. forest cleaning

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	142	52
TOTAL	**142**	**52**

Remarks:
The labour affects the costs more than other factors. Paid labour is a way to achieve additional income for many people in this area. The employer (Directorate General of Agriculture, Sylviculture and Livestock of the Ministry of Rural Development) provides 90% of the cost of the equipment. The lifetime of the equipment is 10-15 years. Costs are estimated according to the time required for afforestation and the entity contracted for the implementation of the activities.

Assessment

Impacts of the Technology

Production and socio-economic benefits

+++ increased fodder production
++ increased fodder quality
++ increased drinking water availability / quality
++ increased irrigation water availability / quality

Production and socio-economic disadvantages

+++ increased expenses on agricultural inputs
+++ increased economic inequity

Socio-cultural benefits

++ improved cultural opportunities
+ improved situation of disadvantaged groups

Socio-cultural disadvantages

+ socio-cultural conflicts

Ecological benefits

++ reduced evaporation
++ increased soil moisture
++ recharge of groundwater / table aquifer
++ reduced wind velocity
++ improved soil cover
++ increased soil organic matter / below ground C
++ reduced emission of carbon and greenhouse gases
++ reduced soil loss

Ecological disadvantages

++ increased competition
++ increase of invasive species

Off-site benefits

++ increased water availability
++ reduced downstream siltation
++ reduced wind transported sediments
++ reduced downstream flooding

Off-site disadvantages

++ Increased damage to neighbours' fields: The forest areas provide genuine refuges for *Numida meleagris* (*Helmeted Guineafowl*) and monkeys. We have observed in some fields (in every bioclimatic zone) a decrease in corn yield due to damage generated by guineafowl after sowing, because they open the pits and consuming the seeds before germination. The monkeys also attack the fields and cause serious damage in the mountainous areas

Contribution to human well-being/livelihoods

++ it improves air quality, promotes the production of endemic species and its use as medicine

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	positive
Maintenance/recurrent	neutral / balanced	very positive

The high costs are associated with its implementation; afterwards they are significantly reduced and the technology builds up the benefits

Acceptance/adoption: Only the state has implemented this technology, because it changes the use of land and, without any subsidies, other land users are not encouraged to agree to it. There is a moderate (growing) trend towards spontaneous adoption of the technology, as there is a continuing campaign of afforestation of state land. There are voluntary associations working in this technology for a better environment.

Concluding statements

Strengths and → how to sustain/improve

Increases the quality of the landscape and reduces the loss of soil by runoff. → increasing the tree cover in areas with low coverage

Encourages the production of livestock, and fuel wood → integrate the community in managing the forest, and manage it in a sustainable way.

Production of firewood and grass → make more forest operations such as pruning or cutting of new seedlings

Protection of soil → strengthen maintenance operations

Weaknesses → and how to overcome

Reduces the percentage of land for agricultural production → increase productivity in cultivated land and reduce the need for the use of forest land, and implement new production technologies such as greenhouses

Impossibility of farming in the forest land → off-farm income creation to compensate

Lack of involvement of farmers in the management of forest areas → capacity building of land users in forest management strategies, elaboration of contracts between State and land users for the management of forest perimeters

Key reference(s): OCDE, CILSS, 1982. Análise do Sector Florestal e Propostas para Cabo Verde. Sahel D (82) 179 – Club do Sahel, pp 203.
MAAA/DGASP, 1996. Rapport de pays pour la Conférence Technique Internationale de la FAO sur les Ressources Phytogénétiques, Leipzig, 1996, pp 38.
Contact person(s): Jacques de Pina Tavares, Instituto Nacional de Investigação e Desenvolvimento Agrário (INIDA), Cape Verde (jacques.tavares@gmail.com)

Above left: Example of a 10 year old forest regenerated by assisted re-afforestation technology (Photo: Miloud Chaker)
Above right: Degraded cork oak forest lacking young trees and with a weak cover of unpalatable herbs (Photo: Abdellah Laouina)

Assisted cork oak regeneration

Morocco – *Takhlif Madoum Elghaba (arabic)*

Assisted cork oak regeneration in the Sehoul forest, by acorn seeding and seedling plantation (derived from a plant nursery), involving careful husbandry and protection from grazing

Because of the accelerated degradation of the Sehoul forest and the difficulties with natural regeneration, the Moroccan State has planned and adopted a policy, based on a global and integrated view. The preservation of forests is an important topic for socio-economic development. The National Plan for Reforestation defines the main lines of the national reforestation strategy and is the framework for the implementation of this technology. The goal of this technology is to prepare plots where acorns should be sown or cork oak seedlings from plant nurseries planted. These test plots are guarded, maintained and watered to allow young plants to grow. Thus, cork oak regeneration ensures the continued existence and development of the forest. It conserves soil and water and fights against desertification. There are several benefits such as cork production, wood production, fodder production and better soil cover. Furthermore this technology positively impacts the socio-economic development of local populations, and services production (landscape, welfare and recreation) for urban populations.

The implementation of this technology needs the following activities: in general, good quality acorns and seedlings are required. Seedlings should come from the same region where they are planted and be certified by the authorities. An initial step in implementation is the clearing and shredding of small, woody plants. Soil preparation consists of 30 cm deep ploughing to loosen the topsoil, and to allow easier root growth. Then rows of pits are dug. Generally, it is crucial to apply correct plantation and seedling according to the season (winter), to ensure a depth of 50 cm in the planting hole, and to water copiously after planting to ensure a good contact between the soil and roots. A fence installed to protect areas from grazing is temporarily required until the trees are robust enough to cope with browsing cattle. The enclosure period usually lasts a minimum of 6 years.

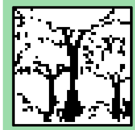
The natural condition is semi-arid with precipitation ranging from 350 to 450 mm per year. The underlying geology consists of quartzite and sandstone, covered by marl. Soils are varied, but the main types are hydromorph and ferrous. Socially, the Sehoul forest is populated by poor farmers, strongly dependent on forest resources (fodder and firewood). The forest is owned by the government, but managed by local communities, who benefit from its use (marketing of cork, pharmaceutical products, charcoal, etc.). The rights of free forest exploitation for the local population are a political problem which needs to be resolved in order to achieve good forest management. Economically, the contribution of forestry to the GDP is low, but its environmental role is essential.

Location: Sehoul
Region: Salé province
Technology area: 0.2 km^2
Conservation measure: vegetative
Stage of intervention: mitigation / reduction of land degradation
Origin: developed through experiments / research (>50 years ago)
Land use: forests / woodlands
Climate: semi-arid, subtropics
WOCAT database reference: QT MOR13e on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/sehoul-morocco
Related approach: Development of rainfed agriculture (QA MOR014e)
Compiled by: Miloud Chaker, Faculté des Lettres et Sciences Humaines, Rabat, Morocco
Date: 19th Aug 2008, updated 17th Aug 2011

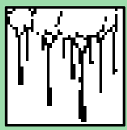
Classification

Land use problems: Overuse is leading to no regeneration and therefore forest ageing, loss of biodiversity and degradation processes, which can ultimately lead to desertification.

Land use

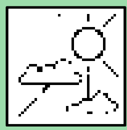


natural forest, and extensive grazing land (before)



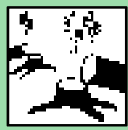
plantation forestry (after)

Climate



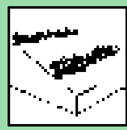
semi-arid, subtropics

Degradation



biological degradation: reduction of vegetation cover

Conservation measure



vegetative: tree and shrub cover

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative:
Experiments / research: > 50 years ago
Externally introduced

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - human induced: over-exploitation of vegetation for domestic use
Indirect causes: urban capital invested in excessive livestock, roads, unorganized tourism and leisure

Main technical functions:
- improvement of ground cover
- increase in organic matter
- increase of biomass (quantity)
- promotion of vegetation species and varieties (quality, eg palatable fodder)

Secondary technical functions:
- increase of surface roughness
- stabilization of soil
- increase of infiltration
- increase / maintain water stored in soil

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): n/a
Soil texture: coarse / light (sandy)
Soil fertility: low
Topsoil organic matter: high (>3%)
Soil drainage/infiltration: medium

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: good
Water quality: good drinking water
Biodiversity: low

Tolerant of climatic extremes: droughts / dry spells, temperature increase, seasonal rainfall decrease, heavy rainfall events,
Sensitive to climatic extremes: seasonal rainfall increase, due to a prevalent danger of water logging

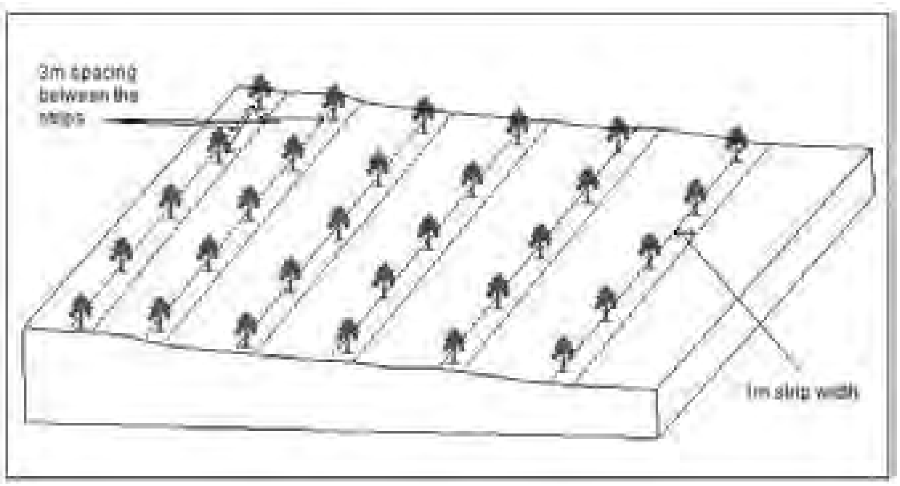
Human Environment

Forests / woodlands per household (ha)

☐	<0.5
■	0.5-1
☐	1-2
☐	2-5
☐	5-15
☐	15-50
☐	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: employee (company, government)
Population density: 10-50 persons/km^2
Annual population growth: < 0.5%
Land ownership: state
Land use rights: communal (organized) (In Morocco, forest belongs to the State but the population has the right to perform pastoral activities, to gather wood, to collect aromatic and medicinal plants, acorns, etc.)
Water use rights: open access (unorganized)
Relative level of wealth: average 80% of land users; 80% of the total land area is owned by average land users

Importance of off-farm income: less than 10% of all income:
Access to service and infrastructure: low: health, employment (e.g. off-farm), drinking water and sanitation; moderate: education, technical assistance, energy, roads & transport
Market orientation: commercial / market (producing and selling cork and related products)



Technical drawing

Contour planting in strips where *Cistus* has been removed (in order to allow more light and avoid competition for moisture) (Chaker Miloud)

Implementation activities, inputs and costs

Establishment activities

1. Soil preparation, weeding
2. Ploughing and digging planting pits
3. Planting and watering
4. Fencing
5. Reduction of density, replacement of weak / dead plants

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	435	0
Agricultural		
- seeds	208	0
- cultivation and weeding (2x)	125	0
TOTAL	**768**	**0**

Maintenance/recurrent activities

1. Weeding and ploughing
2. Watering (first two years)
3. Guarding

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	35	0
Agricultural		
- ploughing, weeding, and watering	125	0 0
TOTAL	**160**	**0**

Remarks:
If planting coincides with a dry season, it takes watering on several occasions, which makes applying the technology more expensive - Stronger fences and more supervising are required if near to habitation. The local wage rate is 5 US$/day.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ increased fodder production + increased animal production + increased wood production	++ reduction of forest pastoral area

Socio-cultural benefits	Socio-cultural disadvantages
++ conflict resolution and reduction (long term) ++ improved conservation / erosion knowledge + community institution strengthening + national institution strengthening + improved health (human recreation)	++ socio-cultural conflicts (short term due to area enclosure)

Ecological benefits	Ecological disadvantages
+++ increased soil moisture +++ reduced surface runoff +++ reduced soil loss ++ increased biomass / above ground C ++ increased animal and vegetation diversity ++ increased soil organic matter / below ground C ++ reduced soil crusting / sealing + recharge of groundwater table / aquifer	

Off-site benefits	Off-site disadvantages
+ reduced damage on neighbours fields (less floods and soil loss) + reduced wind transported sediments + reduced downstream siltation + reduced downstream flooding	+ Increased grazing pressure on neighbouring areas

Contribution to human well-being/livelihoods

+ In the long term. It is too early to assess the technology impacts on the livelihood.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	positive
Maintenance/recurrent	negative	positive

Acceptance/adoption:

Demonstration plot implemented by the government, but not applied by the local communities yet.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Natural resources conservation and fight against desertification →Involve local population in the forest management	Problems because of the high cost of this technology (about 8000 dh/ha, 768 US$) → Costs can be reduced if population commit to respect the converted plots, even without fences and guards.
Cork oak regeneration in order to ensure the existence of cork oak forests → Review the forest exploitation modalities by local populations (beneficiaries)	Forest users ask for subsidies in case of resting processes → Define the beneficiaries for the forest exploitation and its rules, its calendar and its rest areas by founding associations and unions
Improve silvo-pastoral activities → Participative management for the population	For land users, the forest potential by pastoral activities needs to be improved by seeding of palatable species → farmers must be included in the choice of implemented species
Cork production enhancement → Improve cork extraction, timing and marketing techniques	
Improved fodder production in the long term→ provide compensation for enclosure time	

Key reference: Project PMVB 2001, Ministère d'agriculture de Maroc

Contact person: Miloud Chaker, Université Mohamed V, Départment de Géographie, Rabat, Morocco, chaker.m@gmail.com


Above left: Reduction of the density of trees and vegetation removal using machinery. (Photo: João Soares)
Above right: Primary strip network system for fuel management. (Photo: João Soares)

Primary strip network system for fuel management

Portugal - *Rede Primária de Faixas de Gestão de Combustível (RPFGC)(Portuguese)*

Linear strips are strategically located in areas where total or partial removal of the forest biomass is possible. This technology contributes towards preventing the occurrence and spread of large forest fires and reducing their consequences for the environment, people, infrastructures, etc.

There are three types of strip for fuel management in forest areas: primary, secondary and tertiary, defined by the Law 17/2009. The most important differences between them are in terms of size (primary being the widest and the tertiary the narrowest) and scale (primary referring to the district level, secondary to the municipal level and tertiary to the parish level). The primary strip network system for fuel management (RPFGC) is integrated in the National System to Prevent and Protect Forest against Fires and it is defined by the National Forest Authority (AFN).

The RPFGC aims to re-arrange landscape elements, through the establishment of discontinuities in the vegetation cover, in forest areas and in the rural landscape (for example using water bodies, agricultural land, pasture, rocky outcrops, shrubland and valuable forest stands). Land tenure is private in most of the areas covered by the RPFGC. The main objectives of this technology are: to decrease the area affected by large fires; to enable direct access by fire fighters; to reduce fire effects and protect roads, infrastructures and social equipment, urban areas and forest areas of special value; and to isolate potential fire ignition sources.

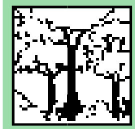
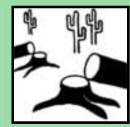
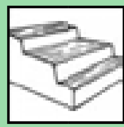
These primary strips are ≥ 125 metres wide and preferably between 500 and 10,000 ha in area. The tree cover should be less than 50% of the area and the base of the tree canopy should not be lower than 3 metres. The RPFGC concept should include the adoption of a maintenance programme. The implementation and maintenance operations can be performed through different agro-forest technologies, such as clearance of bushes and trees, pruning, prescribed fire, harrowing and cultivation of the ground beneath the trees. Timber products can be sold and the removed litter can be used in a biomass power plant or applied to the fields to improve soil fertility, using mulching technology.

This SWC Technology needs considerable financial resources in terms of labour and equipment at the implementation phase. Costs, however, undergo considerable reduction thereafter. The implementation of this infrastructure to prevent and protect the land from forest fire is entirely funded by the government and implemented by the forest municipal services.

Location: Portugal
Region: Mação, Portugal
Technology area: 400 km^2 (strips will occupy 17,52 km^2)
Conservation measure: structural
Stage of intervention: prevention of land degradation
Origin: Externally - recent (<10 years ago)
Land use: forests / woodlands, mixed
Climate: subhumid, temperate
WOCAT database reference: QT POR01 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/macao-portugal
Related approach: Forest Intervention Area (QA POR01)
Compiled by: Celeste Coelho, João Soares and Sandra Valente, University of Aveiro, Portugal
Date: February 2009, updated September 2011

Classification

Land use problems: Forest fires increase due to rural depopulation and to land management abandonment.

Land use		Climate	Degradation	Conservation measure
				
natural forests	agroforestry	subhumid, temperate	biological degradation: detrimental effects of fires	structural: others (strips)

Stage of intervention

- ■ Prevention
- □ Mitigation / Reduction
- □ Rehabilitation

Origin

- □ Land user's initiative
- □ Experiments / research
- ■ Externally introduced: < 10 years ago

Level of technical knowledge

- ■ Agricultural advisor
- □ Land user

Main causes of land degradation:
Direct causes - Human induced: deforestation / removal of natural vegetation (incl. forest fires)
Indirect causes: Property size

Main technical functions:
- control of fires

Secondary technical functions:
- reduction of dry material (fuel for wildfires)

Environment

Natural Environment

Average annual rainfall (mm)

- □ > 4000
- □ 3000-4000
- □ 2000-3000
- □ 1500-2000
- □ 1000-1500
- ■ 750-1000
- □ 500-750
- □ 250-500
- □ < 250

Altitude (m a.s.l.)

- □ > 4000
- □ 3000-4000
- □ 2500-3000
- □ 2000-2500
- □ 1500-2000
- □ 1000-1500
- ▒ 500-1000
- ■ 100-500
- □ <100

Landform

- □ plateau / plains
- □ ridges
- □ mountain slopes
- ■ hill slopes
- □ footslopes
- ▒ valley floors

Slope (%)

- □ flat
- □ gentle
- □ moderate
- □ rolling
- ■ hilly
- □ steep
- □ very steep

Soil depth (cm)

- ■ 0-20
- □ 20-50
- □ 50-80
- □ 80-120
- □ >120

Growing season(s): 1 per year
Soil texture: medium (loam)
Soil fertility: low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: poor (e.g. sealing /crusting)

Soil water storage capacity: low
Ground water table: 5 - 50 m
Availability of surface water: medium
Water quality: good drinking water
Biodiversity: medium

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase, seasonal rainfall decrease, decreasing length of growing period
Sensitive to climatic extremes: heavy rainfall events (intensities and amount), wind storms, floods, droughts / dry spells

Human Environment

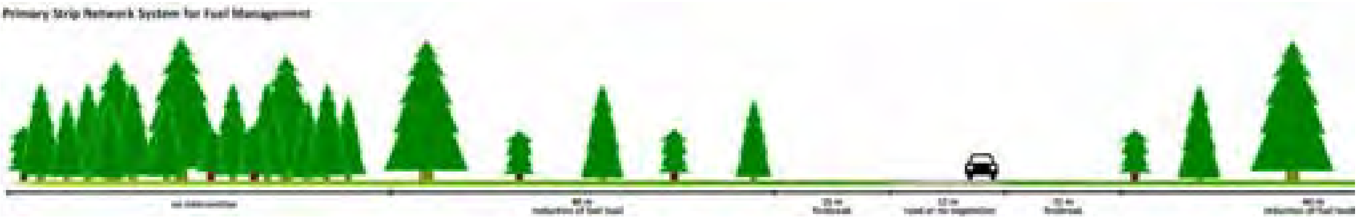
Mixed land per household (ha)

- [x] <0.5
- [ ] 0.5-1
- [ ] 1-2
- [ ] 2-5
- [ ] 5-15
- [ ] 15-50
- [ ] 50-100
- [ ] 100-500
- [ ] 500-1,000
- [ ] 1,000-10,000
- [ ] >10,000

Land user: implemented by government official on private land of small-scale forest owners
Population density: 10-50 persons/km^2
Annual population growth: negative
Land ownership: individual, not titled
Land use rights: individual
Water use rights: open access (unorganised) (Individual, not titled)
Relative level of wealth: mainly average (50% of land users), some poor (50% of land users)

Importance of off-farm income: > 50% of all income
Access to service and infrastructure: low: employment; moderate: education, technical assistance, telecommunications; high: health, market, energy, roads & transport, drinking water and sanitation, financial services
Market orientation: mixed (subsistence and commercial)

Technical drawing
This technical drawing indicates the technical specifications, dimensions and spacing for the Primary Strip Network System for Fuel Management (J. Soares). The figure shows a road as the axis of the RPFGC, but it can also be a river or a ridge, amongst other breaks in the forest cover.



Implementation activities, inputs and costs

Establishment activities

1. Primary system design
2. Shrubs cleaning + Thinning (reduction of fuel load) + Pruning
3. Removing the cut waste material
4. Litter Shredding
5. Transport to the Biomass Plant

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	1076	0
Equipment		
- machine use	568	0
- transport	100	0
TOTAL	**1744**	**0**

Maintenance/recurrent activities

1. *Not known yet*

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour		
TOTAL		

Remarks:
The costs include the activities to ensure the vertical and horizontal discontinuity of the fuel load and also the activities needed to manage the waste produced from the shrubs cleaning and thinning. The costs calculation was made for the implementation of the first section of the RPFGC. The implementation phase lasted for 2 or 3 months during the dry season. This section included 28 ha and 4 teams of forest sappers were involved. The local wage rate is 19 US$/day.

Assessment

Impacts of the Technology

Production and socio-economic benefits

+++ reduced risk towards adverse events (droughts, floods and storms)
++ increased fodder production
++ increased fodder quality
++ increased animal production
+ increased energy production: biomass

Production and socio-economic disadvantages

++ costs of implementation
+ reduced wood production
+ increased maintenance costs

Socio-cultural benefits

++ community institution strengthening
+ national institution strengthening
+ improved cultural opportunities
+ improved SWC/ erosion knowledge

Socio-cultural disadvantages

+ socio cultural conflicts (due to affected private land)

Ecological benefits

+++ reduced hazard towards adverse events
+++ reduced fire risk
+ improved soil cover (outside strips)

Ecological disadvantages

++ decreased soil cover (in strips)
+ increased surface water runoff
+ decreased soil organic matter
+ increased soil erosion locally
+ increased habitat fragmentation

Off-site benefits

+++ reduced damage on public / private infrastructure
++ reduced damage on neighbours fields

Off-site disadvantages

Contribution to human well-being/livelihoods

+ reduced risk of wildfire

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	neutral / balanced	positive
Maintenance/recurrent	neutral / balanced	positive

The maintenance will only start 2 or 3 years after the technology implementation, so no returns are expected at short-term.

Acceptance/adoption: A positive trend towards spontaneous adoption of the technology is expected. After the implementation period there was a high local acceptance of the technology. It is also expected that grazing activities contribute to the technology maintenance

Concluding statements

Strengths and → how to sustain/improve

Fuel load reduction → This will be achieved using prescribed fire and specialised machinery. The efficacy of prescribed fire depends on the collaboration of technicians and forest sapper teams. To guarantee the effectiveness of RPFGC implementation, long-term maintenance has to be ensured.

Reinforcement of the forest path system → Clearing the strips of the RPFGC can enhance the forest track network.

Forest fire prevention and fighting → The know-how of the local stakeholders and communities will contribute to the design of the RPFGC . This information should be integrated into the Municipal Plans to Prevent and Protect Forest Against Fires (PMDFCI). Any further information should be provided to the Civil Protection Agencies and to the Forest Technical Office and also to the local fire-brigade team.

Increase in landscape resilience → This will only be effective if the RPFGC is continuous and without gaps. The acceptance of the RPFGC by the landowners is fundamental to widespread the use of this technology. Information and awareness about the need to change vegetation cover is also very important, in order to avoid extensive areas of monoculture.

Weaknesses and → how to overcome

Soil erosion increase → Forestry good practices should be used in the RPFGC implementation, especially concerning the use of machinery and avoiding disturbance of soil at depth. Soil cover after the removal of the existing vegetation should be promoted (by seeding, mulching or creating a low intensity pasture).

Soil cover reduction → Soil cover after the removal of the existing vegetation should be promoted (by seeding, mulching or creating a low intensity pasture).

Runoff increase → Soil cover after the removal of the existing vegetation should be promoted (by seeding, mulching or creating a low intensity pasture). Excessive vegetation removal should be avoid, especially near water courses where the removal should be nil or minimum.

Budget for implementation and maintenance → European and national funds. Collaboration of the local government providing equipment and labour force. Information and awareness to the landowners about the importance of this technology. Campaigns of national awareness and definition of this technology as 'public use' to overcome some potential social conflicts concerning the land rights.

Key reference(s): Decree-Law n. 124/2006, 28 June. Official Gazette n. 123 – I series: 4586-4599; Decree-Law n. 17/2009, 14 January. Official Gazette n. 9 – I series: 273-295.

Contact person(s): Coelho Celeste, Soares João and Valente Sandra, Department of Enviornment and Planning, Centre for Environmental and Marine Studies, University of Aveiro, 3810 - 193 Aveiro, Portugal. coelho@ua.pt, Sandra.valente@ua.pt

Above left: fire fighter monitoring the spread of a prescribed fire (Photo: Hans de Herder)
Above right: a fire torch being prepared in order to start a prescribed fire (Photo: Hans de Herder)

Prescribed fire

Portugal - *Fogo Controlado (Portuguese)*

Use of prescribed fire (or 'controlled burn') to reduce the fuel load in the form of live and dead plant material and thus to prevent the likelihood of more damaging wildfire.

This technique is an essential management tool that applies fire to control the quantity of forest or scrubland fuels. The type of fire depends on the specific goals and on the weather conditions. Firstly, it is important to consider slope angle and the kind of fuels to be burned. Weather conditions include temperature, wind direction and air humidity. Another important aspect is the ability to control the speed of flame spread. In order to carry out the controlled fire, a plan has to be drawn up and approved and a fully-trained, authorised technician must be present in addition to the appropriate support teams (fire fighters, forest management teams). These teams use water or other means of combating the fire in the event of it possibly getting out of control and are in charge of the burning process.

The main purposes are enhancement of grazing areas and the creation of the so-called primary network for wildfire defence, which is a national network to limit the spread of wildfire. It involves strategically burning key sites (e.g. mountain ridges) to restrict the spread of the wildfire.

An analysis of weather conditions is made prior to carry out the prescribed fire. On the day of the prescribed fire itself, safety checks are made and the specific tasks of all the team members are defined. Wind direction and strength need to be minimal and are strictly controlled during burning. The size of the team depends on the specific problems of the area to be treated. Team size needed for about 10 ha is around 10 persons. The team members start along a line working from the top on the mountain along the contour and move downwards. Gentle breeze should be against the direction of the spreading of the fire. Workers use a drip-feed fuel can. There is also a strategy for prescribed fires by burning a strip along ridges of the mountains to avoid spreading of accidental wildfires and to burn in catchments the lowest point from which fire can spread to different areas and spread in different directions on the slopes.

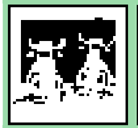
Improved grazing management might also reduce the fuel load. Abandoning grazing in the forest can increase the fuel load and aggravate the occurrence and impact of wildfires. The creation or maintenance of grazing areas is determined by the size of the herd. Prescribed fire used as a means of improving grazing enables the local population needs to be addressed while considering environmental concerns. The prescribed fire also helps to protect the local population and their property by reducing the likelihood of devastating wildfire.

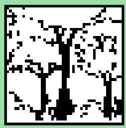
Location: Castanheira de Pêra
Region: Leiria
Technology area: 0.57 km^2
Conservation measure: management
Stage of intervention: mitigation / reduction of land degradation
Origin: Land user - traditional (>50 years ago)
Land use: forests / woodlands, grazing land
Climate: subhumid, temperate
WOCAT database reference: QT POR02 on cdewocat.unibe.ch/wocatQT
DESIRE site information: http://www.desire-his.eu/en/gois-portugal
Related approach: Forest Intervention Area (QA POR01)
Compiled by: Manuela Carreiras (IPC-ESAC), António Dinis Ferreira (IPC-ESAC) and Pedro Palheiro (Forestry Engineer)
Date: 9th Feb 2009, updated 13th Oct 2011

Classification

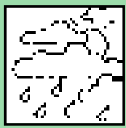
Land use problems: The problem is linked to the loss of traditional natural pasture use. Since there is nowadays no grazing/pasture use of forests, the fuel load remains uncontrolled. It is also linked to minimising wildfire impacts and the creation of grazing land. As more people visit forest areas for leisure and accidentally set fire. Another problem is vandalism and arson.

Land use

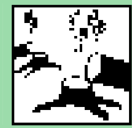

intensive grazing (fodder production)


natural forest

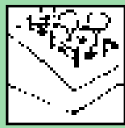
Climate


subhumid, temperate

Degradation


biological degradation: detrimental effects of fires on forest, bush, grazing and cropland (burning of residues)

Conservation measure


management: control / change of species composition

Stage of intervention

	Prevention
■	Mitigation / Reduction
	Rehabilitation

Origin

■	Land user's initiative: >50 years ago
▒	Experiments / research
	Externally introduced

Level of technical knowledge

■	Agricultural advisor
	Land user
▒	Fire men

Main causes of land degradation:
Direct causes - Human induced: deforestation / removal of natural vegetation (incl. forest fires)
Direct causes - Natural: other natural causes, (wildfire with consequences on floods with nutrients erosion)
Indirect causes: population pressure (resulting of land abandon)

Main technical functions:
- control of fires
- reduction of dry material (fuel for wildfires)
- spatial arrangement and diversification of land use (creating barriers in the landscape for fires to spread.)

Secondary technical functions:
- control of dispersed runoff: impede/retard
- increase of infiltration

Environment

Natural Environment

Average annual rainfall (mm)

	> 4000
	3000-4000
	2000-3000
■	1500-2000
	1000-1500
	750-1000
	500-750
	250-500
	< 250

Altitude (m a.s.l.)

	> 4000
	3000-4000
	2500-3000
	2000-2500
	1500-2000
	1000-1500
■	500-1000
	100-500
	<100

Landform

	plateau / plains
	ridges
■	mountain slopes
	hill slopes
	footslopes
	valley floors

Slope (%)

	flat
	gentle
	moderate
	rolling
■	hilly
▒	steep
	very steep

Soil depth (cm)

■	0-20
	20-50
	50-80
	80-120
	>120

Growing season(s): 240 days
Soil texture: coarse / light (sandy), medium (loam)
Soil fertility: low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: medium

Soil water storage capacity: low
Ground water table: >50 m
Availability of surface water: poor / none
Water quality: good drinking water
Biodiversity: medium

Tolerant of climatic extremes: Not permitted during prolonged dry periods
Sensitive to climatic extremes: Weather conditions (wind direction and velocity, temperature and air humidity)
If sensitive, what modifications were made / are possible: As a result of the characteristics of the technique, it is not possible to make modifications except to select the right weather conditions and the fuel load.

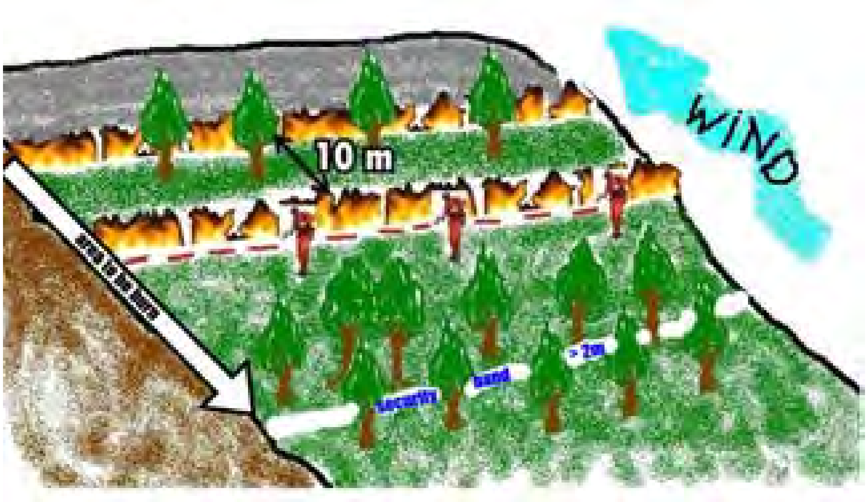
Human Environment

Cropland per household (ha)

☐	<0.5
☐	0.5-1
☐	1-2
■	2-5
☐	5-15
☐	15-50
☐	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: employee (company, government)
Population density: < 10 persons/km^2
Annual population growth: negative
Land ownership: communal / village
Land use rights: communal (organised)
Water use rights: open access
Relative level of wealth: poor, which represents 75% of land users; 50% of the total land area is owned by poor land users

Importance of off-farm income: none
Access to service and infrastructure: low: health, education, technical assistance, employment, market, roads & transport, financial services; moderate: energy, drinking water and sanitation
Market orientation: mixed (subsistence and commercial),for example, mechanised agroforestry



Technical drawing
Prescribed fire is a practice used to manage vegetation in wildfire-prone areas. It consists of slowly burning strategic areas in the wet season, under specific weather and ground conditions and procedures: the soil should be moist, burning typically carried out in thin strips (normally 10m distance between two fire lines) from the top to the bottom of the slope, there should be only a gentle breeze blowing upslope and the ignition points should be 2m apart along the contour. The fire is allowed to progress downslope against the wind, which therefore provides some control. Burning is achieved by a number of the team who are prepared to dowse the flames if the fire gets out of hand. This degree of control is only possible when burning small areas with the same slope angle.

Implementation activities, inputs and costs

Establishment activities

1. Planning and implementation
2. Fire control equipment
3. Monitoring prescribed fire

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	100	0
Equipment - machine use	100	0
TOTAL	**200**	**0**

Maintenance/recurrent activities

1. No maintenance is necessary. Every 3 to 5 years, prescribed fire is carried out again, repeating the process described above.

Maintenance/recurrent inputs and costs per ha per year

Remarks:
Prescribed fire costs: timing, the right number in the team, fuel type and specific local conditions (slope and vegetation) are the most important determining factors affecting the costs.
Calculation of costs has been made based on the prescribed fire conducted for the DESIRE project. They represent the costs to burn 3-4ha, during a morning and including human resources (12 people), equipment (fire torch, fuel, special fire protection clothing, scythes, and hoses) and specialized fire fighting vehicles.

Assessment

Impacts of the Technology

Production and socio-economic benefits

+++ increased fodder production
+++ increased fodder quality (now natural fodder)
+++ reduced risk of production failure
+++ avoid extreme/catastrophic events of hot fires

Production and socio-economic disadvantages

Socio-cultural benefits

+++ community institution strengthening
\+ national institution strengthening
\+ improved food security / self sufficiency

Socio-cultural disadvantages

Ecological benefits

+++ reduced invasive alien species
+++ reduced wild fire risk
+++ increased / maintained habitat diversity
\+ increased biological pest disease control

Ecological disadvantages

\+ decreased soil moisture
\+ decreased soil cover

Off-site benefits

+++ reduced downstream flooding
+++ improved buffering / filtering capacity
++ reduced wind transported sediments
++ reduced downstream siltation
\+ increased stream flow in dry season

Off-site disadvantages

\+ risk of damage to life and property

Contribution to human well-being/livelihoods

++ Livelihoods are directly affected where prescribed fire is carried out to improve grazing. Where carried out to prevent the occurrence of wildfire, the contribution is indirect.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	very positive	very positive
Maintenance/recurrent	not specified	not specified

The major benefit it is to prevent wildfires by reducing fuel quantities. A second benefit it is the improvement in grazing in years after the burn.

Acceptance/adoption:

There is a strong trend towards (growing) spontaneous adoption of the technology. In vulnerable areas, there is a need for reduction of the fuel load, removal of the vegetative cover or promotion of new plant growth.

Concluding statements

Strengths and → how to sustain/improve

The vegetation is adapted to the fire – impact minimisation. → more use of controlled fires.

With prescribed burning, larger areas can be treated compared to other fire control techniques, limited to strips in strategic areas, which are so difficult and expensive, whereas with prescribed burning, there is effective control of the vegetation over a large area". → continue the use of controlled burning.

Difficult operating conditions and high costs make the technology unsuitable for certain areas → continued use of the controlled fire technique instead of other techniques.

Weaknesses and → how to overcome

Air pollution → ensure that the wind direction does not carry smoke over settlements. However, it is not possible to eliminate the smoke problem. In particular, a certain degree of moisture is required in the fuel load to enable the fire to be controlled, in order that the burning temperature is low and this tends to produce smoke.

Lack of knowledge of people living near the burnt areas → improved education via schools, community meetings and in pamphlets.

Possibility of loss of control of the prescribed fire → care needed to prevent this happening.

Safety of the personnel carrying out the burning → conduct risk assessment exercises, carry out detailed planning and only apply the technology under the right weather conditions

Key reference(s): Fernandes, P., Botelho, H., Loureiro, C. 2002. Manual de formação para a técnica do fogo controlado. CNEFF, UTAD, Maio de 2002

Contact person(s): Carreiras Manuela & Ferreira António Dinis, CERNAS, IPC/ESAC, Bencanta, 3040-316 Coimbra, Portugal, mcarreiras@esac.pt, aferreira@esac.pt

Above left: The photo shows the gas collection tank resting on the concrete-built digester. Pipes/tubes at the top of the gas tank supply the house with methane gas. (Photo: R.J. Sebego)
Above right: This photo shows the pilot biogas plant constructed by the DESIRE team in Mopipi. It was installed at one household to serve as a demonstration to the village community. (Photo: R.J. Sebego)

Biogas

Botswana - *Gase ya Boloko (Setswana)*

Production of methane gas from cow-dung for use in household cooking, heating and lighting in order to reduce firewood demand.

Biogas plant: The biogas plant can be constructed in several ways as long as it can provide a medium for the biological material be digested. Biogas is the name given to the gas that is produced during the decomposition of some organic waste specifically to produce methane gas. The gas is then captured in a storage tank (on site) to be used for household energy needs. In many parts of the world where this technology is used (including Botswana) the most common form of input material is cow dung making it more appropriate for rural environments. Advantages: the technology offers two major advantages; first, at every level of use i.e. individual or institutional, savings in terms of energy is realized. The only costs that are borne are at installation, otherwise input of cow dung has a minimal cost of collection (if any at all). The second advantage is that there is reduced usage of fuel wood which translates into less cutting down of trees leading to reduced deforestation and degradation of land. A disadvantage is the initial investment which is significant for poor farmers.

Construction of the biogas plant: construction of the plant consists of three main chambers: namely, the Digester pit where all the microbiological reactions or decomposition of the material takes place. The digester has to be built to be air-tight with the released gas only escaping into the gas holder. The gas holder is connected to the digester by way of a pipe. Its main purpose is to collect all the gas that has been fermented. The mixing pit is the input chamber where the dung is mixed with water and fed into the digester. The amount and quality of water required for this is no constraint, even in this water stressed area. Construction of the biogas plant has to be done according to specifications. A technical drawing of the plant is shown on page 3. The purpose of the technology is to use it for house-hold energy (for cooking, lighting and running appliances).

In Botswana, the technology was introduced by the Rural Industries Innovation Center which is a government funded research institution. Despite the existence of this company for many years, the uptake has been very low due to poor marketing and extension services and lack of financial assistance to poor farmers.

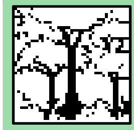
Biogas is suitable either for a farm, cattle post or rural setting where the inputs (cow dung) are easily available. But there are possibilities of experimenting with other bio-degradable materials in major centres where cow dung is not readily available.

Location: Southern District
Region: Kanye village
Technology area: point location
Conservation measure: management
Stage of intervention: rehabilitation / reclamation of denuded land
Origin: Externally - 10-50 years ago
Land use: Forest land and mixed
Climate: semi-arid, subtropics
WOCAT database reference: QT BOT05 on cdewocat.unibe.ch/wocatQT
DESIRE site information: www.desire-his.eu/en/boteti-botswana
Related approach: not documented
Compiled by: Sebego Reuben, University of Botswana
Date: 19th Feb 2009, updated 6th Jun 2011

Classification

Land use problems: Overgrazing of the commons, droughts, saline water and over-harvesting of fuelwood for cooking, heating leading to deforestation and land degradation.

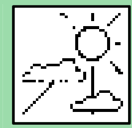
Land use



natural forest selective felling of (semi-) natural forests

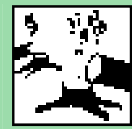
agro-pastoralism (rainfed)

Climate



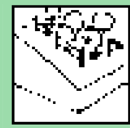
semi-arid, subtropics

Degradation



biological degradation: reduction of vegetation cover

Conservation measure



management: reduction of forest use intensity

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative
Experiments / research
Externally introduced: 10-50 years ago

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - human induced: deforestation / removal of natural vegetation, over-exploitation of vegetation for domestic use, droughts
Indirect causes: land tenure (communal grazing land), poverty (lack of alternative livelihood sources)

Main technical functions:
- reduction of wood exploitation

Secondary technical functions:
- promotion of vegetation species and varieties (quality, e.g. palatable fodder)
- enhancement of tree growth

Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 179 days (Oct - Mar)
Soil texture: coarse / light (sandy)
Soil fertility: very low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: good

Soil water storage capacity: very low
Ground water table: > 50 m
Availability of surface water: poor / none
Water quality: poor drinking water
Biodiversity: high

Tolerant of climatic extremes: n/a
Sensitive to climatic extremes: temperature decrease
If sensitive, what modifications were made / are possible: Biogas technology may be limited under extreme cold conditions whereby fermentation may be limited by cold temperatures.

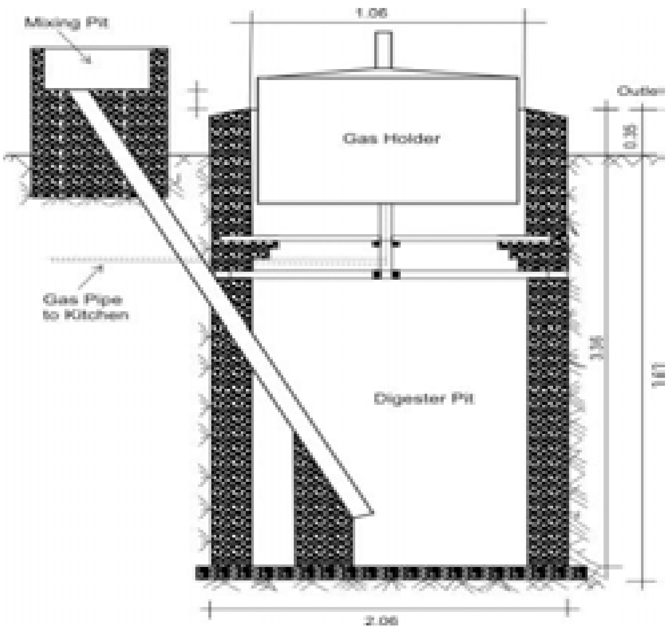
Human Environment

Mixed land per household (ha)

- <0.5
- 0.5-1
- 1-2
- 2-5
- 5-15
- 15-50
- ■ 50-100
- 100-500
- 500-1,000
- 1,000-10,000
- >10,000

Land user: individual privileged large scale land users
Population density: < 10 persons/km^2
Annual population growth: 2% - 3%
Land ownership: communal / village
Land use rights: open access (unorganised) (The SLM can be used by anybody - not specified to any group. Dual grazing rights are a problem because private ranchers can also use the commons).
Water use rights: communal (organised) (The SLM can be used by anybody - not specified to any group).
Relative level of wealth: very rich, which represent 10% of land users; 50% of the total land area is owned by very rich land users

Importance of off-farm income: less than 10% of all income: Saves money for buying commercial gas and electric power. Helps conserve the forests. Limited off-farm income opportunities for everyone including non-adopters of the technology.
Access to service and infrastructure: low: technical assistance, employment, market, energy, financial services; moderate: health, education, roads & transport, drinking water and sanitation
Market orientation: mixed (subsistence and commercial)



Technical drawing
The diagram shows the technical layout of a biogas plant; showing the position of the main components: Digester, Gas holder, Mixing pit, and outlet. Cow dung & or kitchen waste (except bones) is mixed with water to form a sludge. This sludge is fed into the digester pit where decomposition and fermentation takes place. As the sludge ferments, methane gas is produced. Methane is a combustible gas and can therefore be used for cooking and lighting. Specially designed gas stoves and lanterns may be required as the gas would not be purified and hence ‚thicker' than commercially produced gasses. However, the design can include a water filled pipe bend (u shaped) between the gas holder and outlet pipe. The water in this pipe would help to purify the gas before it is fed to the household appliances. The gas holder tank floats in water, through which the gas bubbles escape and methane gas collects into the floating tank. An outlet through which decomposed material leaves the plant is necessary. Old sludge would float and be removed through this opening (Diagram drawn by G. Koorutwe, Department of Environmental Science, University of Botswana).

Implementation activities, inputs and costs

Establishment activities

1. Construction

Establishment inputs and costs per unit

Inputs	Costs (US$)	% met by land user
Labour	198	100
Equipment		
- tank	615	100
- bricks	77	100
- cement	123	100
- plumbing material	154	100
Construction material		
- earth	31	100
TOTAL	**1198**	**100**

Maintenance/recurrent activities

1. Filling up with cow dung and water

Maintenance/recurrent inputs and costs per unit per year

Inputs	Costs (US$)	% met by land user
Construction material		
- cow dung	33	100
TOTAL	**33**	**100**

Remarks: Material, labour and equipment used in construction are the most determining factors affecting the costs (installation cost is US$ 1198). Costs were calculated for labour and material based on the real cost of construction at the Mopipi Site. The local wage rate is 1 US$/day. Each biogas unit is beneficial to one household, so it serves on average 6 persons.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
++ decreased workload ++ energy generation (eg hydro, bio) + decreased labour constraints	++ reduced crop production (removal of dung) ++ increased expenses on agricultural inputs (fertilizer)
Socio-cultural benefits	**Socio-cultural disadvantages**
++ improved conservation / erosion knowledge + improved situation of disadvantaged groups	++ where taboos exist for women harvesting dung from kraals (livestock enclosure); this could constrain adoption + socio-cultural conflicts, in case of no own cattle + unpleasant smell around the village
Ecological benefits	**Ecological disadvantages**
+++ increased plant diversity (only specific species collected) + improved soil cover (more trees) + increased biomass / above ground C (more trees) + reduced concentration of nutrients (dung)	+ decreased soil organic matter (reduced animal manure)
Off-site benefits	**Off-site disadvantages**
+++ improved buffering / filtering capacity +++ reduced wind transported sediments ++ increased water availability ++ reduced damage on neighbours fields + increased stream flow in dry season	

Contribution to human well-being/livelihoods

+ Provides cheaper and alternative source of energy. Reduces workload for fuel wood collection for women and the girl child.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	positive
Maintenance/recurrent	positive	positive

Very costly to set up, if no government aid. It is however very good for long term water provision.

Acceptance/adoption: 1% of land users (10 families) have implemented the technology with external material support. A very insignificant number of individual farmers have used this technology. The technology has mostly been used where the research institution has installed in farmers' properties. Only in very few instances around the country have individuals installed it for themselves. There is little trend towards (growing) spontaneous adoption of the technology. There seems to be very little marketing of biogas in the country.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Low maintenance and inputs are required for this technology → There is need for promotion of the technology	Too expensive for poor farmers to adopt without assistance → Donor/government subsidies
The structures to be put in place are very basic → There is need for the government to subsidize farmers in installing biogas plants, especially in the rural areas.	
Good for rural households where firewood is used extensively. → Improve income of rural families so that they could afford the technology	
Problems of diminishing firewood species are reduced. → Because it is not every or all species that is used for firewood, the targeted species are quickly diminished	
Cost of getting firewood is reduced → Distance to wood collection places are ever increasing hence users have to buy from truck or donkey cart owners	
More time is freed → This especially applies to children (of school going age) in that they would have more time for their home works.	

Key reference(s): Brown, V. J., 2006. BIOGAS: A Bright Idea for Africa. Environ Health Perspectives. 114(5), pp. A300–A303.

Contact person(s): Sebego Reuben, University of Botswana, SEBEGORJ@mopipi.ub.bw


Above left: In 2010, 30 ha of a no-tillage wheat-oat crop rotation with subsoiling and contour ploughing together with barrier hedges were implemented by farmers of the County of Yumbel (Photo: Carlos Ovalle).
Above right: Almost all the landscape of Yumbel city is affected by erosion. (Photo: Ingrid Martínez)

Dissemination of soil conservation technologies in dryland areas

Chile - *Cero labranza con subsolado (Spanish)*

Dissemination of no tillage with subsoiling in the Municipality of Yumbel

The Commune of Yumbel is a rural territory in the *secano* interior of central-south Chile, which has historically been an area of cereal crops and pulses. This has represented for many years the mainstay of the economy of small and medium farmers in the area. Owing to the sharp deterioration in the quality of the soil, caused by years of cultivation without respect for conservation, production potential was quickly fading and plunging farmers into an economic and social crisis caused by low yields and low income from agriculture. However, despite degradation, the commune still has abundant natural resources of soil and water, which will not be used by the forestry industry, and which can be recovered for productive and profitable agriculture. In May 2009, the team of researchers from INIA Quilamapu started this initiative based on promising results obtained in the EU DESIRE project for zero tillage, subsoiling and new crop rotations. The initiative was oriented towards transferring the technologies developed in DESIRE. The project received financial support from the Municipality of Yumbel.

Location: Bíobio and Maule region, Cauquenes, Chile
Approach area: 5000 km^2
Type of Approach: project/programme based
Focus: on conservation only
WOCAT database reference: QA CHL002
Related technology: No Tillage preceded by subsoiling (QT CHL01); crop rotation with legumes (QT CHL 02)
Compiled by: Carlos Ovalle
Date: 11th May 2011

<u>Aim / objectives: The aim was to </u>revitalise agriculture in the district of Yumbel, improve traditional crops using a conservation approach, which enables small- and medium-scale farmers to improve their incomes, create jobs and improve their quality of life. Specific objectives:

- To develop new farming systems based on the application of soil conservation practices (no tillage and subsoiling) that prevent erosion, and allow the development of a more sustainable and economic agriculture.
- To improve crop rotations, introduce grain and pasture legumes to diversify production and use of nitrogen inputs for lower nitrogen fertilizer costs.
- To build-up again the production of grain legumes and cereals in the district of Yumbel
- To renew the genetic material of crop species and varieties currently available to farmers in the area, allowing access to improved varieties of higher yield potential and resistance to diseases.

<u>Methodology: </u>We used a participatory approach, incorporating small producers in the extension programme from the beginning. Three representative areas were selected. Leader farmers were chosen in each sector who were responsible for field work. No tillage machinery was provided by INIA and acquired by a local farmer. The project directly involved 50 farmers and 250 ha of land. Further 400 farmers are being benefited by training on technologies of soil conservation and crop rotations and management.

<u>Role of stakeholders:</u>Municiplity of Yumbel: financing the project of technology transfer INIA and DESIRE project: human and material resources (machinery, transportation researchers, etc.). Ministry of Agriculture (INDAP, Institute of Agricultural Development): financing of management plans for soil conservation. Technology transfer companies: technical assistance directly to the small farmers Farmers: conducting field work and incorporating new technologies.

Problem, objectives and constraints

Problems:
1. Lack of machinery in the area
2. Few service providers
3. Lack of technical knowledge
4. Lack of cash to invest in SLM
5. Failure to implement a subsidy programme for farmers so that they can be organized around the creation of small company of service providers of machinery for subsoiling and no-tillage sowing.

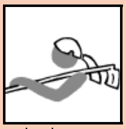
Aims / Objectives:
To revitalising agriculture in the district of Yumbel, improve traditional crops with a conservation approach, which enables small- and medium-scale farmers to improve their incomes, to create jobs and to improve their quality of life.

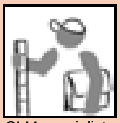
Constraints addressed

	Constraints	Treatments
Financial	Lack of capital and financial resources of the farmers.	State instruments and aids to implement soil conservation plans in the fields of the producers.
Social / cultural / religious	The traditional farming system. Farmers have used the mouldboard plough as the primary tillage implement.	Showing in farm days, the excellent results obtained in the experimental sites with no tillage and new crop rotation.
Technical	Lack of knowledge on sustainable farming practices.	Implementation of a soil conservation programme under the real conditions of the farmers with an environmental and economic sustainability approach.
Institutional	Absence or lack of coordination between institutions responsible for rural development.	Implementation of a participatory rural development project for soil conservation and improvement of agriculture, inspired by the methodologies and experience of the project.

Participation and decision making

Stakeholders / target groups


land users, individual


SLM specialists / agricultural advisors


teachers / school children / students


politicians / decision makers

Approach costs met by:

international	**30%**
government	**70%**
Total	**100%**

Annual budget for SLM component: US$ 60000

Decisions on choice of the Technology (ies): mainly by SLM specialists with consultation of land users
Decisions on method of implementing the Technology(ies): mainly by SLM specialists with consultation of land users
Approach designed by: national specialists, international specialists, land users
Implementing bodies: government

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Active	The producers themselves and the municipality of Yumbel demanded the project implementation given the severe problems of rural poverty and the soil degradation
Planning	Interactive	The technologies are being applied and implementation has been made through interaction with farmers, municipalities, INIA and INDAP
Implementation	Interactive	The farmers implemented the conservation practice in their lands.
Monitoring/evaluation	Interactive	Researchers evaluated this results
Research	Interactive	

Differences between participation of men and women: Yes, moderate
Men are more involved in tillage activities.
Men perform hard labour job in the land, while women participate in household tasks
Involvement of disadvantaged groups: No

Technical support

Training / awareness raising: Training provided for land user, field staff/agricultural advisor. Training was on-the-job, site visits / farmer to farmer, demonstration areas, public meetings, courses
Advisory service: The extension system is very adequate to ensure continuation of activities.
Research: Yes, great research. Topics covered include technology. Mostly on station and on-farm research. There are three experimental sites with evaluations to determine the best choice of conservation tillage systems and crop rotations. Different conservation tillage systems were evaluated and compared to conventional tillage. On these experimental sites, several indicators (chemical, physical and biological) were evaluated.

External material support / subsidies

Contribution per area (state/private sector): Yes. INDAP (INDAP, Institute of Agricultural Development)

Labour: Voluntary..
Input: Equipment (machinery, tools, etc.), agricultural (seeds, fertilizers, etc.), construction material (stone, wood, etc.), infrastructure (roads, schools, etc): fully financed
Credit: The funding for the implementation of new technologies are 50% from the state (programme of recovery of degraded soils of the Government of Chile for soil conservation practices) and 50% of the producers themselves (materials, labour, etc.)
Support to local institutions: The Yumbel project has had permanent participation of INIA (project DESIRE) and INDAP.

Monitoring and evaluation

Monitored aspects	Methods and indicators
bio-physical	Soil fertility (soil nutrient content N, P, K, S), erosion (soil loss, loss of nutrients), quality of soil (compaction, bulk density, structure, aggregate stability) measurements by project staff
economic / production	Crop production (yield, quality), gross margin, profitability observations by project staff

Changes as result of monitoring and evaluation: There were no changes in the approach and in the technology.

Impacts of the Approach

Improved sustainable land management: Yes, greatly improved; Mitigation of water erosion effects and better yields.
Adoption by other land users / projects: Yes, many; because of the great results obtained by few farmers, the approach is being adopted by others.
Improved livelihoods / human well-being: Yes, greatly improved; farmers that perform conservation obtained better yields, less work on the sowing and more time to attend to other activities on the land.
Improved situation of disadvantaged groups: This programme targets small farmers of the commune, who have no access to the technology or to State aid. The results are highly promising regarding the incorporation to the development of this sector.
Poverty alleviation: The improvement in yields and profitability of crops, the diversification of the production and the mitigation of land degradation are the strategies that are being implemented to alleviate poverty.

Training, advisory service and research:

Training effectiveness
Land users - poor
SLM specialists - excellent
Agricultural advisor / trainers - good
School children / students – good
Politicians / decision makers – excellent

Advisory service effectiveness
Land users - good
Politicians / decision makers - good
Technicians / conservation specialists – excellent

Research contributing to the approach's effectiveness
Greatly, The results obtained in the experimental sites (Cauquenes), as a result of the DESIRE Project, are being adopted by Policy Makers (SAG) to generate new policies and financing instruments to help the farmers.

Land/water use rights: These do not apply because in the area there are no water rights as there is rainfed agriculture and the farmers are all owners of their land.
Long-term impact of subsidies: Positive long-term impact - Greatly
Main motivation of land users to implement: Increased production , Increased profit(ability), improve cost-benefit-ratio , Rules and regulations (fines) / enforcement , Prestige / social pressure , Payments / subsidies, Reduced workload, Affiliation to movement / project / group / networks, Environmental consciousness, moral, health, Well-being and livelihoods improvement, Aesthetic
SLM: Sustainability of activities: It is uncertain whether the land users will be able to sustain the approach activities.

Concluding statements

Strengths and → how to overcome	Weaknesses and → how to overcome
Great interest of farmers to improve their incomes and conditions of life	Insufficient training on soil conservation for the farmers or for technical assistance companies → training, field days, demonstrative sowings, explanatory publications, practical work with farmers and technicians.
A strong commitment from the local authorities with the project	Delay in allocation of resources of the instruments of the state → synchronizing the availability of resources with the needs of the farmers for the execution of the work (supply purchases, rental equipment, etc.)
High rural population in this commune, involvement of young farmers (under 40 years)	Lack of no-tillage machinery → organization of associative farmers enterprises for the purchase of machinery and agricultural implements.
Assistance programmes from the State oriented towards tackling soil degradation → This project has been sustained over time and will remain at least for 3 to 4 years.	

Key reference(s): -
Contact person(s): Ovalle Carlos, Instituto de Investigaciones Agropecuarias. covalle@inia.cl

Above left: One of the key steps in the participatory approach is good socialization so that all stakeholders (with 15 partner groups) are well informed of the various stages of project (Photo: Jacques Tavares)
Above right: Photograph taken during a field trip to exchange ideas, experiences and viewpoints in the field (basin of Longueira) to understand better the problems of desertification (aridity) and land degradation (caused by runoff) (Photo: Jacques Tavares)

Training, information and awareness raising

Cape Verde – *Formação, Informação e Sensibilização (Portuguese)*

Integration of stakeholders in the implementation of natural resource conservation activities.

Aim / objectives: Immediately after independence, the Cape Verde government initiated in collaboration with its international partners an unprecedented campaign of afforestation. Its main goal consists of fighting desertification and the drought impacts that previously produced thousands of victims and forced migration of the Cape Verde population.

Methods: Among the specific objectives are: 1) reduction of soil erosion; 2) firewood production improvement for rural families; 3) better land production; and 4) land user vulnerability mitigation.

Stages of implementation: To achieve this objective, the Cape Verde government was in need of labour provided by the population, which was easily accepted. With the financial and technical support of the government, municipalities, international projects of rural development (FAO, GTZ, etc.), NGOs (Platforms of Local and National Associations,), the technical assistance of the Rural Development Ministry (MDR) and the help of the local population, nowadays, more than 20% of the surface area of the archipelago is planted with trees. Several steps have been reached: firstly the population has been prepared (information, awareness raising and training), then reconnaissance, topographical surveys and treatments of watershed were carried out where plantations were established. It was also necessary to import seeds from many countries, to create nurseries, to treat seeds and to train Cape Verde technicians.

Role of stakeholders: The role of the population was to participate in field work, to work in collaboration with the MDR technicians, to operate the nursery and finally to transport the seedlings to the field and plant them. All these steps were achieved with the technical support of the MDR and some fund providers.

The village suffers from substantial soil erosion, amounting to 6-10,000 tons per square km per year before the afforestation campaigns. The slopes are very steep (around 20-35 degrees). The main income of local farmers is from orchards.

Location: Watershed of Ribeira Seca, Island of Santiago, Cape Verde
Approach area: 71.5 km^2
Type of Approach: project/ programme based
Focus: on conservation only
WOCAT database reference: QA CPV001e on cdewocat.unibe.ch/wocatQA
DESIRE site information: www.desire-his.eu/en/ribeira-seca-cape-verde
Related technology(ies): Fruit tree afforestation (QT CPV03), Aloe vera live barriers (QT CPV06). Dams, Wall of stones, Contour furrows. etc.
Compiled by: Jacques Tavares, INIDA, Cape Verde
Date: 10 Oct 2011

Problem, objectives and constraints

Problems:

- desertification, drought, lack of water, erosion, loss of soil fertility, low soil cover, lack of firewood, loss of biodiversity,
- low take-up by the local population in the management of technologies (soil and water conservation measures), the low education level of some farmers including women, and the degree of land user poverty.

Aims / Objectives:

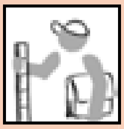
- fight against the desertification and the drought impacts,
- improvement of the living standards of the local population and particularly of the rural population through vegetation and animal production increase

Constraints addressed

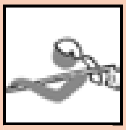
	Constraints	Treatments
Financial	Hydraulic measures such as check dams and contour wall stones need more financial resources	Better involvement of the donors and the State
Legal / land use and / water rights	Lack of mechanisms for the implementation and the monitoring of created laws	Boosting the local authorities (town council) and the main community associations so that they can be taken as a model.
Social / cultural / religious	Land tenure problems and socio-economic vulnerability of rural families	Strengthening the awareness raising activities for large land owners about land conservation to protect the long term productivity. Balancing the socio-economical gap between urban and rural communities by supporting farmers, pastoralists and associations

Participation and decision making

Stakeholders / target groups



SLM specialists / agricultural advisors



land users, individual, groups

planners

politicians / decision makers

***Approach costs met by:**

International	50.2%
Government	49.8%
Total	**100%**

Total budget: 15,119,500 US$

*In the framework of the project of management and enhancement of Picos and Engenhos watersheds on Santiago Island (2005-2010)

Decisions on choice of the Technology (ies): mainly by SLM specialists with consultation of land users
Decisions on method of implementing the Technology(ies): mainly by SLM specialists with consultation of land users
Approach designed by: national specialists, international specialists
Implementing bodies: international, government, NGOs, local community / land users

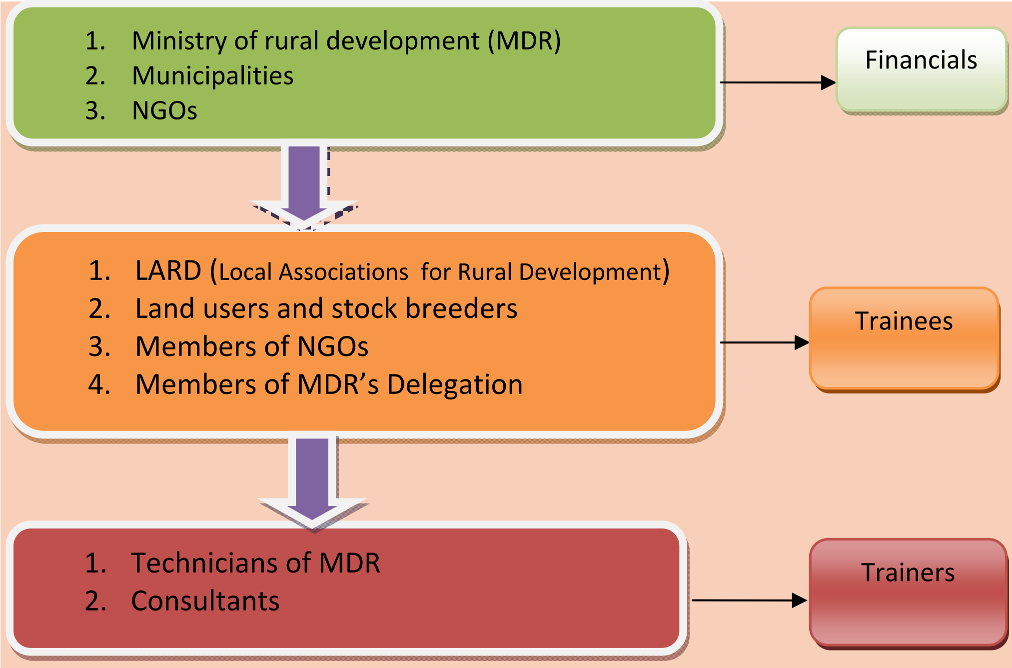
Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Capacity building	accelerated method of participatory research (rapid rural appraisal?), interviews/questionnaires, workshops/seminars
Planning	none	
Implementation	payment	intermittent works, responsibilities over small steps
Monitoring/evaluation	none	
Research	none	

Differences between participation of men and women: Yes, moderate
Generally women stay at home for the household. That is why 40% of the homes are managed by women, because men migrate to other areas or countries (women as heads of families).

Involvement of disadvantaged groups: Yes, great
More than 80% of land users in Cape Verde have small incomes. Land users are involved in all the work carried out in the field implementation steps. More than 90% of the workforce comes from socially and economically disadvantaged groups.

Flow diagram of the training approach



Technical support

Training / awareness raising: Training provided to specialists of SLM, students, politician / decision maker, field staff / agricultural advisor, land users. Training was on-the-job, through site visits and farmer to farmer interaction
Advisory service: Name: ZOPP (German Participative Approach Method), Key elements: 1, Participative 2. Integrated 3. Practical. The extension service and rural extension are under the responsibility of delegations of Directorate General for Agriculture, Forestry and Livestock (DGASP), which are distributed over different municipalities. These delegations sometimes act as bridges between farmers and the advisory service. The extension system is very adequate to ensure continuation of activities. Ninety-nine per cent of these practices are achievable by the technicians of the government. However, dams of medium importance require external support.
Research: Yes, a little research. Topics covered include sociology, economics / marketing, ecology. Mostly on-station and on-farm research.

External material support / subsidies

Contribution per area (state/private sector): Technical assistance is a general form provided by the State unless the event is organized and conducted by an NGO or delegations of MDR.
Labour: Paid in cash. Because of poverty, labour is paid.
Input: The use of inputs depends on the type of farming system. In other words, with respect to rainfed agriculture, the purchase of seed (800 g costs about 100 escudos, about 1.20 US$) represents a general input and remains the only input that the project introduced in the agricultural fields. However, for irrigated agriculture inputs are more important, in particular fertilizers and pesticides.
Credit: Agricultural credit is one of the lowest in Cape Verde. This idea was born during the 1980s, several years after the Independence of Cape Verde. It all started in the framework of co-operation with the United States, in which an agency worked directly with community-based organizations with support from the government. In the 2000s, the system worked very well. The interest rate was indeed very low (less than 5%) but the amount made available to the associations or direct beneficiaries was quite limited. In 2005, within the project "Management and Enhancement of the watersheds of Piocs and Engenhos in the Island of Santiago", agricultural credit was introduced with an interest rate of 5% for the livestock sector and irrigated agriculture. Although the number of members was limited, it worked relatively well. However, for the area of rainfed agriculture and forestry, there is no credit for the time being.
Support to local institutions: Yes, great support with finances, training and equipment.

Monitoring and evaluation

Monitored aspects	Methods and indicators
bio-physical	Regular measurements by – Technicians and researchers of the Ministry of Rural Development
area treated	Regular measurements by – Technicians and researchers of the Ministry of Rural Development and OASIS
no. of land users involved	Regular measurements by - Technicians' and Researchers of the Ministry of Rural Development DGASP/ Delegations of Ministry of Rural Development/OASIS/ Platform of local Associations for Rural Development

Impacts of the Approach

Improved sustainable land management: Yes, a large impact.
Adoption by other land users / projects: Yes, many. All projects of MDR (Ministry of Rural Development) adopt this approach.
Improved livelihoods / human well-being: Currently, the Cape Verdean agriculture presents a significant improvement over the previous decades as well as irrigated agriculture. As for rainfed agriculture, a lot of agricultural land has been reclaimed or created. However, cereal yields have increased only slightly due to the high variability of rainfall, low soil fertility and water erosion. However, the irrigated sector recorded year after year very positive results due to the improvement in the provision of surface water (with tanks, dams, etc.), the introduction of new irrigation techniques (drip irrigation), capacity building of farmers and increasing demand for garden products. These findings have resulted in a significant improvement in farmers' income and their living conditions in a general form.
Improved situation of disadvantaged groups: All shares of capacity building are oriented to both men and women and also young land users. However, the status of some women as household heads limits sometimes their participation.
Poverty alleviation: Capacity building campaigns have played a role in the notorious burden of poverty. Many land users were able to increase their income through increased agricultural output, working as stonemasons, security guard, etc.
Training, advisory service and research:

Training effectiveness:	Advisory service effectiveness
Land users - good	Land users - excellent
SLM specialists - good	Politicians / decision makers - moderate
Agricultural advisor / trainers - good	Planners - good
School children / students - moderate	Teachers - good
Politicians / decision makers - moderate	Technicians / conservation specialists - good

Land/water use rights: The approach moderately reduced the land/water use rights problems because managing multiple sources of irrigation water is currently the responsibility of local farmers organized in association.
Long-term impact of subsidies: Positive long-term impact – greatly / negative long-term impact - none
Main motivation of land users to implement: The implementation of actions and works of soil and water conservation is a source of income for farmers and especially the poorest farmers and women as unemployed heads of households. For several years the implementation of these actions against desertification and land degradation were achieved through local associations of farmers under contract. These associations received technical support from the Ministry of Rural Development, especially for certain works such as small dams and other waterworks.
SLM: Sustainability of activities: The involvement and empowerment of community-based associations in the implementation of rural development actions intended to ensure the sustainability of these actions. Thus, the handling and monitoring of short- and medium-range actions are in the hands of intervention associations. In contrast, far-reaching actions such as hydraulic works are the responsibility of the State regarding their handling**.**

Concluding statements

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
The approach works with existing decentralized bodies (central government, municipalities or local governments, MDR delegations) → Strengthen human, financial and material resources of these entities. Create synergies and boost communication between these entities.	Established land tenure system could not be solved with the approach → The church should be more integrated in the land problems, because it owns a large part of agricultural lands.
Creation of multidisciplinary teams → The monitoring system of measures and actions to conserve and protect natural resources should be provided by a representative and multidisciplinary team.	The high rural poverty could not be tackled sufficiently → More dynamic programmes against poverty are required
Involvement of community associations and NGOs in the approaches implementation → NGOs as community representatives are spearheading the fight against desertification and the conservation of natural resources. Their effective involvement requires, among other things, to understand not only their needs but also the priorities of their requirements.	Santiago is still the most favoured island benefiting from the approach compared with others → Programmes should be more integrated
Active participation of stakeholders in the process → The sustainability of participation requires a particular form of involvement that happens through the enhancement of their knowledge but also through actions or measures of small and medium size which are carried out by them through a fair and proper contract.	Weak exchanges (knowledge) between the land users of the various islands →Create a fund able to support the exchange of knowledge between the land users of the main agricultural islands
	A slow process between the consultation and identification phases and the implementation → Reduce this time
	Not enough financial resources to solve the agricultural problems of the land users → Reinforce the synergies and dialogue between the rural development programs and projects

Key reference(s): And Emilia, V., 1995. Diagnostico inicial junto da comunidade. Volume II, Guia Para o Formador. Minstério de Agricultura-Projecto GCP/CVI/032/ITA “ Consolidação das actividades do Centro de Formação de São Jorge”, pp 99.

Contact person(s): Jacques de Pina Tavares, INIDA-MDR, jacques.tavares@gmail.com; Amarildo dos Reis, INIDA-MDR areis@inida.gov.cv

Above left: A 7-year-old plantation of *Agave cupreata* (*"Maguey papalote"*). Titzio project, Michoacán de Ocampo state (Photo: Christian Prat)
Above right: A 1-year-old *Agave inaequidens* plantation on eroded soil (Acrisol) and volcanic tuff (so-called *'tepetate'*) in El Calabozo – Potrerillos sub-catchment of Cointzio basin, Michoacán de Ocampo state. (Photo: Eduardo Ríos)

Participative actions for economic benefits of agave forestry

Mexico - *Recuperación de tierras degradadas por agaveforestería a traves de acciones participativas para beneficios económicos (Spanish)*

Land reclamation with local agave (to produce Mezcal) associated with trees, shrubs and grasses planted through participative actions for economic benefit

Aim / objectives: Rehabilitation of degraded land is achieved by using native agave (*Agave inaequidens*) and trees, shrubs and grasses which creates, over the medium-term (7-10 year), a sustainable production of an alcoholic drink (*mezcal*) and/or pharmaceutical products and/or fodder for cattle and/or wood. Further objectives are water conservation, biodiversity, generation of permanent employment (plant reproduction, planting, alcoholic drink/ pharmaceutical production), carbon sequestration, generation of higher family incomes and a reduction in the amount of livestock and number of animals and uncontrolled grazing (the main cause of soil erosion). These positive impacts of the approach contribute to preventing the rural population from emigrating to the cities or abroad.
Methods: Coordination, cooperation and systematic participatory process among stakeholders are the basis of the approach. Promoting participatory processes occurs through workshops, interviews with community leaders, field visits conducted with owners of the land to recognize the problems and identify areas of opportunity, training courses, exchange of experiences with other people who are developing similar projects at different stages. Technical advice and the links with scientists, technicians and public officials in charge of project beneficiaries is given under a two-way process of mutual learning and seeking to strengthen self-management capabilities that inspires innovation at the different stages. The key to success of a participatory approach lies in liberating and developing community leadership and self-organization processes.
Stages of implementation: The project is part of a regional planning context and a basin scale approach of intervention. The watershed of the site project is included in a special programme of the Ministry of Environment and Natural Resources of Mexico which gives the opportunity of developing and financing a medium- to long-term project. The participatory process is delivered from planning, organizing, programming and implementing to financing, training, monitoring and disseminating the results. The strategic perspective of the project includes capacity-building of land owners for greenhouse and nursery management, the technical assessment for the improvement of the agave forestry system, guidance with quality production of *mezcal* and marketing support to diversify products and sell them in order to make the project financially self-sustaining and profitable. All these stages range from short- to medium- and long-term.
Role of stakeholders: The government finances the project through grant resources, promotes the participation of beneficiaries and monitors it, seeking the management of resources and intersectoral participation. Scientists and academics share their knowledge, techniques and methodologies for implementation, improvement, evaluation and monitoring of each stage, and they support capacity-building of the community. The owners of the land and the community implement and develop each of the activities from building and maintaining the greenhouse and nursery, planting agaves, trees and shrubs, to the use and production of *mezcal* and other commercial products.

Location: Michoacán state, Morelia, Mexiko
Approach area: 0.1-1 km^2
Type of approach: traditional, innovative, and project based
Focus: mainly on other activities than SLM
WOCAT database reference: QA MEX002 on cdewocat.unibe.ch/wocatQT
DESIRE site information: http://www.desire-his.eu/en/cointzio-mexico
Related technology: Land reclamation by agave forestry with native species, QT MEX002 on cdewocat.unibe.ch/wocatQA
DESIRE site information: www.desire-his.eu/en/cointzio-mexico
Compiled by: Christian Prat, Institut de Recherche pour le Développement (IRD), France, Alejandro Martínez Palacios, Universidad Michoacana San Nicolas de Hidalgo (UMSNH), Mexico and Eduardo Ríos Patrón, Secretaria del Medio ambiente y Recursos Naturales (SEMARNAT), Delegación en Michoacán, Mexico.
Date: 21 May 2010, updated Nov 2011

Problem, objectives and constraints

Problems:
Social and economic problems: Agriculture and livestock in the region are primarily for subsistence. The level of poverty and marginalization of the people of the project site is medium to high with low education levels. People need to migrate to the cities or outside the country to supplement the family budget. Prices of farmer productions are too low and do not allow economic survival. Therefore, only 10 to 20% of the total incomes are derived from agricultural products! This explains why the children of farmers do not want to become farmers and lands are less and less cultivated. In correlation, as the livestock price is good and animals can be raised with little input of time. Thus the number of animals is increasing and as they are grazing everywhere, they have a strong soil erosion impact.

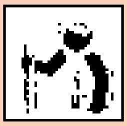
Aims / Objectives:
Rehabilitation of degraded land is done using native agave (*Agave inaequidens*), trees, shrubs and grasses which creates, over the medium-term (7-10 years) sustainable production of an alcoholic drink (*mezcal*) and/or pharmaceutical products and/or fodder for cattle and/or wood.

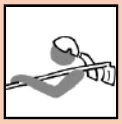
Constraints addressed

	Constraints	Treatments
Financial	Potential constraints in the final stages of the project when receiving revenue from the sale of *mezcal* and other products	Strengthening capacities of organization and administration, promoting transparency and accountability in the community. Development and consolidation of the formation of cooperatives as an alternative to social enterprise
Social / cultural / religious	The social arrangement of the "*ejido*" requires all people to agree on moving forward with different activities. The level of education and migration.	Systematic and constant promotion of the participatory process through community assembly meetings, workshops, community exchange travel, experiences and training. Promote complementarity and targeting of resources from other sectors.
Institutional	The risk that the six-year change in administration does not follow the care programme in the area.	Strengthening self-management capabilities of the group of beneficiaries of the project. Involving other government levels and sectors funding training and monitoring of subsequent stages.
Technical	Lack of validation and technology transfer of agave forestry. Lack of information on the requirements of these species of agave. Potential risk to move from non-intensive system to an intensive one due to economic and market factors.	Development of technological packages for an agave forestry system as a basis for the production of *mezcal*, considering soil erosion levels and system arrangements. Promote only ecologically diversified, non-intensive systems. Design environmental and ecological monitoring stage.
Legal / land use and / water rights	Federal, state and municipal regulations for preventing clearance of woods, biodiversity uses, forest exploitation, water concessions and water quality must be applied. Mexican official standards of *mezcal* production must be used.	Conduct a thorough review with a focus on prospective different stages of a project and the legal implications and regulations that must be met at these stages. Inform land owners about their rights, obligations and mechanisms of fulfilment.

Participation and decision making

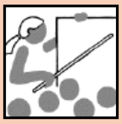
Stakeholders / target groups


SLM specialists / agricultural advisors


land users, individual, groups


planners


politicians / decision makers


teachers / school children / students

Approach costs in % met by:

- government	80
- local government (district, county, municipality, village, etc.)	10
- local community / land user(s)	10
Total	**100**

Total budget 2,000-10,000 US$
(estimated budget by ha, without alcoholic drink production)

Decisions on choice of the Technology: It is the result of proposals, visits and discussions between all the stakeholders, so it is a joint decision.
Decisions on method of implementing the Technology: It is the result of proposals, visits and discussions between all the stakeholders, so it is a joint decision.
Approach designed by: Federal environmental authority, national and international scientists and land owners

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Self-mobilisation	Balance alternatives and take decision to test the agave forestry
Planning	Interactive	Planning, organizing and programming the project, defining responsibilities, time and initial investment. Identification of agave seeds and a proper place to install the greenhouse and nursery.
Implementation	Self-mobilisation	Building and maintenance of greenhouse and nursery, selecting the sites for the plantation and planting. Training of land users by other land users to produce mescal according to quality rules for a recognized product.
Monitoring/evaluation	Self-mobilisation	In each field: monitoring plant growth, status of the protection against cattle grazing, indications of soil erosion.
Research	Interactive	Monitoring by some land users of some parameters defined by scientists.

Differences between participation of men and women: Yes, moderate
Traditionally, women have been more responsible for the house and the area close to it. They are less involved in the field activities of the agave forestry project, but are involved in production and commercialization. On the other hand, women are worried about the possible impacts of alcoholic drink on communities, because alcoholism is a social concern.

Involvement of disadvantaged groups: Yes, high
There has been no discrimination inside the communities up to now

Workshop with women from eight rural communities of the Calabozo - Potrerillos watershed. They are defining their problems and proposing solutions. EU-DESIRE project and small catchments SEMARNAT project, San Rafael Coapa community, Morelia municipality, April 2010 (Photo: C. Prat)

Technical support

Training / awareness raising: Training was provided for the land users, field staff/agricultural advisors. Training was on-the-job anc during public meetings. Training focused on explaining which plants to select for seeds, how to create and maintain plants in greenhouses how to transplant them and how to organise their planting in the field depending on the aim (scattered for production or in rows to create a green barrier formed from trees, shrubs, grasses and agaves)
Advisory service:
Name: Plant (native agave, trees, shrubs, grasses) production advises.
Key elements:
1. Plant selection
2. Management of plants under greenhouse
The extension system is well suited to ensure continuation of activities
Research: Yes, a considerable amount. Topics covered include economics / marketing, ecology, technology. Mostly on-station research No information exists about the production conditions of this agave species, especially concerning the sugar quantity and quality producec by the plant which will be used for alcoholic drink production (e.g. whether it grows better in the shade or in full sunlight, or more appropriate for mature or young plants).

External material support / subsidies

Contribution per area (state/private sector): No
Labour: Voluntary, paid in cash.

Input:
- Equipment (machinery, tools, etc.): shovel, hammer, pickaxe; partly financed
- Agricultural (seeds, fertilizers, etc.): plastic bags for plants, soil, compost; partly financed
- Construction material (stone, wood, etc.): wood, metal tube, stones, plastic for greenhouse; fully financed
- Transport: transportation of people and materials, partly financed

Credit: Credit was not available
Support to local institutions: Yes, good support with finance, training, equipment, transport

Monitoring and evaluation

Monitored aspects	Methods and indicators
bio-physical	Biodiversity, water quality, water usage, degradation and soil rehabilitation indicators. Participatory collection of data by landowners, public officials and technicians.
technical	Indicators of improvement of technical capabilities of the nursery operators, capacity building for the production of *mezcal* and other products and comparative indicators of different arrangements of agrosystems based on other biophysical and economic indicators.
socio-cultural	Migration, poverty, education indicators by surveys and statistical models.
economic / production	Indicators of profitability, revenue from each stage per person, economic valuation of soil improvement
area treated	Regular observations by project staff, government and land users.

Changes as result of monitoring and evaluation: There were no changes in the approach and the technology.

Impacts of the Approach

Improved sustainable land management: Yes, a high impact - it is a new and easily-implemented technology with a high economic potential (commercialisation of products of very high value)
Adoption by other land users / projects: it is too early to answer this question
Improved livelihoods / human well-being: it is too early to judge, but it is supposed to improve it
Improved situation of disadvantaged groups: it is too early to judge, but it is supposed to improve it
Poverty alleviation: it is too early to judge, but it is supposed to alleviate it
Training, advisory service and research:

Training effectiveness
Land users - excellent
SLM specialists - excellent
Agricultural advisor / trainers - excellent

Advisory service effectiveness
Land users - excellent
Technicians / conservation specialists - good

Research contributing to the approach's effectiveness
A large contribution (owing to the lack of information about the species of agave as well as the native trees, shrubs and grasses to be used, research is fundamental to find the best approach)

Land/water use rights: Help – existing land / water use rights helped greatly in the implementation of the approach.
Long-term impact of subsidies: Positive long-term impact – greatly; negative long-term impact – none (The major part of subsides will finish at medium-term of the SLM approach because, as the project is supposed to generate very large funds as a result of the sale of alcoholic drink. Part of this money will replace the subsides.)
Main motivation of land users to implement: Production, increased profit(ability), improved cost-benefit-ratio, payments / subsidies, environmental awareness, morale, health, well-being and livelihood improvement
SLM: Sustainability of activities: Yes, the land users can sustain the activities required for the approach.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Productive project which generates economic benefits over the medium-term → as a result of the money earned, it will be possible to extend the area concerned and subsides will not be necessary anymore	Selling alcoholic drink is not necessarily beneficial from a health and societal point of view → maintenance of a campaign to reduce consumption and develop a responsible attitude to alcohol
The project is done in a participative way where different kinds of stakeholders are involved: administrators, politicians, scientists and the public. → maintenance of the interaction between stakeholders from the workshops, present results to other authorities and appropriate fora.	Women particularly, are worried about the possibility of the increase in alcohol consumption → since alcoholic drink will be produced in a semi-industrial way for the external market, it is not supposed to be consumed by the communities themselves

Key reference(s): Colunga-García Marín P., D. Zizumbo-Villareal, J.T. Martínez. 2007. Tradiciones en el aprovechamiento de los agaves mexicanos: una aportación a la protección legal y conservación de su diversidad biológica y cultural. In: En lo Ancestral hay Futuro: del Tequila, los Mezcales y otros Agaves. P Colunga-GarcíaMarín, L Eguiarte, A Larqué, D Zizumbo-Villarreal (eds). CICY-CONACYT-CONABIO-SEMARNAT-INE. México D.F., pp:85-112

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Christian Prat, IRD-Institut de Recherche pour le Développement, France christian.prat@ird.fr
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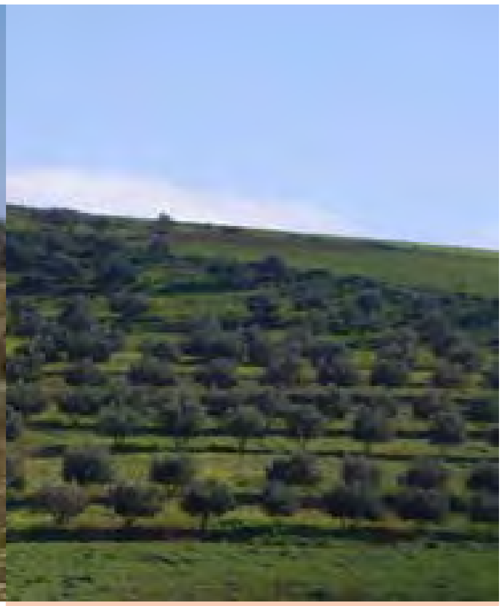


Above left: 5-year old olive tree plantation with intercropping (Photo: Nadia Machouri)
Above right: 12-year old olive tree plantation, which was implemented as part of the Sehoul PMVB. Production intensification and soil improvement are achieved through fruit tree plantations. (Photo: Nadia Machouri)

Development of rainfed agriculture

Morocco – *Projet de mise en valeur des terres en Bour de Sehoul (PMVB) (French)*

Development of unfavourable zones by integrating all components which can enhance the production, increase incomes and provide a sustainable natural resources management

Aim / objectives: The main objectives are to involve all the partners in the development of rainfed agriculture, the conservation of the natural resources, the enhancement of crop and animal agricultural production, the increase in income and improvement of farmers' conditions of life, and a better response to the needs and protection of the production potential. A further aim is the integration of the local agriculture into the national context and the opening up to the outside world.

Stages of implementation and methods: The implementation of the project goes through several phases including:
The identification phase of people's needs and farming or environmental problems of the region.
- Formulation of the proposed development by a committee of administrators and local stakeholders.
- Feasibility study and planning of the implementation steps in technical terms.
- Implementation of project components after the effective registration of the project in the Finance Act, with distribution of tree seedlings and support for the establishment of water harvesting structures for olive trees on sloping land.
- Assistance of project operation and maintenance. The aim is to support farmers' organisations benefiting from the project in order to develop their necessary skills for efficient project operation, establishment and maintenance and other issues that can ensure sustainability.
- Evaluation of the completed project in order to capitalize on the experience gained during preparation and execution of the project.

Role of stakeholders:
- Land users: participation in the consultations made by the SLM specialists, who are responsible for monitoring the projects.
- SLM specialists / agricultural advisors: implementation of the technology after consultation with the population.
- Politicians / decision makers: discussion with the population
- Planners: Participatory diagnosis, meetings with target population, questionnaires

Location: Sehoul, Salé province, Morocco
Approach area: 0.4 km^2
Type of Approach: project/programme based
Focus: mainly on conservation with other activities
WOCAT database reference: QA MOR14e on cdewocat.unibe.ch/wocatQA
DESIRE site information: www.desire-his.eu/en/sehoul-morocco
Related technology: Planting of olive trees with intercropping (QT MOR14e)
Compiled by: Rachida Nafaa
Date: 29th Jan 2009, updated 19th Aug 2011 by Nadia Machouri

Problem, objectives and constraints

Problems:

Cereal crops only provide irregular incomes (due to the frequency of bad years) and they cause degradation on sloping land, because the ground is bare at the beginning of the rainy season. Pasture, the second activity in terms of land use, but the primary activity in terms of history and incomes, also causes land degradation. Tree crop harvesting is therefore an economic and ecological alternative. The tree plantations should therefore be implemented with SWC measures, which requires know-how that is unfortunately still lacking. The goal of the project is to overcome this lack of knowledge.

Aims / Objectives:

- Increase in land users' incomes
- Intensification of agricultural production (animal and crops)
- Opening up of the region to form a national and worldwide perspective, and remove its marginality

Constraints addressed

	Constraints	Treatments
Financial	High costs for the technology implementation for a mainly poor population	Bearing the technology implementation costs by the project
Social / cultural / religious	Distrust of the population due to the fear of land expropriations	Participative approach to gain the confidence of the population
Technical	Lack of know-how in modern agroforestry	Agricultural extension and support for users who perform this new land use
Legal / land use and / water rights	Act on private lands belonging to people who fear land expropriation during the project	Contracts between the beneficiaries and the project about the duties of each stakeholder
Other	Extensive pastoralism based on grazing in fallow land, stubble fields and Mediterranean vegetation is reduced, what causes conflicts among inhabitants	Incentive measures for animal housing and fodder cultivation

Participation and decision making

Stakeholders / target groups

land users, groups | SLM specialists / agricultural advisors | planners | politicians / decision makers | teachers / school children / students

Approach costs met by:

International (World bank, FAO)	**30%**
Local government (Ministry of Agriculture)	**70%**
Local community / land user(s)	**0%**
Total	**100%**

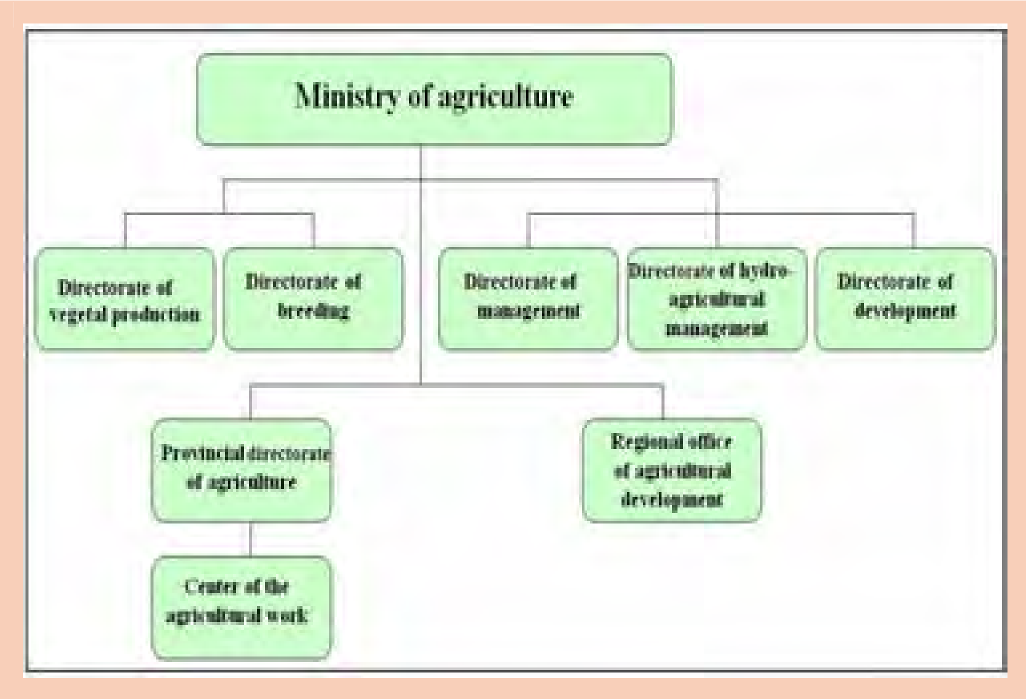
Annual budget for SLM component: US$100,000-1,000,000

Decisions on choice of the Technology (ies): mainly by SLM specialists with consultation of land users
Decisions on method of implementing the Technology(ies): by SLM specialists alone (top-down)
Approach designed by: national specialists
Implementing bodies: government (at the national scale, this approach is implemented by the Ministry of Agriculture as part of the 33-94 law about PMVB), other (at the regional scale, the external services of the Ministry of Agriculture are responsible for the approach implementation)

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	None	
Planning	Interactive	Participative assessment, meetings with the target population, questionnaires
Implementation	Payment/external support	This is achieved by SLM specialists appointed by the implementing bodies of the Ministry of Agriculture
Monitoring/evaluation	None	
Research	None	

Differences between participation of men and women: Only men participated in the approach.
Involvement of disadvantaged groups: No



Organogram: Legally, the project of rainfed agriculture development (PMVB) is based on the 33-94 law, which is coordinated by the Directorate of Management in the Ministry of Agriculture.

Technical support

Training / awareness raising: Training was conducted through site visits and farmer to farmer. Training focused on soil working, use of productive seeds, fertilization, livestock genetic improvement, livestock accompaniment.
Advisory service: The agricultural extension focuses on: 1. Neighbourhood services ensured by the local technicians; 2. Field trips to the land users; 3. Livestock vaccination campaigns.
The extension system is entirely adequate to ensure continuation of activities. The external services of the Ministry of Agriculture are responsible each year for the distribution of olive tree seedlings with 80% subsidies to enhance land users' planting efforts.
Research: Yes, moderate research. Mostly on station and on-farm research. Academic research on different parts of the project.

External material support / subsidies

Contribution per area (state/private sector): No contribution per area. The private sector did not really participate; only farmers participated by their work.
Labour: Paid in cash. Local workforce employed for the project is paid in cash for all the work achieved.
Input: Agricultural (seeds, fertilizers, etc): Fruit tree seeds are fully financed
Credit: Credit was not available.
Support to local institutions: Yes, moderate support to population organisations.

Monitoring and evaluation

Monitored aspects	Methods and indicators
bio-physical	Ad hoc observations by project staff
technical	Ad hoc observations by project staff
economic / production	Ad hoc measurements by project staff
no. of land users involved	Regular measurements by project staff
management of approach	Ad hoc measurements by project staff

Changes as result of monitoring and evaluation: There were no changes in the approach and in the technology.

Impacts of the Approach

Improved sustainable land management: Yes, moderate – farmers' income increased after olive tree planting.
Adoption by other land users / projects: Yes, many - land users showed an increasing interest after the PMVB implementation.
Improved livelihoods / human well-being: Yes, a little - incomes have been improved a little, for the few land users who have initially implemented this approach. This includes, however, only a small part of the population.
Improved situation of disadvantaged groups: -
Poverty alleviation: No, because the small farmers and landless peasants have not really benefited from the PMVB approach
Training, advisory service and research:

Training effectiveness
Land users - poor
SLM specialists - good
Agricultural advisor / trainers - good
Teachers - fair
School children / students – fair
Planners - fair
Politicians / decision makers – fair

Training was not very useful for land users because it had a very short duration and it consisted only of a few trips and field visits.

Advisory service effectiveness
Land users - good
Politicians / decision makers - poor
Planners - poor
Teachers - poor
Technicians / conservation specialists – good
School children / students – poor

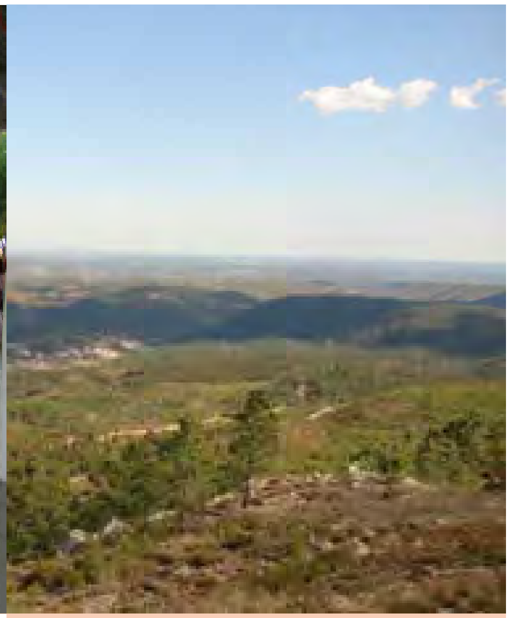
Technicians of the local work centres provided necessary advices for the land users using tree growing

Land/water use rights slightly hindered the implementation of the approach. It was difficult to act on private land because of the fear of land expropriation by the project. The approach moderately reduced the land/water use rights problem. The project approach is based on incentives like contracting procedures and total financing of technology implementations done on private lands.
Long-term impact of subsidies: Low positive long-term impact and no negative long-term impact.
Seedlings have been provided free of charge by the Ministry of Agriculture to encourage land users to change the system, because 3 to 4 years are needed before the trees become productive. Furthermore, tree plantations stop animal breeding activities on that piece of land. That is why this approach leads toward an integrated change. Incentives were not enough, and they were supplied more too large land users who did not need them than to small land users.
Main motivation of land users to implement: Payments / subsidies, production and increased profit(ability), better cost-benefit-ratio.
SLM: Sustainability of activities: Yes, the land users can sustain the approach activities.

Concluding statements

Strengths and → how to overcome	Weaknesses and → how to overcome
Creation of a local dynamic → Support stakeholders organizations	Lack of agricultural strategies for this region, which is impaired by the nearby growing urbanization → Agriculture should not only be planned when needs are dictated by the cities of Rabat and Salé (primarily horticulture)
Wide coverage of diverse agro-ecological zones → Approach extension towards the most disadvantaged agro-ecological zones	Low level of involvement of local stakeholders → Elected local people have to integrate agricultural development programmes in their global strategies and not only suggest services in order to win the elections
Implication of all local stakeholders and national or international beneficiaries → Strengthen the cooperation between the private sector and every potential stakeholder	Few synergies between all development actors → Because of the proximity of Rabat and Salé, the management of this region is done from the cities. Local autonomy can be a first step in more local development involvement.
Development of assessment abilities at local and central scale → Spreading this assessment abilities and reinforce them	Few training and supervision for young people → Incentive measures for young people and women through developing their human capacities
Land users support → Strengthen local structures in charge of agricultural extension	Inadequate government subsidies →The government has to provide help in order to meet the needs (fodder, support for poor land users) in order to implement SLM activities, to change land uses or to adopt more profitable cultivation
Financial support to help poor land users to implement SLM technologies → Subsidies for expensive SLM activities	

Key reference(s): Le PMVB des Sehoul, evaluation, Ministère de l'Agriculture, Direction Provinciale de l'Agriculture, Rabat-Salé, 2003.
Contact person(s): Nadia Machouri, Université Mohammed V, Rabat, nadachouri@yahoo.fr



Above left: ZIF Information Session (Photo: AFLOMAÇÃO)
Above right: Forest Intervention Areas in Mação Municipality (Photo: João Soares)

Forest Intervention Area (ZIF)

Portugal - *Zona de Intervenção Florestal (Portuguese)*

Forest Intervention Area (ZIF) is a territorial unit, where the main land use is forestry. This approach assembles and organizes small forest holders and defines a joint intervention for forest management and protection. Defined by law in 2005, and revised in 2009, each ZIF of private forest has to include at least a contiguous area of 750 ha, 50 landowners and 100 forest plots, and has to be managed by a single body, defined by ZIF members.

<u>Aim / objectives</u>: The ZIF overall objective is to promote the efficient management of forest and to mitigate current constraints of forest intervention (e.g. land size and tenure). Other objectives are to develop structural measures for fire prevention, to integrate local and central administration actions and to implement the national and regional forest management policy at the local level. The final purpose of ZIF areas is to improve productivity in rural forest areas, contributing to rural development.

<u>Methods</u>: The idea emerged after the catastrophic wildfires of 2003 and was developed and presented by a group of stakeholders (landowners, forest associations, City Council, among others) to the Ministry of Agriculture, Rural Development and Fisheries. The ZIF approach was legislated by Law 127/2005, and revised under Law 15/2009. Each ZIF assembles small properties, which will be jointly managed by a single entity, which can be a non-profit-making and voluntary organization or some other group of people approved by the forest owners. Each ZIF will have a Forest Management Plan (PGF), where the forestry operations and activities for ZIF area are defined accordingly to the guidelines of the Regional Plan for Forestry Management and Planning (PROF), and a Specific Plan to Forest Protection (PEIF), which includes actions to protect forest against biotic and abiotic risks. The management entity should have a team with qualifications and experience in forestry and with technical ability to design these plans.

<u>Stages of implementation</u>: The legal constitution of ZIF includes six mandatory steps, namely the constitution of the founding group (group of landowners with at least 5% of a continuous area inside the ZIF), the prior consultation meeting, the public consultation, the final audience meeting, the proposal submission to the National Forest Authority (AFN) and legal publication of each ZIF (already done). After these procedures, the PGF and PEIF of each ZIF will be designed by the management entity and evaluated and approved by AFN. The implementation activities can then be implemented by the management entity or by individual landowners following the rules described on the plans. PEIF validity is five years and PGF validity is 25 years (still in preparation). [See figure below].

<u>Role of stakeholders</u>: The founding group is mainly composed of forest owners and producers and is the starting point for creating a ZIF. The management entity administers the ZIF in order to achieve their main purposes and the aims defined on the plans. AFN will support and monitor ZIF activities. ZIF non-supporting landowners are obliged to have a PGF for their land, as well as to accomplish the PEIF of the ZIF.

Location: Mação, Portugal
Approach area: 400 km^2 (29 ZIF)
Type of Approach: project/programme based
Focus: increase land management and profitability
WOCAT database reference: QA POR01 on cdewocat.unibe.ch/wocatQA
DESIRE site information: www.desire-his.eu/en/macao-portugal
Related technology(ies): Primary strip Network system for fuel management (QT POR01), Prescribed fire (QT POR02)
Compiled by: Celeste Coelho, Sandra Valente and João Soares, University of Aveiro
Date: February 2009, updated September 2011

Problem, objectives and constraints

Problems:

- lack of forest planning and management, forest fires, land structure and tenure, land abandonment, rural depopulation and ageing.

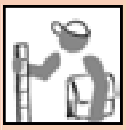
Constraints addressed

	Constraints	Treatments
Financial	High implementation cost	Governmental incentives
Institutional	Scepticism about the practical effects of this approach. Very high costs for implementation and lack of private investment	ZIF pilot areas will motivate implementation and investment into other ZIFs.
Legal, land use and water rights	Land structure and tenure (private holdings)	Minimum area to constitute a ZIF is 750 ha.
Social / cultural / religious	Social resistance to this approach. Landowners fear to lose tenure rights. Difficult to reach and find owners due to inheritance and out-migration. Rural depopulation occurred in the last decades.	Financial support, creation of new job opportunities in rural areas.

Participation and decision making

Stakeholders / target groups

land users, individual



SLM specialists / agricultural advisors

politicians / decision makers

Approach costs met by:

ZIF constitution: Permanent Forest Fund	100%
ZIF implementation activities:	
National Strategic Reference Framework	~ 60%
Land users	~ 40%
Total	**100%**

Overall budget for the implementation of 1 ZIF with 1000 ha in about 5 years: US$> 1,200,000

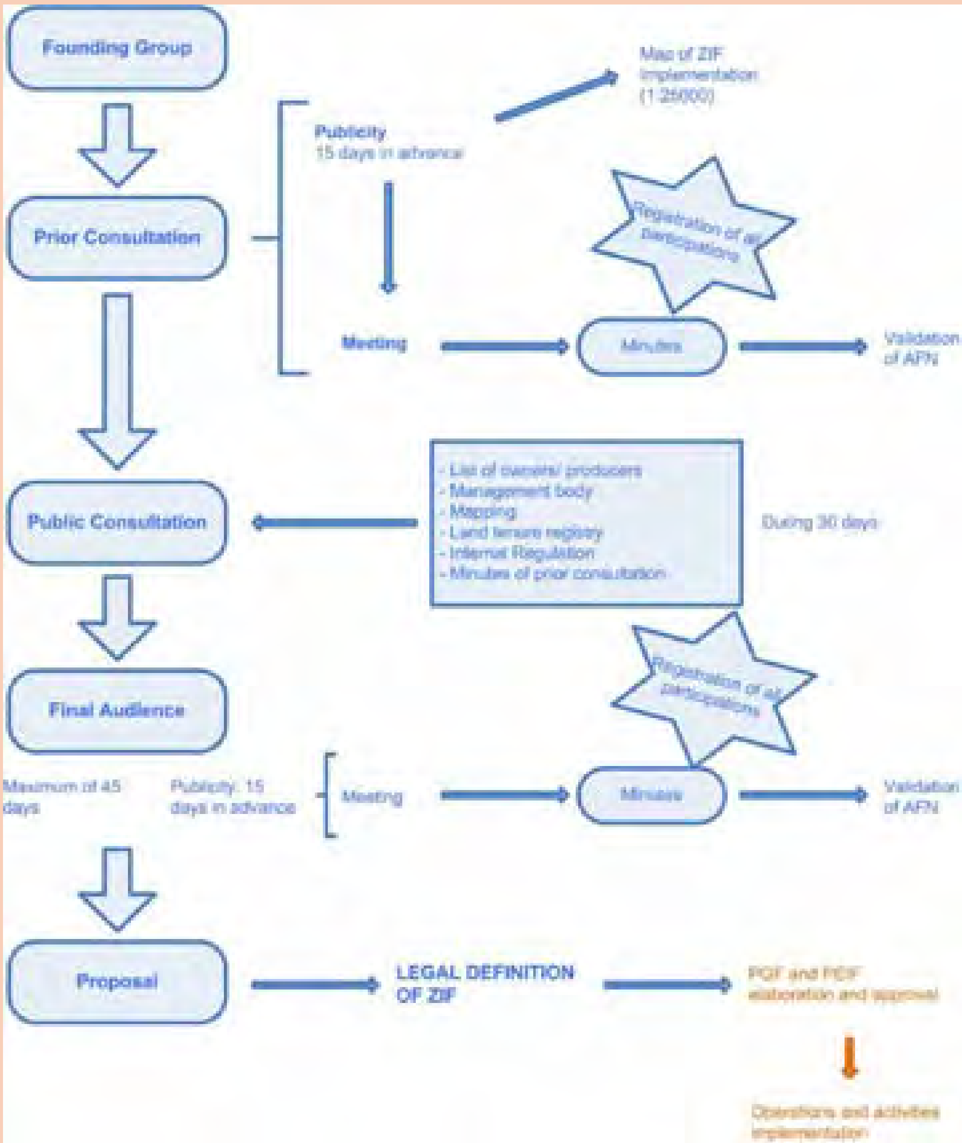
Decisions on choice of the Technology (ies): mainly by SLM specialists with consultation of land users
Decisions on method of implementing the Technology(ies): by SLM specialists alone (top-down)
Approach designed by: national specialists (based on an initial idea from Mação local specialists; the national ZIF legislation emerged in 2005 and was revised in 2009)
Implementing bodies: local community / land users, other (private organizations), local government (district, county, municipality, parish)

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Interactive	Balance alternatives and take decision to test the agave forestry information sessions about ZIF approach; informal contacts, door-to-door approaches and formal agreement of the landowners to become ZIF members
Planning	Passive	information sessions to present the ZIF plans (PGF and PEIF).
Implementation	Interactive	management activities can be made by the land owners or by the ZIF management entity. Regular meetings with ZIF members
Monitoring/evaluation	Interactive	not defined yet
Research	Interactive	on-farm research, good practice demonstration and collaboration with research projects.

Differences between participation of men and women: No

Involvement of disadvantaged groups: Yes (in the sense that the majority of forest owners are usually pensioners, with low incomes)



Organogram:

Legal process related with the ZIF constitution (blue)
Elaboration and approval of the ZIF plans (orange)
Implementation of the plans (orange)

Technical support

Training / awareness raising: Yes, through information sessions and individual contacts with opinion leaders.
Advisory service: Information sessions with the following key elements: 1. About ZIF process; 2. Explaining rational of ZIF for specific municipality and its conditions like depopulation, forest fires, etc.; 3. Elaboration of the ZIF plans. The extension system is well set up to ensure follow-up activities.
Research: Topics on forestry, politics, sociology, economics / marketing, ecology.
Mostly on station and on-farm research.

External material support / subsidies

Contribution per area (state/private sector): Yes, through FFP (Permanent Forest Fund) and QREN (National Strategic Reference Framework).
Labour: Voluntary: landowners can work on their properties or can be substituted by the ZIF management entity. Some activities, such as the implementation of the Primary Strips Network System for Fuel Management can be supported by the municipality services.
Input: Equipment (machinery, tools, etc.), printer, toners, map production (fully financed)
Credit: Not available
Support to local institutions: Yes. City council supports the forest association activities.

Monitoring and evaluation

Monitored aspects	Methods and indicators
The monitoring procedures are not structured yet	

Impacts of the Approach

Improved sustainable land management: Yes, to a considerable degree. Reduction of the number and likelihood of forest fires.
Adoption by other land users / projects: Yes, many instances. The initial social resistance to the approach will diminish through the existence of a successful ZIF.
Improved livelihoods / human well-being: Yes, moderate.
Improved situation of disadvantaged groups: Yes, moderate; It is expected that the increase in land productivity through the implemented technologies will help to improve the socio-economic situation of these rural groups.
Poverty alleviation: Yes, moderate. It is expected that the implementation of this approach will contribute to the improvement of rural socio-economic conditions through productivity increase, creation of employment and promotion of local products.

Training, advisory service and research:

Training effectiveness	Advisory service effectiveness
SLM specialists - good	Land users - good (Information sessions; Dissemination)

Land/water use rights: Private ownership greatly hinders the implementation of the approach, but the approach greatly reduces the land/water use rights problem.
Long-term impact of subsidies: Great positive long-term impacts
Main motivation of land users to implement: Rules and regulations (fines) / enforcement, affiliation to movement / project / group / networks, aesthetic, forest fires
Sustainability of activities: No, the forest owners do not have the financial capacity to apply and support these activities by themselves.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Improve forest management → promotion of the planting of more fire-resilient species which are better adapted to the local conditions. AFN should: (i) provide information about the guidelines; (ii) develop new policies and tools, which are more suitable to the local level; (iii) support and implement public awareness campaigns about forest values and services, and (iv) provide financial support to ZIF constitution and implementation activities.	Costs related to the approach → major financial support from the government needs to be provided.
Increase productivity → present land tenure and structure of forest holdings constitute a bottleneck for forest productivity. The integrated management of the ZIF will allow a better management and use of the land, increasing the exploitation of timber and non-timber products and also increasing the resilience to wildfires.	Rather complex process: unclear role for the non-adherent landowners within the ZIF; ZIF has to follow many laws and plans; control and monitoring activities still not defined → clarification and simplification of the bureaucratic process of the ZIF.
Restoration of burnt areas → The use of forest species to enable the protection and recovery of degraded soils or soils with high erosion risk has a very positive influence on the rehabilitation of burnt areas. However, many of these species are not economically attractive at short or medium term. The management of the land using ZIF model will allow the definition of the most affected areas for an urgent intervention.	Highly bureaucratic nature of the ZIF approach → simplification of the bureaucratic process.
Prevention of forest fires → the increase of forest management will contribute to the decrease of large forest fires. The implementation of integrated and global measures to fire prevention will be suitable within the ZIF approach.	Unattractive investment (low public support and lack of private support) → the need to review and reform the existing QREN or provide others means of support. Incentives to private initiative or donors should be found.
Social conscience → through awareness campaigns and information sessions provided at national and local level.	

Key reference(s): Decree- Law 127/2005, 5 August. Official Gazette n. 150 - I series A.: 4521-4527; Decree-Law 15/2009, 14 January. Official Gazette n. 9 - I series: 254-267; AFN (2011). Caracterização das Zonas de Intervenção Florestal. Lisboa, Autoridade Florestal Nacional: 54.

Contact person(s): Coelho Celeste, Valente Sandra, Soares João, Department of Environment and Planning, Centre for Environmental and Marine Studies, University of Aveiro, 3810-193 Aveiro, Portugal; coelho@ua.pt, sandra.valente@ua.pt

Above left and right: Stakeholders at the experimental plot with drip irrigation (Photos: Anatoly Zeiliguer)

Concerted thinking on common problems of water scarcity

Russian Federation - *:Жить рядом – думать об общей воде (Russian)*

Testing and disseminating a water-saving technology like drip irrigation

Aim / objectives: The objective of the Rural Development Programme (RDP) is to assist farmers who have to deal with difficult environmental conditions (drought, steep slopes) in applying sustainable farming practices either at the implementation phase or for maintenance. The programme is carried out to: 1) improve the socio-economic conditions of rural areas; 2) prevent land abandonment, and 3) prevent on-site and off-site damage caused by land degradation and erosion. To achieve these objectives, the RDP identifies different lines of action: 1) compensation for difficult natural conditions; 2) combating erosion; 3) reducing farming intensity; and 4) promoting eco-friendly agricultural practices.

Methods: The main method used in RDP is to provide farming subsidies for farming practices following a cross-compliance principle. Each line of action implies a combination of conservation measures that are subsidised, but only when applied in combination. Hence, single conservation measures outside of these lines of action are not subsidised.

Role of stakeholders: The level of subsidy is based on estimated implementation and maintenance costs and possible loss of productivity caused by the conservation measures. These values were obtained after consultation with various stakeholder groups including farmer organisations with agricultural cooperatives. However, because of limited resources, not all farmers will receive subsidies for conservation measures. Priority is given to: 1) farmers who have 50% of their land within the *Nature 2000* network, a European-wide network of protected areas for the preservation of habitats and threatened species; 2) farmers with >50% of their land in unfavourable zones; and 3) farmers who did not receive subsidy in previous RDPs.

Furthermore, areas with slopes of more than 20% are not subsidised in this programme since it is recommended that no agriculture should take place. Instead, reforestation of these areas is subsidised. RDPs are developed for a period of seven years. At the end of this period, a new RDP is defined and priorities and levels of subsidies may be changed. The present RDP is valid for the period 2007-2013.

Location: Russia, Pallasovsky district, Volgograd region
Approach area: 1000 km^2
Type of Approach: project/programme-based
Focus: on conservation only
WOCAT database reference: QA RUS001 on cdewocat.unibe.ch/wocatQA
DESIRE site information: www.desire-his.eu/en/dzhanibek-russia and www.desire-his.eu/en/novy-russia
Related technology(ies): Drip irrigation (QT RUS01
Compiled by: Anatoly Zeiliguer, Moscow State University of Environmental Engineering
Date: 27th Feb 2009, updated November 2011

Problems, objectives, and constraints

Problems:
The main problem to be addressed by this approach is the conflicts over the common use of water supplied to the villages. In this dry area, water is scarce and has to be brought from remote rivers, lakes and artificial water storage facilities through irrigation channels. In the dry season, when water demand exceeds availability, there is a pivotal problem of poor water availability for all villagers. During the most difficult period, water even has to be transported to the villagers' houses by car.

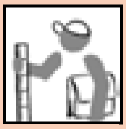
Aims / Objectives:
To consider the common problems of water scarcity at villages remote from water sources. To provide the best examples of water usage and initiate implementation of water-saving technologies.

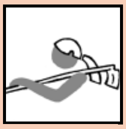
Constraints addressed

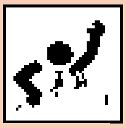
	Constraints	Treatments
Social / cultural / religious	People do not know much about water-saving technologies. Whatever they learn about, they are convinced that it is very complicated or too costly	Organization of training seminars, sharing ideas between farmers.

Participation and decision making

Stakeholders / target groups


SLM specialists / agricultural advisors


land users, individual, groups


politicians / decision makers

Approach costs met by:

international non-government (EU research project DESIRE)	100%
Total	**100%**

Annual budget for SLM component: US$2,000-10,000

Decisions on choice of the Technology(ies):): mainly by SLM specialists in consultation with land users
Decisions on method of implementing the Technology(ies): mainly by land users supported by SLM specialists
Approach designed by: national specialists
Implementing bodies: local community / land users

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Interactive	SLM specialists - introducing the technology to people Planners - introducing the technology to people ready for testing it
Planning	Interactive	SLM specialists - planning of test implementation Land users - agreement to test the technology
Implementation	Active – payment / external support (materials for drip irrigation)	SLM specialists – implementation of schemes development Land users – preparation of experimental plots
Monitoring/evaluation	Active – payment / external support (materials for drip irrigation)	Land users - simple monitoring of drip irrigation system performance
Research	Active – payment / external support (materials for drip irrigation)	Land users – reporting of water used for irrigation, workload and harvested yield

Differences between participation of men and women: No.
Involvement of disadvantaged groups: Yes, moderate. Owing to simple installation and control of drip irrigation, it is promising that disadvantaged people grow vegetables and fruits for their own consumption in order to improve their income and to save water for domestic use

Technical support

Training / awareness raising: Training provided for land users. Training in the form of demonstration areas, public meetings
Training focused on drip irrigation technology, knowledge about varying quantities for plants during the growing season according to the hydrological cycle, etc.
Advisory service:
Name: Drip irrigation technology
Key elements:
1. Water cycle: elaborated and explained to stakeholders during an initial stakeholder workshop as well as during field visits
2. Water-saving technologies: explained to stakeholders during stakeholder workshops. They were based on conceptual approaches and data gathered during field monitoring
The extension system is quite adequate to ensure continuation of activities. The government cannot provide special services in order to ensure its continuation; however, farmer-to-farmer dissemination is working.
Research: Yes, a moderate amount of research. The major topic covered the technology implementation
Mostly on station and on-farm research.
The implementation of drip irrigation technology under local conditions was performed by a team from the Moscow State University of Environmental Engineering under the framework of the EU-DESIRE project.

External material support / subsidies

Contribution per area (state/private sector): agricultural activities are subsidised by government
Labour: Voluntary, paid in cash and rewarded with material support. Materials (pipes for irrigation system, water tank) for the implementation of the experimental plots were supplied to land users. Some of the land users' activities, like monitoring of soil water capacity, were paid with small amounts of cash. Other work was implemented voluntarily.
Input:
Equipment – tools; fully financed. As this drip irrigation is in a testing phase, the materials for the irrigation system were financed by the project and not by the land users.
Credit: This was not made available.
Support to local institutions: Yes, moderate support with training
The local administration organized some demonstration and training activities for local users.

Monitoring and evaluation

Monitored aspects	Methods and indicators
bio-physical	*Ad hoc* measurements by government through farm visits and sampling of soils for chemical parameters (for example to control for ecological farming practices)
technical	Comparison of water consumption using drip irrigation and furrow irrigation. The very high water efficiency as well as the minimal rate of water used for crop growing by drip irrigation was clearly demonstrated.
economic / production	Ad hoc measurements by land users by comparing production between years

Changes as result of monitoring and evaluation: There were no changes in the approach, but there were several changes in the technology. Some changes were made as a result of bio-physical monitoring of plant development according to water quantities, fertilizer application, etc.

Impacts of the Approach

Improved sustainable land management: Yes, considerable; decreased water use.
Adoption by other land users / projects: Yes, some. Land users share their knowledge and experience with each other. Where this occurs, drip irrigation disseminates amongst the stakeholders.
Improved livelihoods / human well-being: Yes, moderate. Possibilities to grow vegetables, to increase their income and to diversify their food.
Improved situation of disadvantaged groups: Yes, moderate. It enables people with low income to avoid having to buy vegetables in the market by growing them for their own use and for sale.
Poverty alleviation: Yes, a little. The practice allows people to produce food on their subsidiary plots.
Training, advisory service and research:

Training effectiveness	Advisory service effectiveness	Research contributing to the approach's effectiveness
Land users - good	Land users - good	Moderately, research is not finished yet
SLM specialists - fair	Planners – good	
Agricultural advisor / trainers - good	Technicians / conservation specialists – good	

Land/water use rights: The implementation of the approach moderately hindered by existing land/water use rights.
Long-term impact of subsidies: Subsidies may help to start implementation that will have long-term positive impacts on efficient water use at villages with scarce water resources.
Main motivation of land users to implement: Production: by using this technology people can increase food production.
Well-being and livelihoods are improved: People want to save water, but also to improve their well-being
SLM Sustainability of activities: Yes, land users can sustain the approach activities.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Concerted thinking by stakeholders on common problems of water scarcity in villages remote from water sources → Provide best-practice examples of water usage and initiate implementation of water-saving technologies	Relatively high starting implementation costs
Sharing water-saving knowledge with other users → Implementation of water-saving technologies and dissemination of these skills to neighbours.	
Combating land degradation → sharing this knowledge with other users	
Reduction of labour input → Giving people more time for other activities	
Increasing the well-being of people: food availability for land users becomes enriched in terms of vegetables and some vegetables can be sold on the market → Dissemination of these opportunities to other people	

Key reference(s): Zeiliguer, A., G. Sokolova, V. Semeonv, O. Ermolaeva. Results of field experimentations at 2008 to grow tomatoes under drip irrigation at Pallasovsky District of Volgograd Region. Proceeding of conference at MSUEE. 2008, p. 45-56.
Contact person: Anatoly Zeiliguer, MSUEE – Moscow State University for Environmental Engineering, 19, Prjanishnikov Street, 127550 Moscow, Russia. Tel/fax:+7499 9764907, e-mail: azeiliguer@hotmail.ru

Above left and right: Discussion in a workshop on the usefulness of soil conservation measures and the need for agricultural subsidies (Photo: Joris de Vente).

Regional rural development programme

Spain - *Programa de desarrollo rural de la región de Murcia (Spanish)*

Regional development programme to protect natural resources and stimulate rural economies.

Aim / objectives: The objective of the Rural Development Programme (RDP) is to assist farmers who have to deal with difficult environmental conditions (drought, steep slopes) to apply sustainable farming practices either in the implementation phase or for maintenance. The programme is carried out to: 1) improve the socio-economic conditions of rural areas; 2) prevent land abandonment, and 3) prevent on-site and off-site damages caused by land degradation and erosion. To achieve these objectives, the RDP identifies different lines of action: 1) compensate for difficult natural conditions; 2) fight against erosion; 3) reduce farming intensity; and 4) promote ecological agriculture.

Methods: The main method used in the RDP is through subsidies of farming practices following a cross-compliance principle. Each line of action implies a combination of conservation measures that are subsidised, but only when applied in combination. Hence, single conservation measures outside of these lines of action are not subsidies.

Role of stakeholders: The level of the subsidy is based on estimated implementation and maintenance costs and possible loss of productivity caused by the conservation measures. These values were obtained after consultation of various stakeholder groups including farmer organisations with agricultural cooperatives. However, because of limited resources, not all farmers will receive subsidies for the conservation measures. Priority is given to: 1) farmers who have 50% of their land within the Nature 2000 network, a European wide network of protected areas for the preservation of habitats and threatened species; 2) farmers with >50% of their land in unfavourable zones; and 3) farmers who did not receive subsidy in previous RDPs.

Furthermore, areas with slopes of more than 20% are not subsidised in this programme since it is recommended that no agriculture takes place in these areas. Instead, reforestation of these areas is subsidised. RDPs are developed for a period of 7 years. Every seven years, a new RDP is defined and priorities and levels of subsidies can change. The present RDP is valid for the period 2007-2013.

Location: Murcia, Guadalentín basin, Spain
Approach area: 11,313 km^2
Type of Approach: project/programme-based
Focus: mainly on conservation with other activities
WOCAT database reference: QT SPA01 on cdewocat.unibe.ch/wocatQA
DESIRE site information: www.desire-his.eu/en/guadalentin-spain
Related technology(ies): Reduced contour tillage in semi-arid environments (QT SPA01), Vegetated bench terraces (QT SPA02), Ecological agriculture of almonds and olives using green manure (QT SPA05), Reduced tillage of almonds and olives (QT SPA06)
Compiled by: Joris de Vente, EEZA-CSIC
Date: 12 May 2009

Problem, objectives and constraints

Problems:
The main problems addressed by the approach are low income and low productivity of farmers in rural areas, subsequent land abandonment, and erosion and land degradation processes causing on-site and off-site damage.

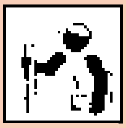
Aims / Objectives: 1) improve the socio-economic situation of rural areas; 2) prevent land abandonment; and 3) prevent on-site and off-site damage caused by land degradation and erosion.

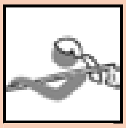
Constraints addressed

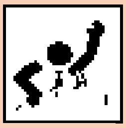
	Constraints	Treatments
Financial	Many technologies require an investment and maintenance, or even reduce productivity because they occupy land	A subsidy equal to the loss of productivity and implementation and maintenance costs.
Social / cultural / religious	The problem is not always recognised by everyone and certain practices are cultural	Information and training by the regional extension services and the farmers organisations.
Technical	Some technologies require establishment of vegetation cover, which is difficult under arid conditions	Advice about which vegetation types to use and subsidy to cover the implementation costs.

Participation and decision making

Stakeholders / target groups


SLM specialists, agricultural advisors


land users, groups


politicians, decision makers

Approach costs met by:

International	41%
Government	10%
local government (district, county, municipality, village, etc.)	49%
Total	**100%**
Total budget	US$> 1,000,000

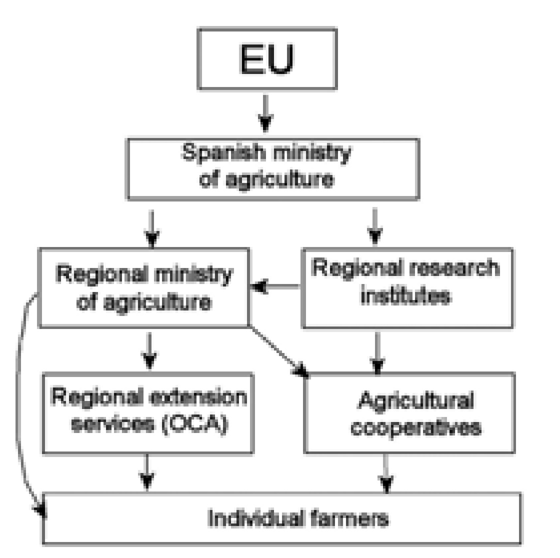
Decisions on choice of the Technology(ies): mainly by SLM specialists
Decisions on method of implementing the Technology(ies): by politicians / leaders
Approach designed by: national specialists, international specialists
Implementing bodies: international, government, local government (district, county, municipality, village, etc.), land users

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Self-mobilisation	Petitions towards policy makers and farmers organizations to pay attention for production under difficult environmental conditions
Planning	Interactive	Land users were sporadically consulted through farmers organizations, and participated in protest meetings against initial versions of the RDP that they considered insufficient regarding payments for the agricultural sector
Implementation	Interactive	Land users implemented SLM technologies themselves with help from technicians of regional government and farmers organisations
Monitoring/evaluation	None	
Research	None	

Differences between participation of men and women: Yes, moderate. Traditionally land users and agricultural activities are dominated by men.

Involvement of disadvantaged groups: Yes, little. The focus of the approach is on the socio-economic situation of farmers with a relatively low income and under marginal conditions.



Organogram
To be fit for purpose, since 2007 the RDPs are designed at the regional level using advice from scientific institutes. The boundary conditions regarding the overall environmental and economic objectives and available finances are received from the European and national level. The regional extension services have a role in the dissemination of information and control of correct implementation of measures by farmers.

Technical support

Training / awareness raising: Training provided for field staff/agricultural advisor. Training was on-the-job through site visits and farmer to farmer. Training focused on technical assistance for implementation of technologies by technicians of farmers' organisations and from the extension services.
Advisory service: Name: agricultural extension services (Oficina Comarcal Agraria, OCA)
Key elements: 1. Control 2. advice
Currently, the extension system is strongly focused on control rather than advice and training activities. There is more information and awareness building required for land users. Information is often only available at political/research level and to some extent at the level of the farmers organisations but not at farm level.
Research: Yes, moderate research. Topics covered include economics / marketing, ecology, technology, geography. Results from national and international research projects of recent decades were used as well as experimental results from regional and national research institutes such as the 'Instituto Murciano de Investigación y Desarrollo Agrario y Alimentario'(IMIDA) and the Spanish national research council (CSIC).

External material support / subsidies

Contribution per area (state/private sector): Yes. Subsidies are provided by the regional ministry, state and EU programmes.
Labour: Land users implement measures themselves on a voluntary basis
Input:
- Agricultural (seeds, fertilizers, etc.): seeds, partly financed; fertilizer and biocides, fully financed
- Construction material (stone, wood, etc.): stones, fully financed
- Productivity loss: Fully financed

Credit: Credit was not available.
Support to local institutions: Yes, little support with training. Information to agricultural cooperatives**.**

Monitoring and evaluation

Monitored aspects	Methods and indicators
bio-physical	*Ad hoc* measurements by government through farm visits and sampling of soils for chemical parameters (for example to control for ecological farming practices)
technical	*Ad hoc* measurements by government through farm visits to control the actual implementation of SLM measures
economic / production	*Ad hoc* measurements by land users by comparing production between years
area treated	Regular observations by government by farm visits and mapping with GIS tools
no. of land users involved	Regular observations by government by documentation of all farmers who participate in the subsidy programme

Changes as result of monitoring and evaluation: There were several changes in the approach and the associated technologies. RDP's are evaluated and redefined every 7 years.

Impacts of the Approach

Improved sustainable land management: Yes, moderate. Awareness and motivation to apply SLM amongst land users has increased due to the approach.
Adoption by other land users / projects: Yes, many. RDPs are developed for all regions in Spain, and need approval from national government and from the EU.
Improved livelihoods / human well-being: Yes, little. Because of the approach the economic situation of farmers is slightly improved.
Improved situation of disadvantaged groups: Yes, moderate. Because of the approach the economic situation of farmers in marginal areas is slightly improved.
Poverty alleviation: Yes, little. Because of the approach the economic situation of farmers in marginal areas is slightly improved.
Training, advisory service and research:

Training effectiveness	Advisory service effectiveness	Research contributing to the approach's effectiveness
(There is strong lack of training of land users.) Land users - poor SLM specialists - fair Agricultural advisor / trainers - good	Land users - poor Politicians / decision makers - fair	- Moderately Advice from various research institutes was used to design the RDP and technologies.

Land/water use rights: None hindered the implementation of the approach
Long-term impact of subsidies:
Positive (moderate) long-term impact. The subsidies are there during the period of the RDP. In a new phase of a RDP a subsidy may disappear or change considerably. This introduces a level of uncertainty for farmers to make long-term investments.
Main motivation of land users to implement:
Rules and regulations (fines) / enforcement
Payments / subsidies
Environmental consciousness, moral, health
SLM Sustainability of activities:
It is uncertain whether the land users will be able to sustain the approach activities.

Concluding statements

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
The approach is an effort to provide an integrated way of how SLM can be achieved. Therefore, no separate measures but a complete SLM plan at the farm level → Include more SLM measures in the approach.	There is a lack of land user participation in the design, implementation and training of the approach → Organise stakeholder meetings, information sessions and trainings for land users.
All implementation and maintenance costs as well as loss of productivity are subsidised → There should be enough funding for all farmers willing to apply the measures, and there should be continuity between new versions of the RDPs.	There is a lack of transparency in communication → Farmers' organizations and regional extension services should have a more active role to coordinate activities and communication
	There is a lack of organization amongst land users → Farmers' organizations and regional extension services should have a more active role in co-ordinating activities and communication.

Key reference(s): CARM 2008. Programa de Desarrollo Rural de la Región de Murcia 2007-2013 Tomo I. 508pp, http://www.carm.es/neweb2/servlet/integra.servlets.ControlPublico?IDCONTENIDO=4689&IDTIPO=100&RASTRO=c431$m1219
Contact person : Joris de Vente, EEZA-CSIC, Joris@sustainable-ecosystems.org

Above left: Stakeholders discussing in the field various aspects of SLM approach. (Photo: Cyprien Hauser).
Above right: The system is based on various runoff water harvesting systems, as jessour, tabias. (Photo: Mongi Sghaier).

Dryland watershed management approach

Tunisia

Integrated land and water management approach, including vegetative, management, and agronomic measures.

Aim / objectives: The overall purpose of the approach is to prevent soil and water loss by combined measures and to provide a better environment. Soil and water conservation (SWC) technologies, based on harvesting area of surface water and underground water, are implemented to conserve soil and water and to improve the production and the biodiversity.

Methods: This approach is designed for the exploitation of water runoff for agricultural development, particularly for fruit trees cropping (mainly olives). This can be achieved through erosion reduction and aquifer recharge via runoff water infiltration into the terraces, slope angle and length reduction, runoff retaining, infiltration increase and soil loss reduction.
The system is based on various runoff water harvesting systems, as jessour, tabias. It is marked by fruit tree development, notably olives. On the terraces, the fruit trees are arranged in inter-rows with the three main species encountered in the study areas. Generally, olive trees are planted, with in between rows almonds and/ or fig trees.
SWC technologies play an importance role in arid zones. Since the 1970s, the Tunisian state has encouraged the local population to conserve water and soil in arid zone. Successive programmes and strategies of water and soil conservation have been developed and were implemented in all three natural regions of Tunisia (North, Centre and South).These techniques can be implemented by farmer with governmental subsidies or by government intervention in the projects and programmes of water and soil conservation. During the last decade, the Tunisian government implemented the first national strategy for soil and water conservation (1990-2000) and the second national strategy for soil and water conservation (2001-2011). These strategies mobilized important funds at national and regional levels. About 672.5 ha of SWC technologies were built and about 550 ha of SWC technologies are planned for the second national strategy.

Stages of implementation: 1) Assessment of the current natural resources and socio-economic conditions; 2) Proposition of actions at local and regional level; 3) Aggregation and coherence at the national level; 4) implementation of national action plan at local and regional level.

Role of stakeholders: Different levels of intervention are observed from the individual farm, through the community level, the extension / advisory system, the regional or national administration, or the policy level, to the international framework. The participative approach is usually applied in the construction of SWC technologies.

Location: Oum Zessar Watershed, South-east of Tunisia
Approach area: 350 km^2
Type of Approach: recent initiative / innovative
Focus: on conservation only
WOCAT database reference: QA TUN09 on cdewocat.unibe.ch/wocatQA
DESIRE site information: www.desire-his.eu/en/zeuss-koutine-tunisia
Related technologies: Rangeland resting (QT TUN11), Gabion check dams (QT TUN10), Jessour (QT TUN09)
Compiled by: Mongi Sghaier, Mohamed Ouessar, Mongi Ben Zaied, Naceur Mahdi, IRA, Tunisia
Date: 9th Jun 2009, updated Sep 2011

Problem, objectives and constraints

Problems: The problems originate in the scarcity of water which is leading to conflicts over resource use between farmers.
Oversized techniques leading to prevention of runoff from upstream to downstream reduce agricultural production and therefore the farm income, which causes a lack of cash to invest in SLM. In some cases irreversible land degradation is the result. The problems are mainly related to the lack of technical knowledge, the high costs of investment and the lack of tangible and assessable impacts of SWC activities, technically or socially.

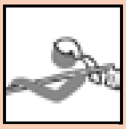
Aims / Objectives: The objectives of the approach are to control soil and water loss to reduce floods and enhance fertility, to enhance rainfed agriculture productivity, to improve the livelihoods of farmers, to contribute to the production increase among farmers and pastoralists, to recharge the groundwater and to extend the area of cropland.

Constraints addressed

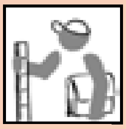
	Constraints	Treatments
Financial	High cost investment	Public projects (National strategy of SWC), subsidies
Institutional	Land fragmentation, complexity of land tenure	Users organization, participation
Technical	Designing parameters	Training , enhancing SWC specialists guidance

Participation and decision making

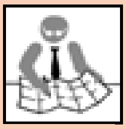
Stakeholders / target groups



land users, individual and groups



SLM specialists / agricultural advisors



planners

Approach costs met by:

International	20%
Government	55%
Local community / land user(s)	20%
National non-government	5%
Total	**100%**

Total budget: US$ 10,000 - 100,000

Decisions on choice of the Technology (ies): mainly by land users supported by SLM specialists
Decisions on method of implementing the Technology(ies): mainly by SLM specialists with consultation of land users
Approach designed by: national specialists, international specialists, land users
Implementing bodies: government, local community / land users

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Interactive	Farmers and local population are very familiar with traditional SWC applied. Therefore the receptiveness to these techniques is very high. There is state encouragement through subsidies.
Planning	Interactive	Workshops/seminars; After a programme is granted, the implementing agency and local communities work together.
Implementation	Payment/external support	Responsibilities are divided into major steps; In practice, local communities are the major part to manage and carry out.
Monitoring/evaluation	Interactive	Participative evaluation; Interviews/questionnaires.
Research	Interactive	It can give some suggestions or questionnaires.

Differences between participation of men and women: These are moderate. Special attention has been paid to make women participate in the approach. Nevertheless, men have much more technical knowledge and skills than women.
If SWC technologies have to be constructed by manual labour, men can achieve more.

Involvement of disadvantaged groups: Yes, great
Poor and old people are especially involved through their participation in the special programme against unemployment in rural area. Some unemployed young people may benefit from agricultural development programmes.

The treatment of the catchment starts from the upstream and continues to piedmont areas, and ends in the downstream section of the catchment. Attention should be given to ensure sufficient water allocation to all the sections of the catchment as well as to the different users (rainfed agriculture and rangelands, irrigated areas, drinking water, industry and tourism). (Drawing: Patricia Home, in Genin D., Guillaume H., Ouessar M., Ouled Belgacem A., Romagny B., Sghaier M., Taamallah H. (Eds.), 2003: Entre Désertification et Développement: la Jeffara tunisienne. IRA-IRD.)

Technical support

Training / awareness raising: Training was provided for land users and field staff/agricultural advisors. The capacity building programme and activities have benefited farmers representing the diversity of land users (women and men); representatives of NGO; local and external stakeholders, engineers and technicians responsible of the services of agriculture and forest. Training focused on teaching them how to design and build SWC technologies, how to implement these technologies and about the participatory approach.

Advisory service: 1) Training and demonstration open days; 2) Demonstration plots implemented in private farms; 3) Target farmers groups are visited by specialist to help and advise them.
The extension system is adequate to ensure continuation of activities. At each governorate level, there is a SWC division which is in charge of SWC activities, including its extension.

Research: There has been good use of research results. Topics covered include technologies and approaches. Mostly on station and on-farm research. Land users have been involved. SWC technologies construction is based on scientific design, according to local conditions.

External material support / subsidies

Contribution per area (state/private sector): Yes, construction material
Labour: Voluntary, rewarded with in-kind support by government subsidies
Input: Machinery equipment and construction material (stone) was partly financed, fertilizer was not financed.
Credit: Credit was promoted through agricultural banks with various interest rates, usually lower than market rates
Support to local institutions: moderate support with financial resources, capacity building, training, institutional support.
The financial schema is made of three main components: self-financing from farmers and beneficiaries, subsidies from the government and credit from bank.

Monitoring and evaluation

Monitored aspects	Methods and indicators
bio-physical	Ad hoc measurements by project staff – Indicators are runoff loss, sediment load, soil moisture
socio-cultural	Ad hoc observations by project staff – Investigation of land users perceptions of cultural change
economic / production	Ad hoc measurements by project staff - investigation/ of yield, income of land users, rainfed productivity
area treated	Ad hoc measurements by government
management of Approach	Ad hoc measurements by government - Impact assessment

Changes as result of monitoring and evaluation: There were few changes in the approach for local adaptation, for example at the institutional level.

Impacts of the Approach

Improved sustainable land management: Yes, moderate. Land users can harvest water and irrigate crops in dry seasons. Meanwhile, the cropland area is enlarged.
Adoption by other land users / projects: Yes, many.
Improved livelihoods / human well-being: Yes, there is considerable improvement, because of increased farm income.
Improved situation of disadvantaged groups: Yes, considerable; for disadvantaged women and men, there are employment opportunities and food self-sufficiency.
Poverty alleviation: Yes, considerable; this approach increases the farm income, the food self-sufficiency and employment opportunities
Training, advisory service and research:

Training effectiveness	Advisory service effectiveness
Land users - good	Land users - good
SLM specialists - good	Politicians / decision makers - good
Politicians / decision makers –good	

Training was effective for all target groups. The land users accept the approach when they get the real benefit. The decision makers accept the approach when they realize that the approach can produce combined social, economic and ecological benefits.

Land/water use rights: The approach helped in the privatization of the land and has therefore greatly reduced the land/water use rights problems. This in turn has rendered the local interventions much more efficient.

Long-term impact of subsidies: As more and more payment is currently being made to land users on the basis of the area treated, land users rely more and more on being paid for investments into SWC. The willingness to invest in SWC measures without receiving financial support has decreased. Thus the use of incentives in the current approach is considered to have a negative long-term impact.

Main motivation of land users to implement: Increased profit(ability), improve cost-benefit-ratio by increasing farm income, production by increasing yield and food self-sufficiency, payments / subsidies by investing in SWC technologies, well-being and livelihoods improvement by more employment opportunities.

SLM: Sustainability of activities: It is uncertain whether the land users will be able to sustain the approach activities.

Concluding statements

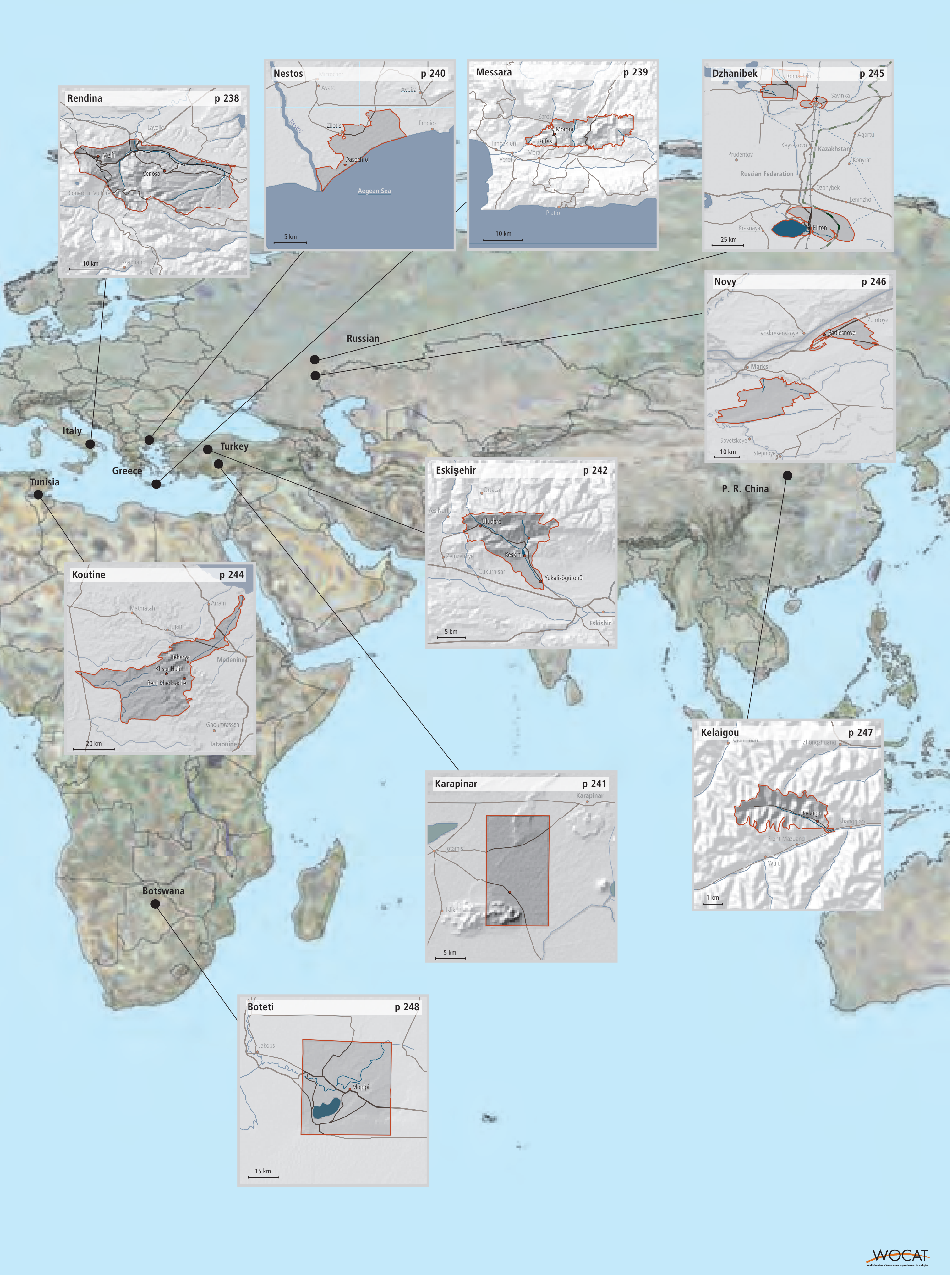
Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Many people involved and trained at different levels (pyramid system) → participatory approach	High costs: farmers depend on external support from the government; they are not willing to invest their labour without payments → New approach should give farmers loans for construction as now they use machines to do the work. In addition, search for cheaper SWC technologies and for improving the benefits.
More participation and involvement of local population → Improve participatory approach and increase confidence between partners	Less confidence between partners and less participation → improve dialog and communication; improve efficiency of SWC activities and participatory approach.
Improvement of livelihood → spreading and improvement of a more holistic SLM approach focusing on livelihoods	Low impact on livelihood conditions → improve efficiency of SWC activities and participatory approach
Reduction of soil erosion → ensure the durability of the works implemented	Abandonment of the works, less maintenance → Continue to support farmers and local institution and organisation. Repairing and maintaining in time.

Key reference(s): Genin D., Guillaume H., Ouessar M., Ouled Belgacem A., Romagny B., Sghaier M., Taamallah H. (Eds) 2006. Entre la désertification et le développement : la Jeffara tunisienne. CERES, Tunis; de Graaff J. & Ouessar M. (Eds.) 2002. Water harvesting in Mediterranean zones: an impact assessment and economic evaluation. TRMP paper n° 40, Wageningen University, The Netherlands

Contact person(s): Sghaier Mongi (sghaier.mon@gmail.com), Ouessar Mohamed (Med.Ouessar@ira.agrinet.tn), Institut des Régions Arides, 4119 Medenine, Tunisia

Desire for Greener Land

Location of mapping case studies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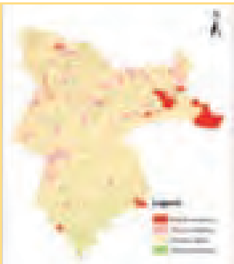
2.2 Mapping case studies

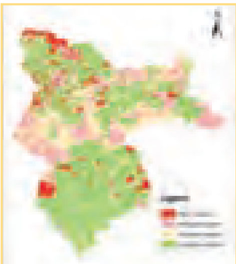
This section shows examples of degradation and SLM maps of the DESIRE study sites. The aim is to give a spatial overview of the land degradation phenomena and of SLM technologies in the areas, complementary to the information provided by the individual case studies on Technologies (QT) and Approaches (QA) in section 2.1. The maps were created using the WOCAT-LADA-DESIRE mapping methodology (WOCAT/LADA/DESIRE 2008), as described in chapter 1.2. The various map themes of land degradation and SLM that can be produced with the method are explained in the table below. The selection of map themes per study site includes the land use type map, which served as base map for determining land degradation and SLM, plus three other map themes. The three themes, which may vary between different sites, were chosen to illustrate some of the spatial relationships between the land use types and degradation and SLM in each site.

Land use

Land use type
Featuring the main land use types, e.g. cropland, grazing land, forest/woodland, mixed land use, or other land use. In some cases including subdivisions of main land use types, for example cropland into annual and perennial cropping and grazing into extensive or intensive grazing. Further subdivisions are possible based on physiographic or geomorphologic criteria, administrative units or socio-economic criteria.

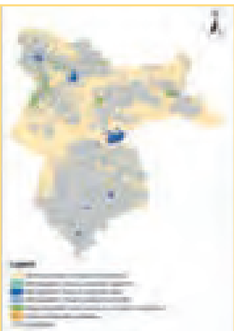


Area trend of land use
The increase or decrease in areas with the major land use types over the past 10 years.



Intensity trend of land use
The increase or decrease in intensity of use of the major land use types over the past 10 years.

Land degradation



Dominant types of land degradation
The major types of land degradation, each with several subtypes:

B: Biological degradation, e.g. reduction of vegetation cover (Bc), quality and species composition / diversity decline (Bs), detrimental effects of fires (Bf), quantity / biomass decline (Bq)

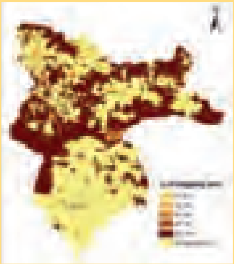
C: Chemical soil deterioration, e.g. soil fertility decline/loss of organic matter (Cn), salinisation (Cs)

E: Soil erosion by wind, mainly loss of topsoil (Et)

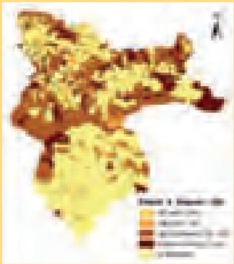
H: Water degradation, e.g. aridification (Ha), change in quantity of surface water (Hs), change in groundwater / aquifer level (Hg)

P: Physical soil deterioration, e.g. compaction (Pc) and sealing/crusting (Pk)

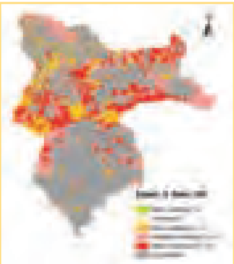
W: Soil erosion by water, e.g. sheet erosion (Wt), gully erosion (Wg), mass movements (Wm) or off-site effects like flooding and siltation (Wo)



Extent of land degradation
Extent of the degraded area in % of the area of each map unit.

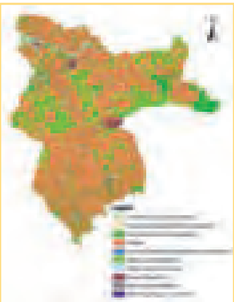


Degree of land degradation (weighted by area)
The degree of degradation, referring to the intensity of the land degradation process, weighted against the extent for each map unit: Degree * Extent (%)/100.



Rate of land degradation (weighted by area)
The degradation rate indicates the trend of degradation over the past 10 years, weighted against the extent for each map unit: Rate * Extent (%)/100.

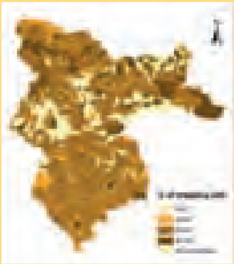
Land conservation



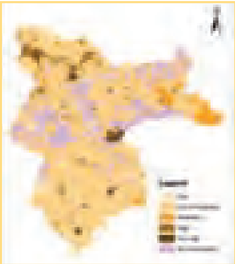
Land conservation groups
SLM technologies are clustered into groups which have names familiar to most SLM specialists and rural development specialists. The technology groups cover the main types of existing SLM systems.

CA: Conservation agriculture / mulching
NM: Manuring / composting / nutrient management
RO: Rotational system / shifting cultivation / fallow / slash and burn
VS: Vegetative strips / cover
AF: Agroforestry
AP: Afforestation and forest protection
RH: Gully control / rehabilitation
TR: Terraces
GR: Grazing land management
WH: Water harvesting
SA: Groundwater / salinity regulation / water use efficiency
WQ: Water quality improvements
SD: Sand dune stabilization
CB: Coastal bank protection
PR: Protection against natural hazards
SC: Storm water control, road runoff
WM: Waste management
CO: Conservation of natural biodiversity
OT: Other

Land conservation measures
A conservation measure is a component of an SLM Technology, which may consist of a combination of several conservation measures. The WOCAT framework distinguishes four categories of conservation measures:
1. Agronomic (e.g. mulching)
2. Vegetative (e.g. contour grass strips)
3. Structural (e.g. check dams)
4. Management (e.g. resting of land)



Land conservation – total area extent
Extent of the area under SLM measures in % of the area of each map unit.



Effectiveness of conservation measures (weighted by area)
Effectiveness of SLM measures in reducing the degree of degradation or preventing degradation, weighted against the extent for each map unit: Effectiveness * Extent (%)/100.

Effectiveness trend of conservation measures (weighted by area)
Historical trends in the effectiveness of conservation measures. The increase or decrease in effectiveness was assessed over the past 10 years, weighted against the extent for each map unit: Effectiveness trend * Extent (%)/100.

Land recommendation

Expert recommendation
Expert recommendation concerning interventions on how to address degradation:

A: Adaptation to the problem: the degradation is either too serious to deal with and is accepted as a fact of life, or it is not worthwhile the effort to invest in.

P: Prevention implies the use of conservation measures that maintain natural resources and their environmental and productive function on land that may be prone to further degradation, where some has already occurred. The implication is that good land management practice is already in place: it is effectively the antithesis of human-induced land degradation.

M: Mitigation: is intervention intended to reduce on-going degradation. This comes in at a stage when degradation has already begun. The main aim here is to halt further degradation and to start improving resources and their functions. Mitigation impacts tend to be noticeable in the short to medium term: this then provides a strong incentive for further efforts. The word 'mitigation' is also sometimes used to describe reducing the impacts of degradation.

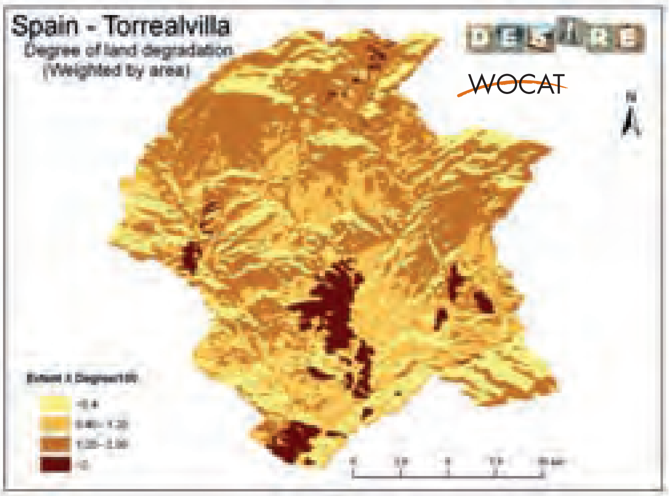
R: Rehabilitation: is intervention when the land is already degraded to such an extent that the original use is only possible with extreme efforts as land has become practically unproductive. Here longer-term and more costly investments are needed to show any impact.

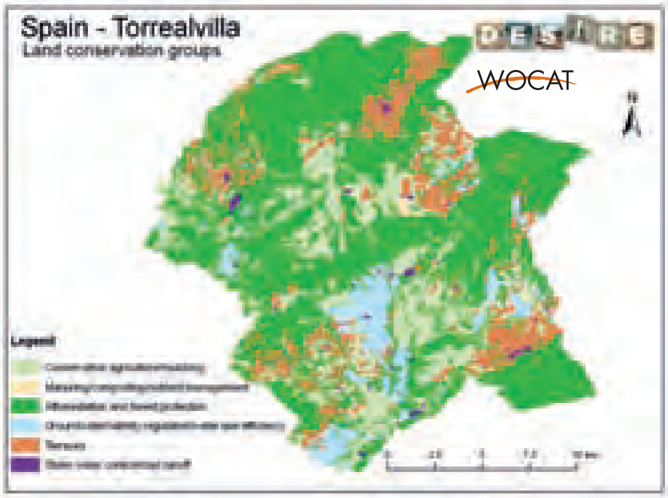
References:

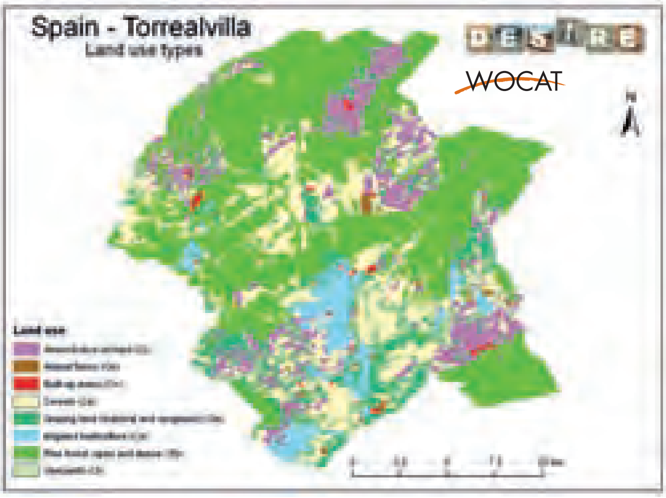
- WOCAT/LADA/DESIRE 2008. A Questionnaire for Mapping Land Degradation and Sustainable Land Management. Liniger H.P., van Lynden G., Nachtergaele F., Schwilch G. (eds), Centre for Development and Environment, Institute of Geography, University of Berne, Berne.

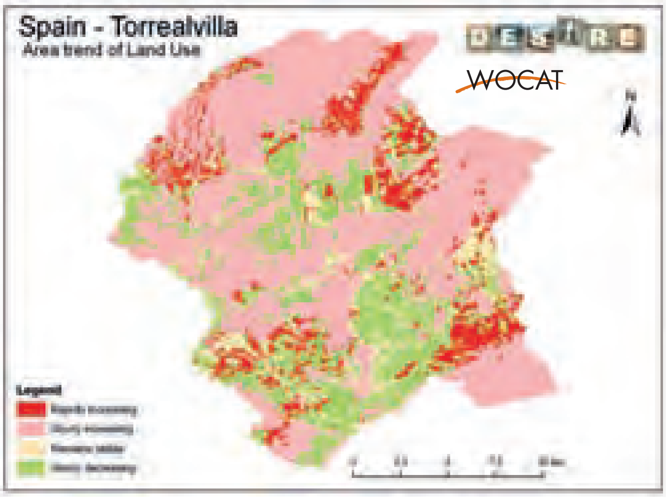
Spain – Torrealvilla

The Torrealvilla area has many different land uses, including pine forest, almond and olive orchards, cereals, irrigated horticulture, viticulture and grazing in shrub- and rangelands. The area covered by orchards is rapidly increasing, while the area with cereals is decreasing. Land degradation is predominantly in the form of surface erosion by water, and by the decrease of the groundwater level in irrigated areas. The degradation is most severe (at highest degree) in the area with irrigated horticulture, and in some of the almond and olive orchards. About half of the area is already treated with various conservation measures: vegetative measures addressing tree and shrub cover in the areas covered by forest, the orchards and the grazing land, structural measures in the irrigated land, and agronomic measures addressing the cover of the soil surface in the land with cereal culture. Although the effectiveness of some of these measures is high, especially in the irrigated area, experts recommend SLM technologies targeted to prevention and mitigation of SLM in all non-forest land use types. An example from the ones documented in this book is the use of concentrated runoff by water harvesting for irrigation purposes, to reduce the extraction of irrigation water from the groundwater.



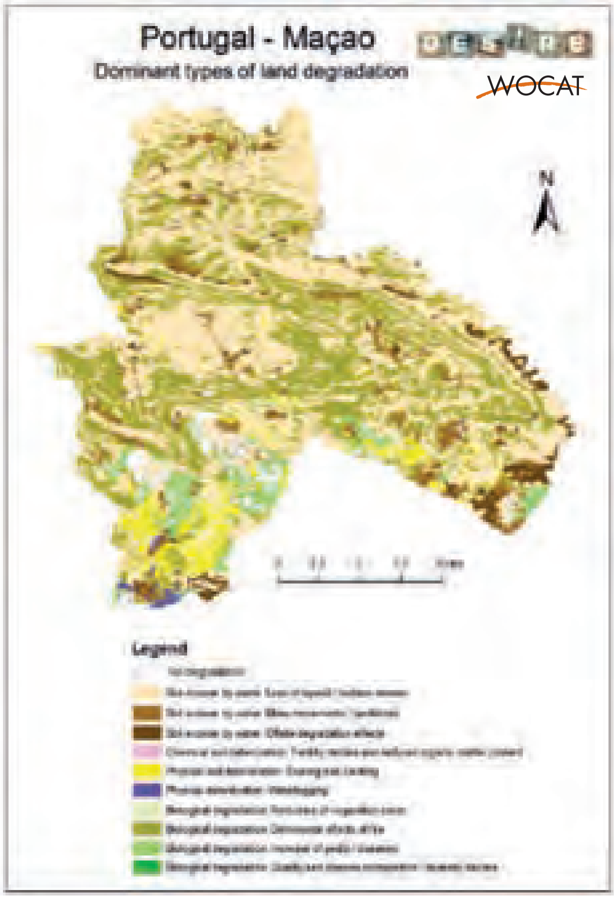






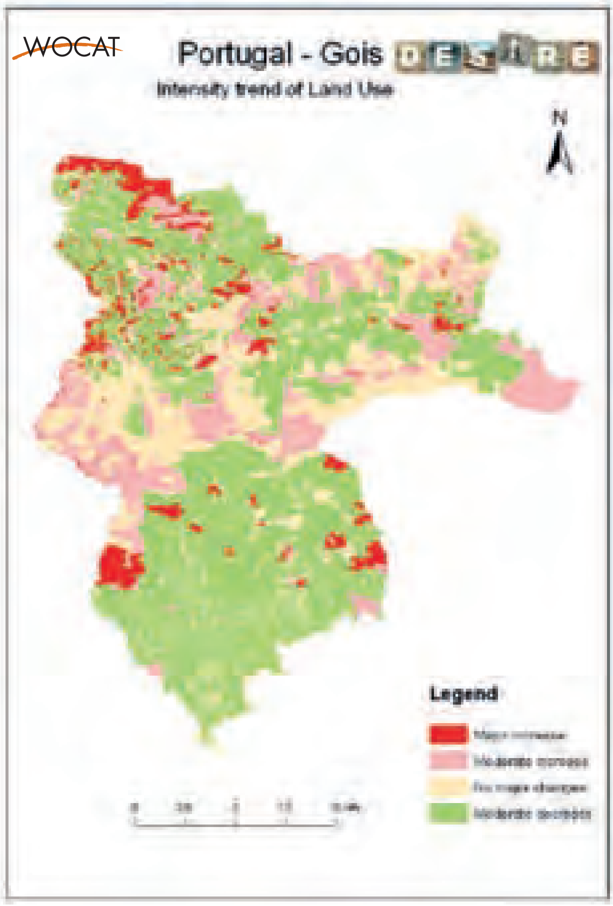
Portugal – Maçao

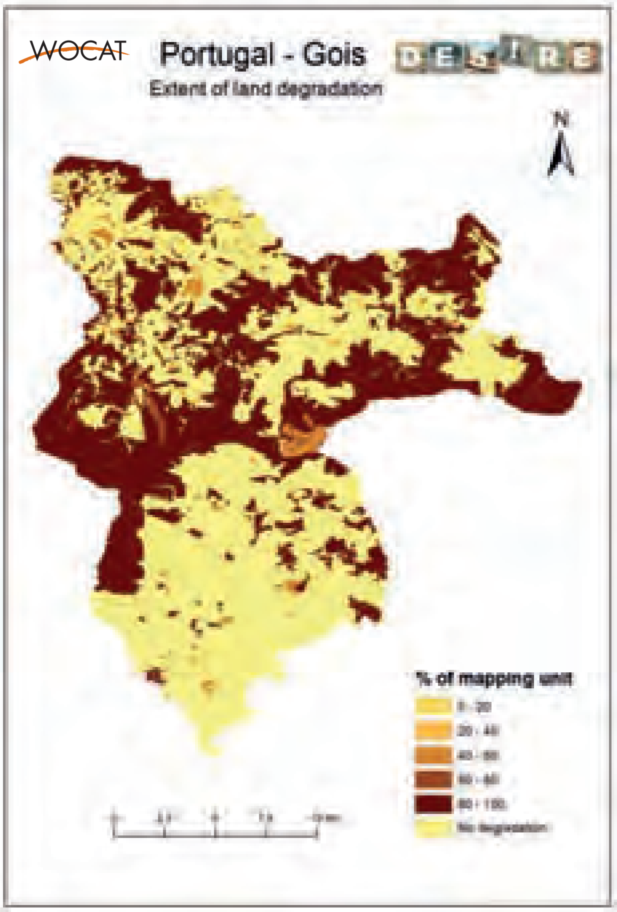
The Maçao area has widespread land degradation in the forest in the form of soil erosion by water and biological degradation due to fire. Soil erosion by water is also reported to affect the cropland, where its rate is slowly increasing, but the degree is larger in the forest. Conservation measures to remediate the soil erosion are implemented over more than 80% of the forested area with soil erosion. These include agronomic measures, aiming to increase the vegetation and soil cover. However, the effectiveness of these measures is low and decreasing. This offers scope for the SLM technologies documented in this book (primary strip network system for fuel management and prescribed fire).

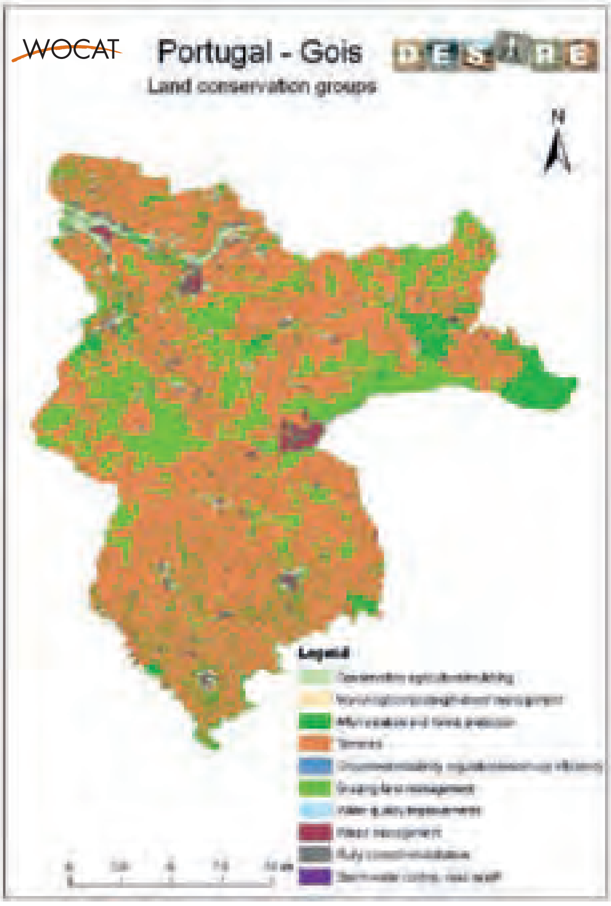


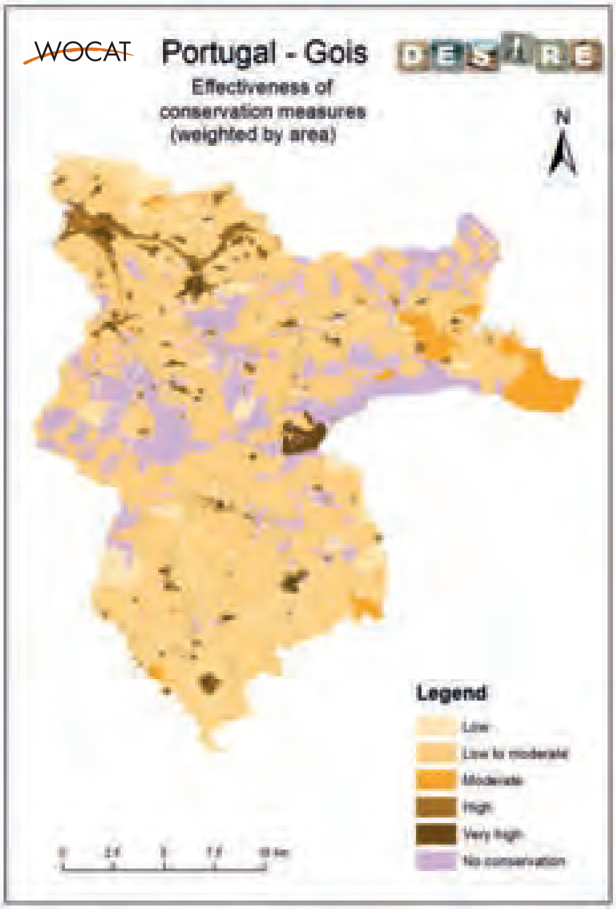
Portugal – Góis

The Góis area is covered with Eucalyptus and Pine forest, with a major increase of use intensity in parts, and at the same time a decrease in other parts. Land degradation (by soil erosion and some biological degradation) is extensive in the areas with increasing intensity of use of the forest due to out-migration of the land users. In these areas, there are no conservation measures at present, or measures with low effectiveness (terraces). SLM technologies remediating the incidence of forest fires (primary strip networks and prescribed fire) are proposed for the area and described in this book.



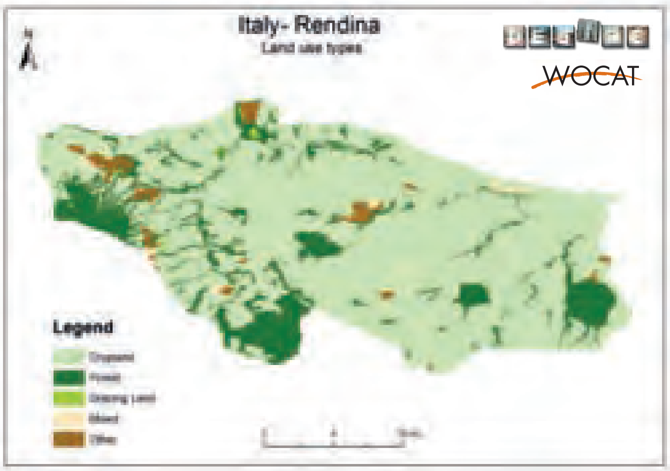


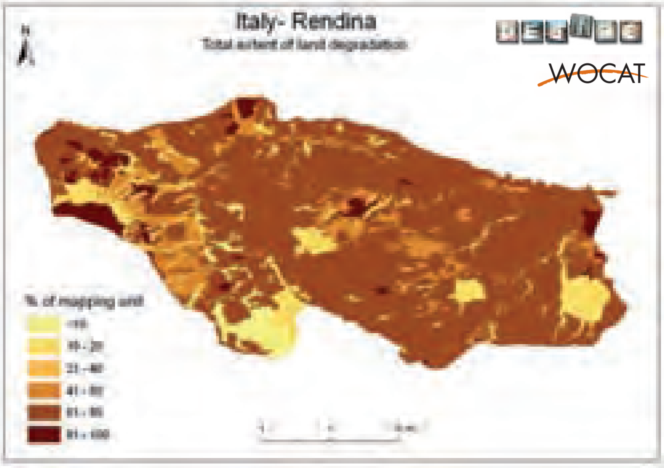


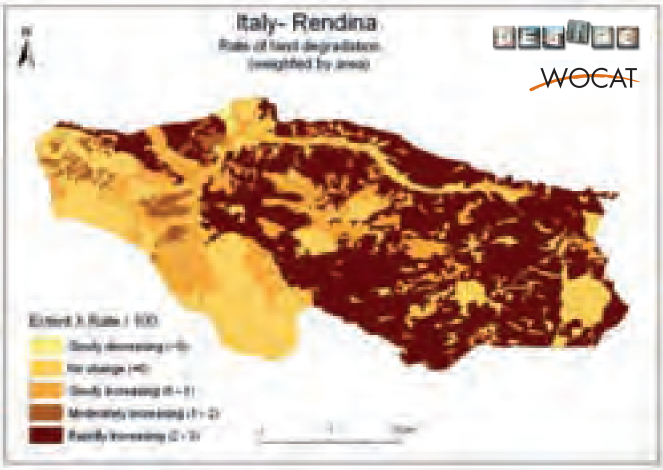


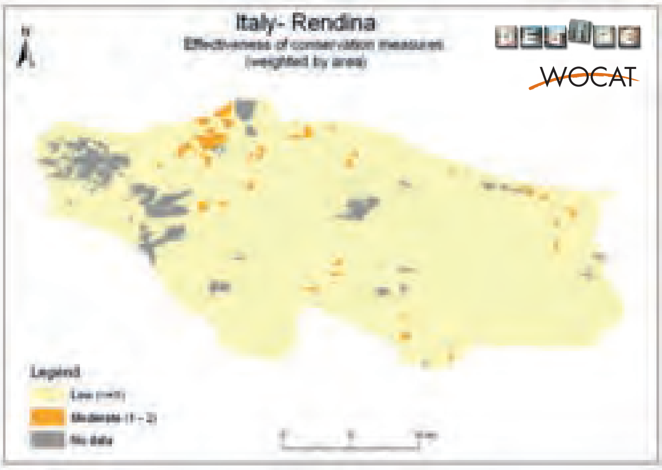
Italy – Rendina

The Rendina area experiences soil erosion by water in large parts of the area under cropland (>60%), at a rapidly increasing rate. This is aggravated by land levelling. Existing conservation measures (no tillage, fallow and cover crops) are inadequate in reducing the soil erosion. This is testified by the low effectiveness of current conservation measures.



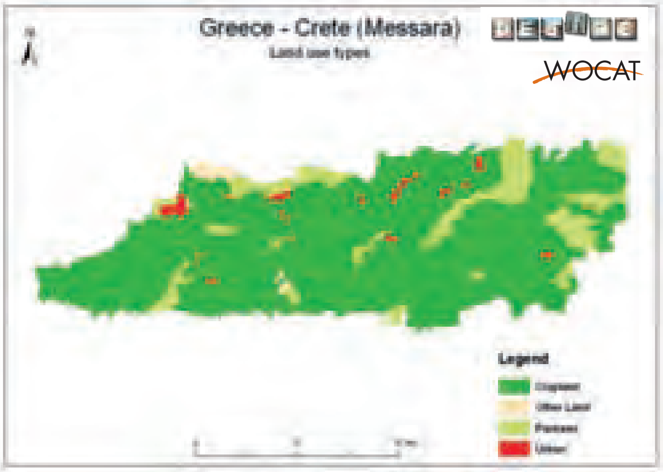


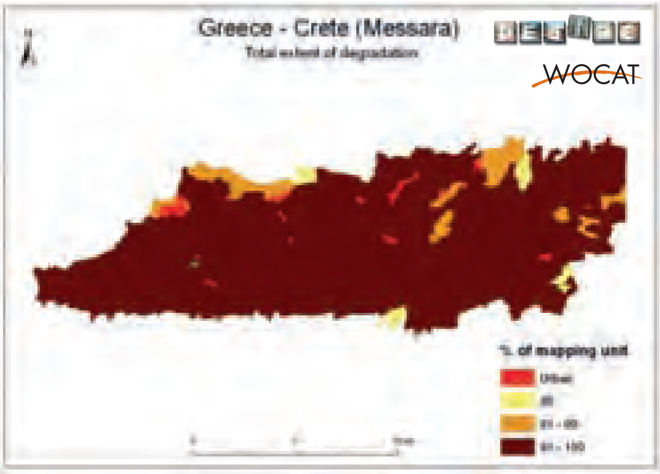


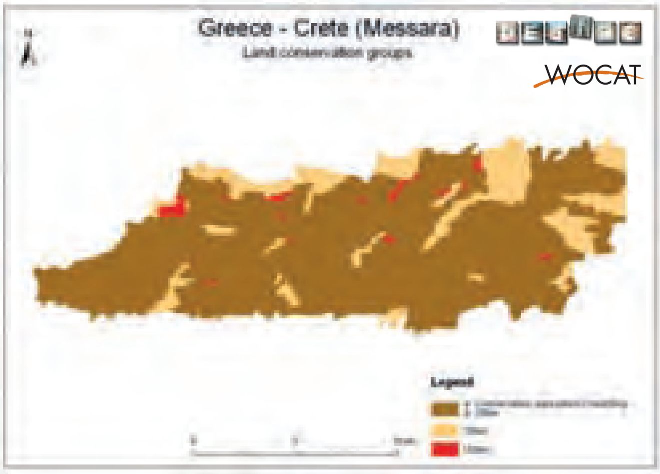


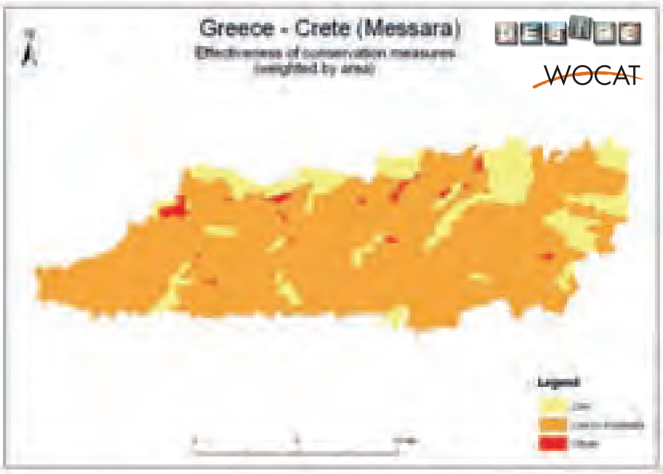
Greece – Crete (Messara)

The cultivated area in the study site in Crete has widespread land degradation. Soil erosion due to surface runoff and tillage operations, collapse of terraces, overgrazing, and salinization of lowland, and overexploitation of groundwater are the major processes of land degradation in the area. Current conservation measures include contour tillage and mulching. Their effectiveness is low to moderate, as indicated in the effectiveness map. The SLM technology documented in this book (olive groves under no-tillage operations) aims to minimize soil losses.



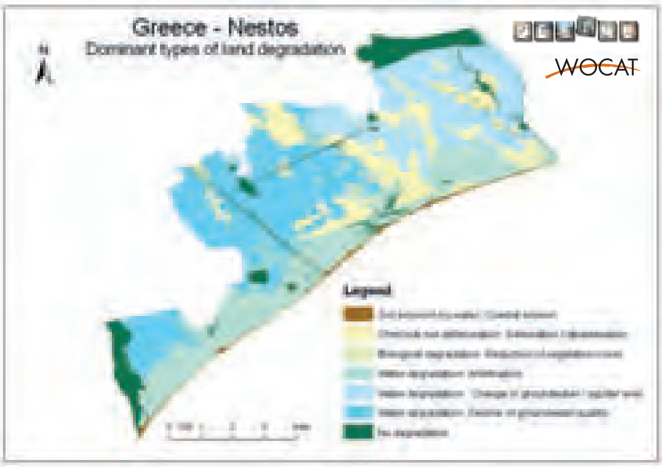


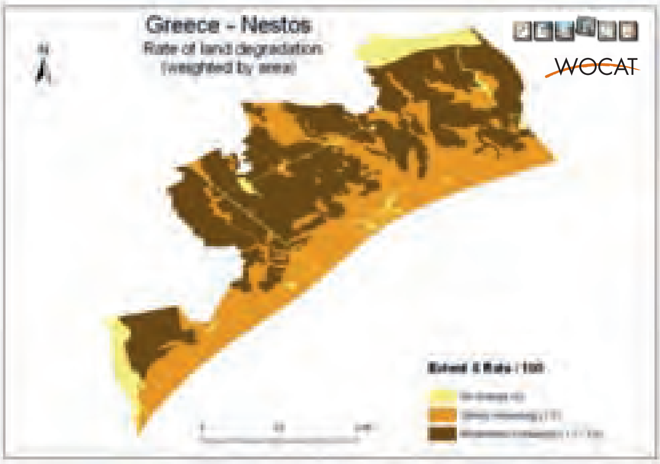




Greece – Nestos

This area has chemical deterioration such as salinization and alkalinisation, and water degradation of various forms in the cultivated irrigated part (aridification, change in groundwater level, decline of quality).
The rate of this degradation is moderately increasing, despite conservation measures for soil surface treatment in this area (covering 30-90%). The SLM technique proposed in this book (transport of fresh water from local streams) addresses all mentioned forms of degradation.





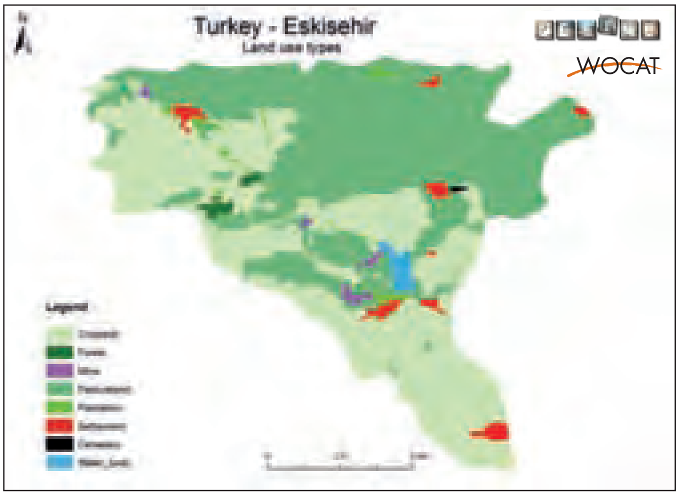
Turkey – Karapinar

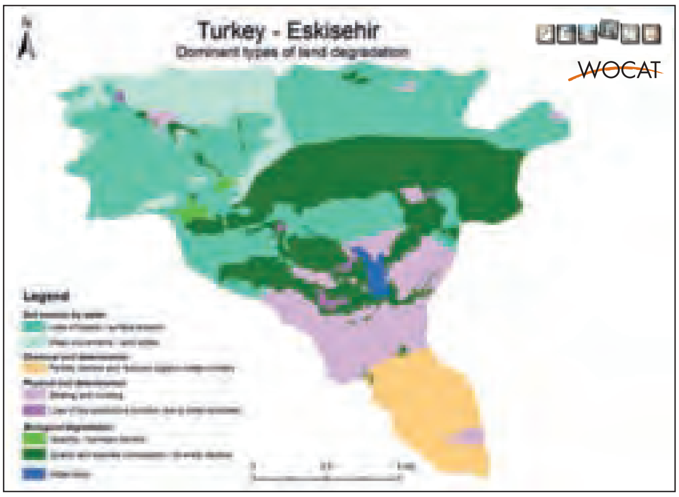
The Karapinar area is used for growing cereals and grazing. The intensity of (irrigated) cereal production is increasing. In recent years irrigated agriculture has rapidly expanded due to new market pressures, developing techniques and subsidies, as a result ground water levels have dropped dramatically. The area is affected by wind erosion, the grazing area to a larger extent than the cropped land. Current conservation measures include the change of management and intensity level in the area with grazing and soil surface treatment and increased vegetation cover in the cropland. These measures are applied over large parts of the pasture land (>60%) and of the cropland (>40%), but the effectiveness is low, especially in the cropland. Drip irrigation is proposed and documented in this book as an SLM technology for the cropland to save groundwater.

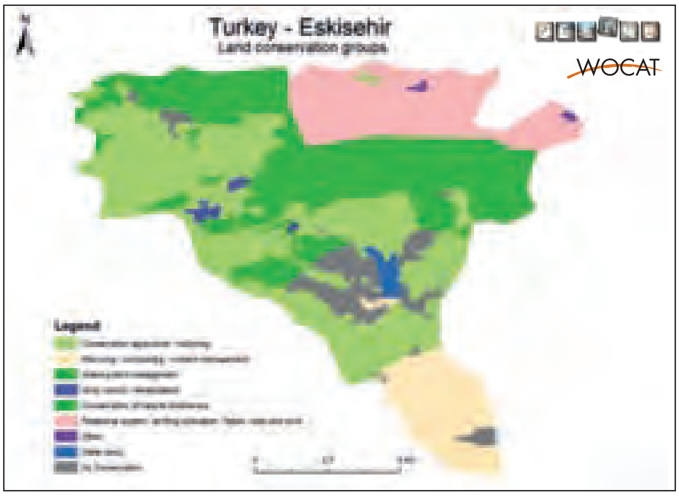
Turkey – Eskişehir

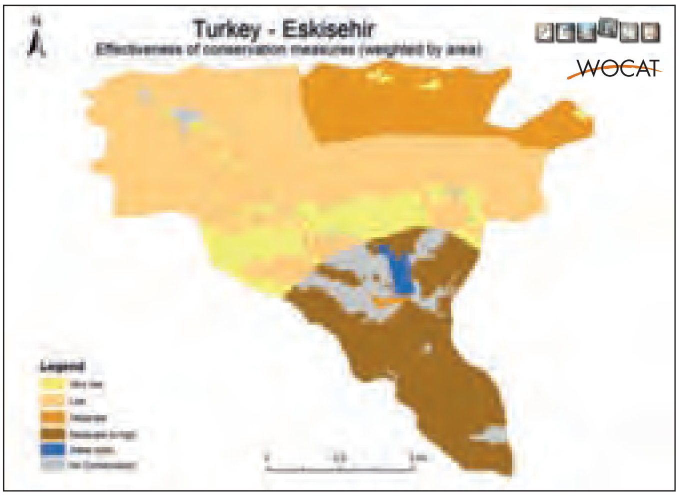
The Eskeheşir study site has industrial activities and intensive agricultural land use in the form of irrigated sugar beet and sunflower and rainfed cereals. The intensity of agriculture is expected to increase due the increased investments in the country. The cropland experiences land degradation in the form of surface erosion by water, sealing and crusting, and soil fertility decline and reduced soil organic matter content. Land degradation is most widespread and severe in the pastures close to the settlements, especially in the central part of the area near the lake, where it causes a decline in the quality and diversity of the species composition of the herbs.

Current land conservation is most widespread in the northern part of the area under pasture, where rotational systems are being used to remediate surface erosion by water. The effectiveness is low to moderate. Conservation agriculture and mulching are applied to remediate surface erosion and sealing and crusting in the cropland. The effectiveness to remediate soil erosion is low. This book documents fodder crop production as a SLM technology to remediate respectively surface erosion and quality and diversity decline in the pasture area.



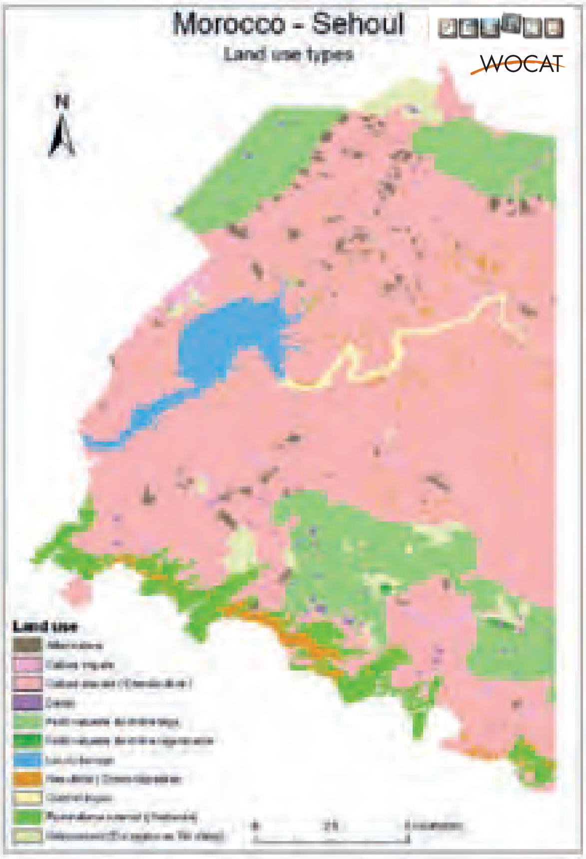


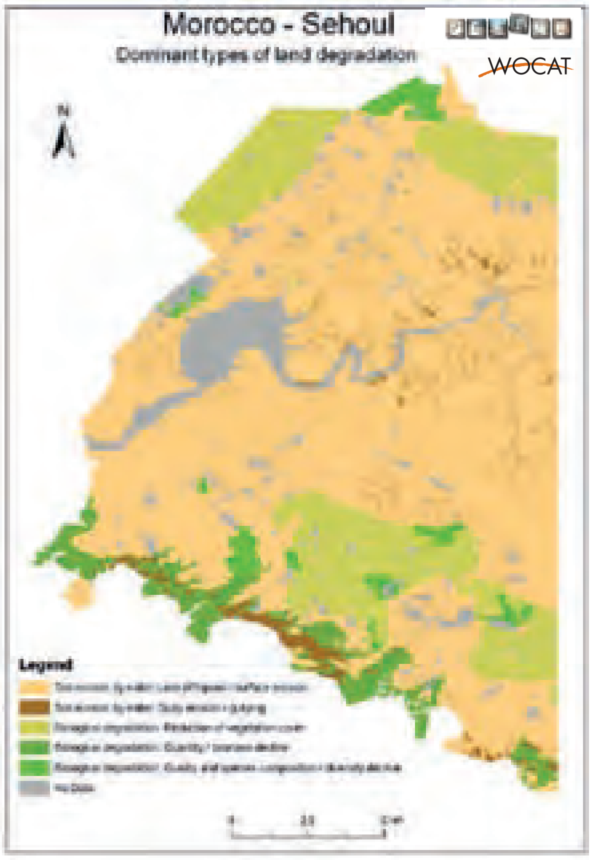


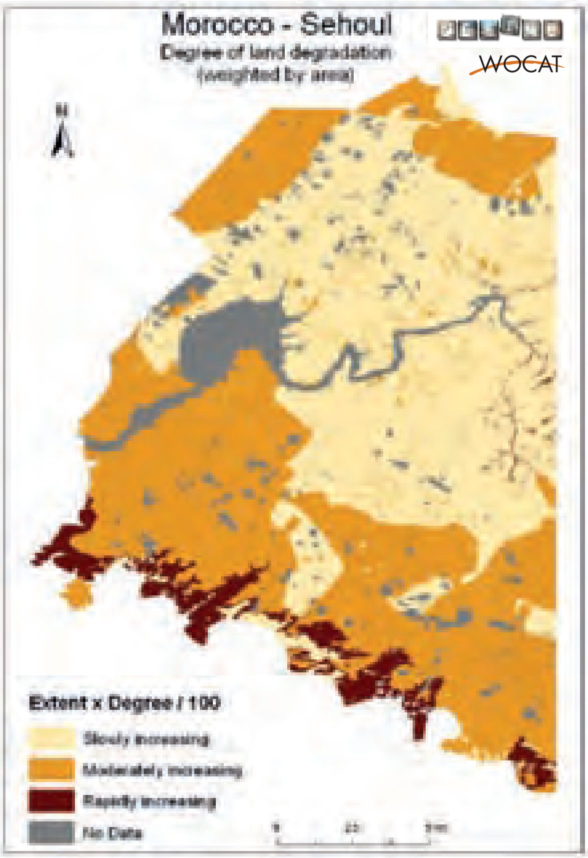


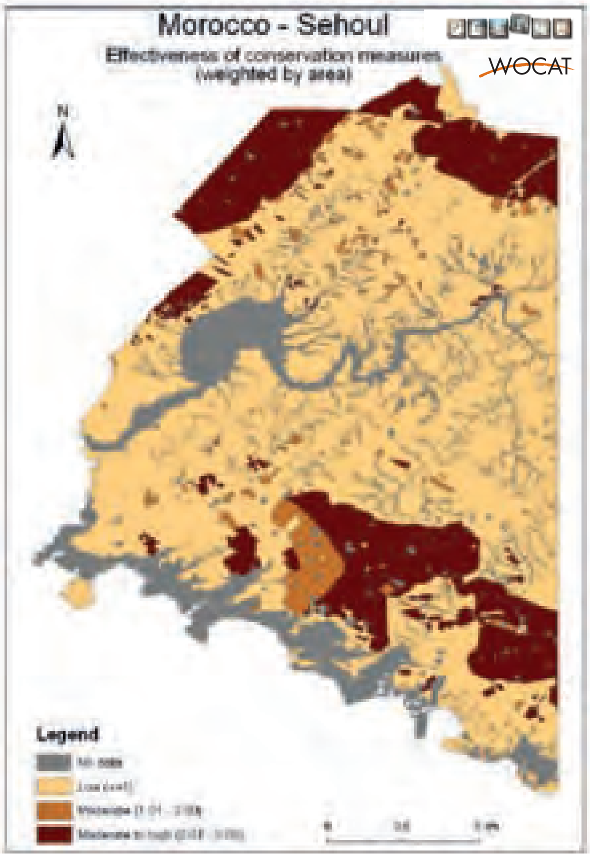
Morocco – Sehoul

The Sehoul area has rainfed and irrigated cropland with cereals on the plateaux, and remnants of natural cork oak forest, used for grazing apart from the timber and non-timber forest products. Extensive pastoralism is practiced on the steep borders of the plateaux, resulting in land degradation by mostly soil erosion (surface erosion and gullying). Soil erosion is also prominent in part of the cultivated area. Biological degradation is found on the plateau borders and in the forest due to the reduction of the vegetation cover and the decline of biomass and biodiversity. Current conservation measures include agronomic measures in the cropland addressing soil organic matter and fertility decline, and vegetative measures improving tree and shrub cover in the forest. The effectiveness of the measures in cropland is low, motivating the SLM technologies of cereal-legume rotations described in this book. For the plateau borders measures remediating gullying are proposed by planting *Atriplex*.





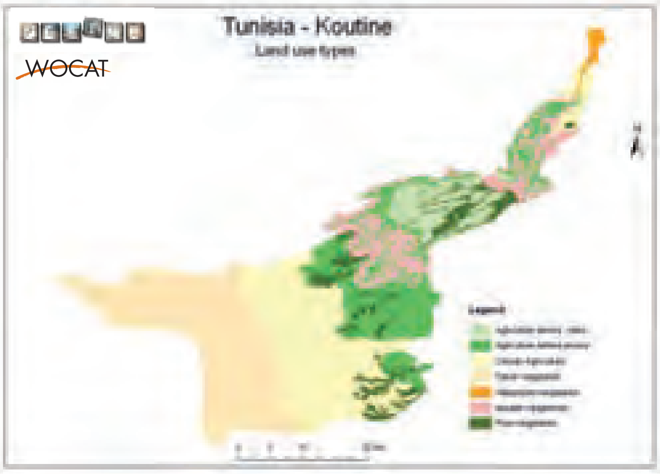


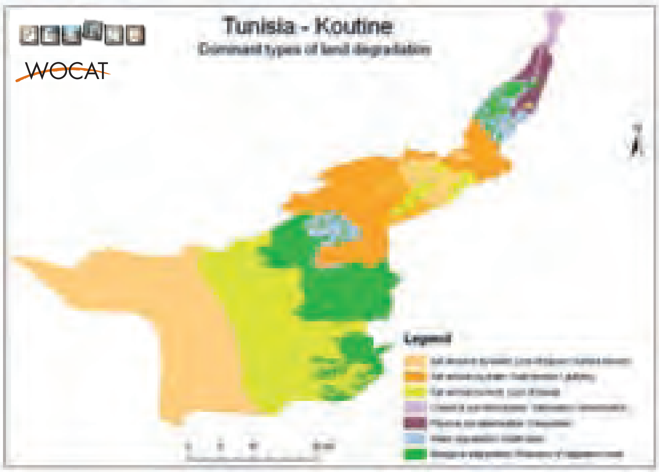


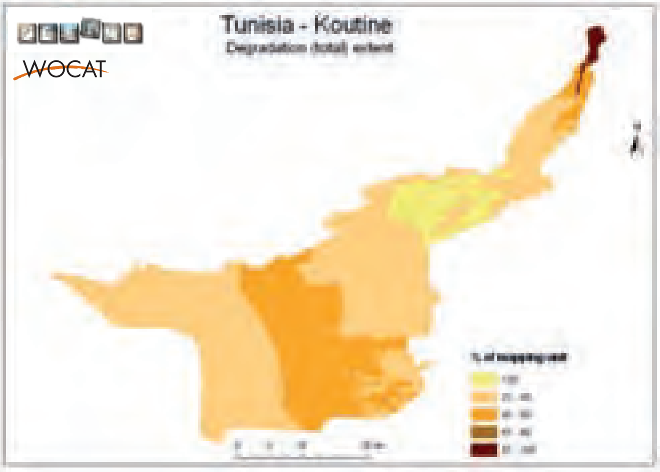
Tunisia – Koutine

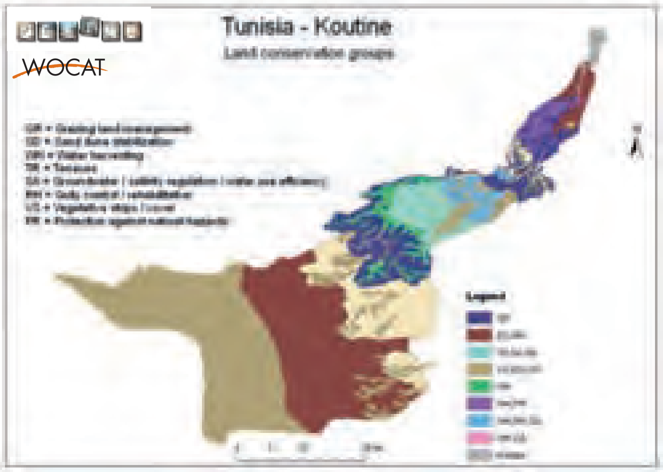
The Koutine area in Tunisia is used for cropland, including the production of cereals, and for grazing in various types of rangeland. The areas with agriculture behind *tabia*[1] and with cereals are increasing, while the rangeland is shrinking. As a result, the remaining rangeland is being used more intensively.

Land degradation of many different forms (soil erosion by water and wind, biological, physical and chemical degradation) is affecting more than half of the area, except for the area used for agriculture behind *tabias*. A wide range of traditional soil and water conservation techniques is applied in the area. The measures are most widespread in the areas behind *tabia* and *jessour*[1] (covering more than 40%), and have a high effectiveness. But in the rangelands current conservation measures have a low effectiveness, and the rate of land degradation is increasing. Rangeland resting is recommended by the local specialists as an SLM technique for these areas, and documented in this book.





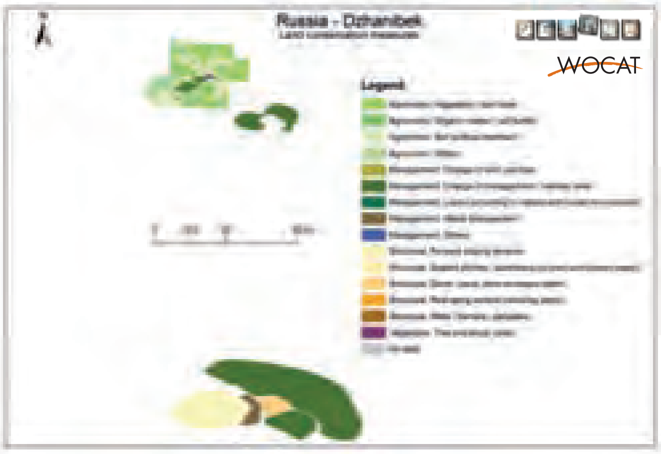




[1] Tabias and jessour are runoff water harvesting techniques comprised of a dyke (50-150 m in length, 1-1.5 m 10 in height), a spillway (central and/or lateral) and an impluvium. The tabia systems contains two additional lateral bunds (up to 30 m long) and sometimes a small flood diversion dyke (mgoud) (Alaya et al., 1993, in: DESIRE WB-3 StakeholderWorkshop 1 report by Sghaier et al., 2008).

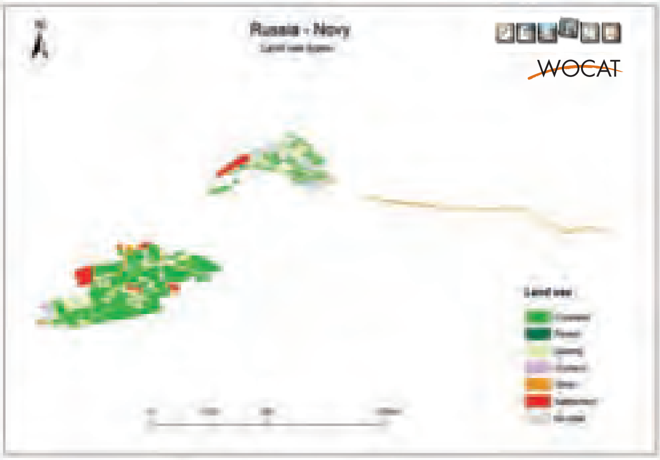
Russia – Dzhanibek

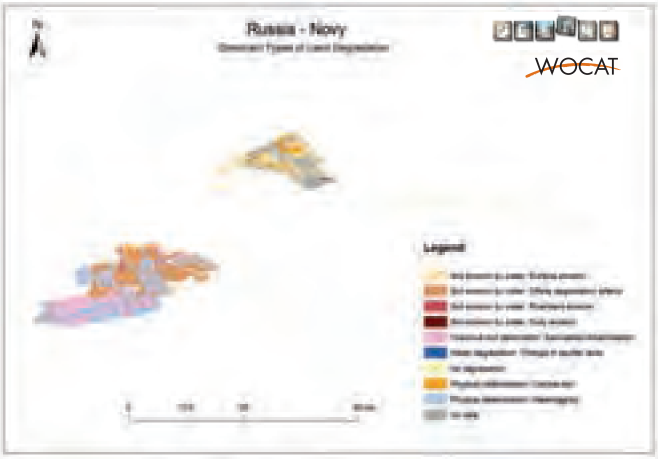
The Dzhanibek area, mainly used for grazing and cropland, is characterised by various forms of land degradation, mostly chemical and physical soil deterioration, and water degradation. Various conservation measures are implemented in the area over small surfaces (10-30% of the grazing area, 5-10% of the cropland). These include soil surface treatment and a reduced intensity of use in the grazing area in response to acidification and compaction. In the cropland measures aiming to increase the vegetation and soil cover are meant to remediate the decline of soil fertility and soil organic matter. The effectiveness of conservation measures is low. Drip irrigation is an example of the SLM technologies proposed for this area to address the water degradation in the cropland and mixed land use.

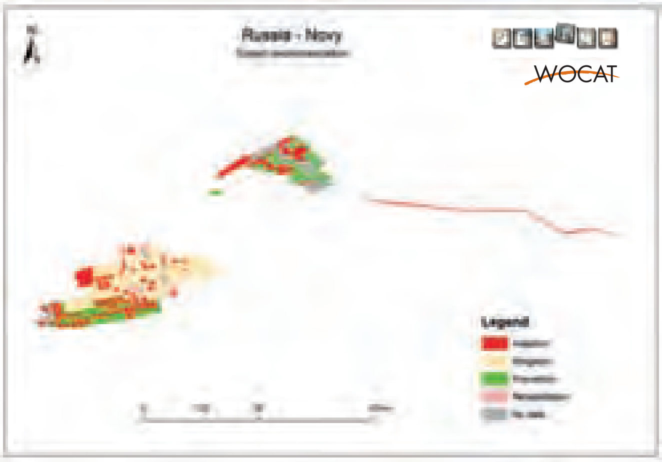


Russia – Novy

Land use in the Novy site mainly consists of cropland and grazing land. The circular shapes of the areas previously (or still) irrigated with pivot sprinkler systems are clearly visible. These areas are degraded by surface erosion or water logging. Adjacent cropland is affected by off-site effects of surface erosion, and by soil salinization and alkalinisation. Current conservation measures in the area include ditches to drain and convey irrigation water, and surface treatments in the irrigated cropland. The effectiveness of these measures is low at most places. Experts recommend adaptation of irrigation practices in the cropland, and of grazing practices in the area used for grazing, and SLM techniques targeted to prevention and rehabilitation of the mentioned forms of land degradation in the cropland area, including part of the areas formerly irrigated using the pivot sprinkler systems. An example of an SLM technique that can be used for both prevention and rehabilitation is drip irrigation, documented in this book.

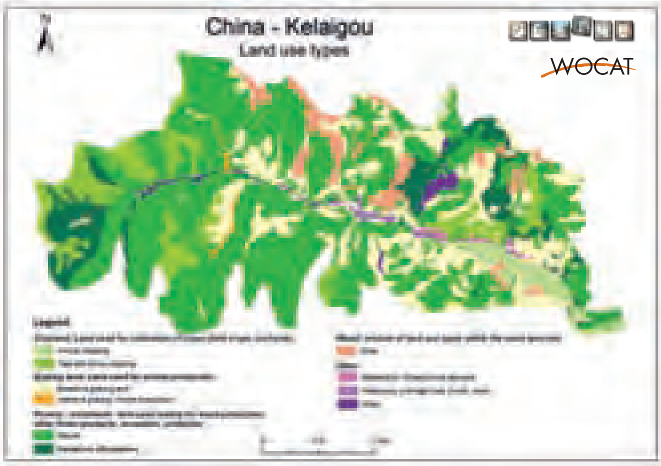


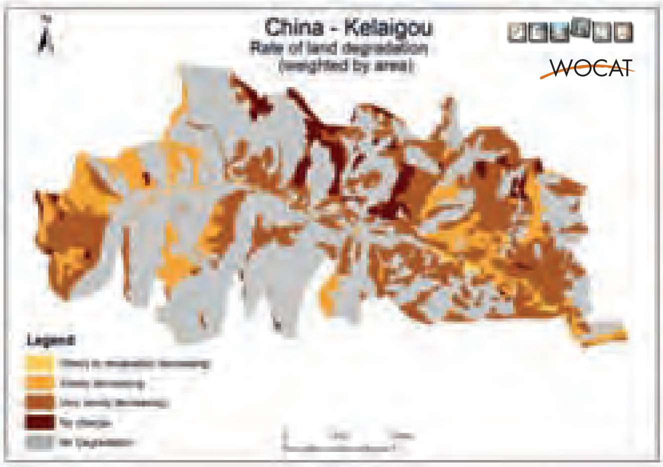


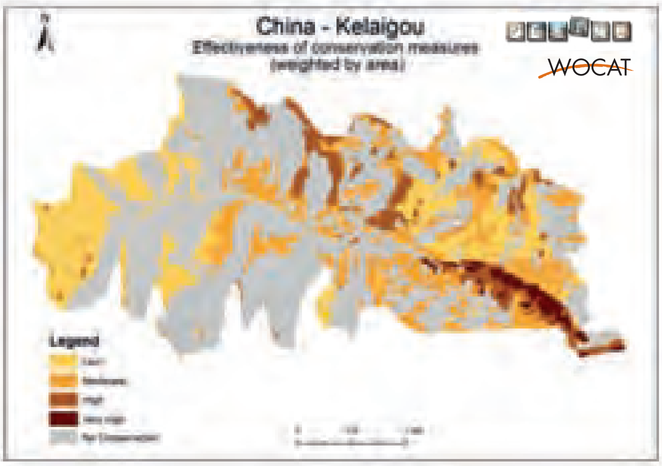


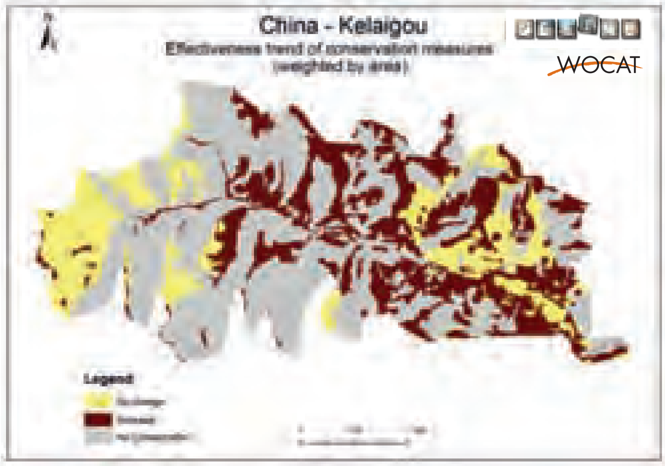
China – Kelaigou

Natural forest covers the larger part of the area. No degradation is reported for this area. Land degradation (reported uniquely in the form of surface erosion by water) is severe in the areas with tree and shrub cropping and mixtures of land use types. The rate of land degradation is slowly decreasing in all degraded areas, but not changing in the areas with mixed land use types, although this area under conservation measures for more than 75%, and the effectiveness is reported as high. This may point at a time lag in the response of land degradation to the implementation of conservation measures. This is confirmed by the increasing trend of effectiveness reported for these areas. Only small parts of the severely degraded land with tree and shrub cropping are under conservation measures (<25%), of which the effectiveness is reported as low, and not increasing. This calls for the wider implementation of measures in the areas with tree and shrub cropping and mixed land use, like the progressive bench terrace described in this book.



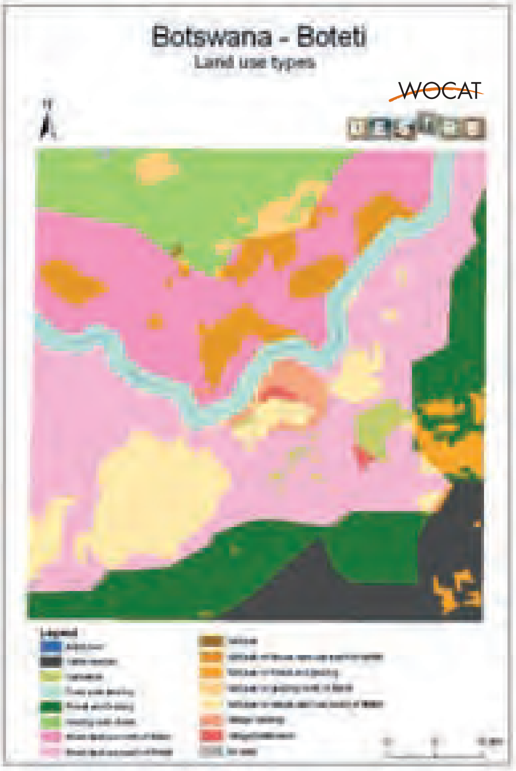






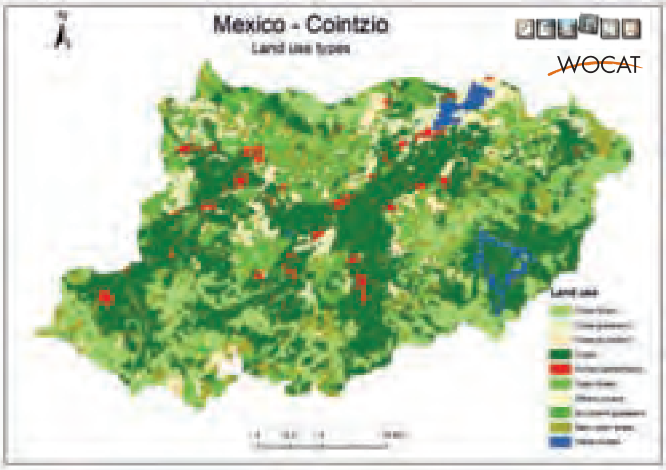
Botswana – Boteti

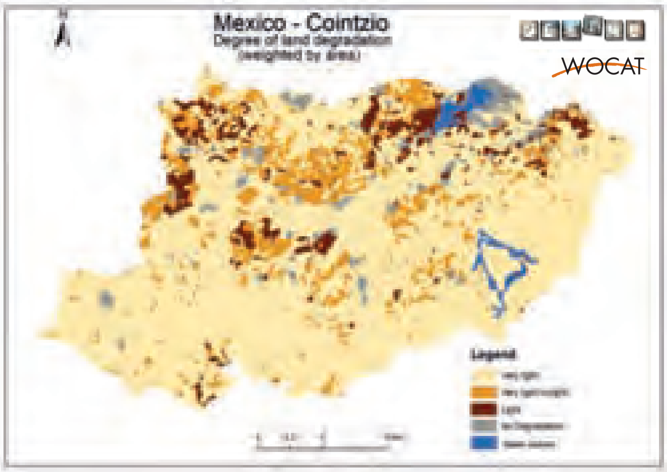
The main land use type is grazing. Dominant types of degradation are water degradation (aridification) and salinization and alkalinization in the areas with salt pans, and degradation of the vegetation in all other land use types. The degree of degradation is moderate to strong in the areas with salt pans, and moderate in the mixed land use south of Boteti river. Degradation is slowly increasing for all land use types, except in the grazing land in the northern part. Current conservation measures include changes in the timing of cropping activities in the floodplain, and changes in the intensity of grazing in the grazing land around the villages (village grazing) and in the cattle ranging. However, in the larger part of the area, used for grazing and mixed land use, no conservation measures are applied ('Others' in the legend). For this area, the biogas conservation technology documented in this book was proposed. It addresses the degradation of vegetation by benefiting from the high livestock intensity to produce biogas as an alternative source of fuel. Roof rainwater harvesting offers an alternative water source in response to the declining groundwater table and the high salinity of this water source.

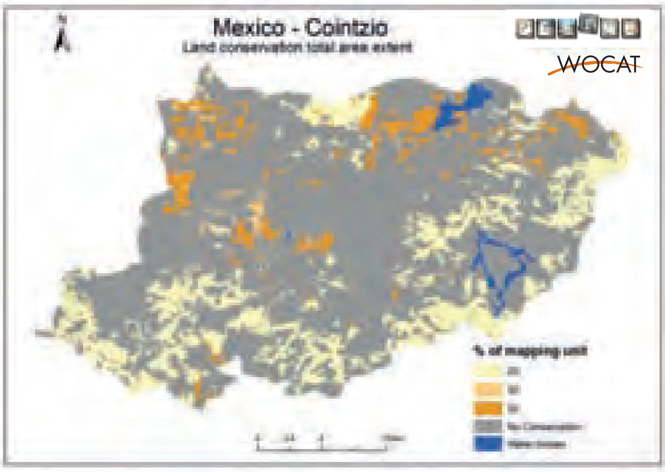


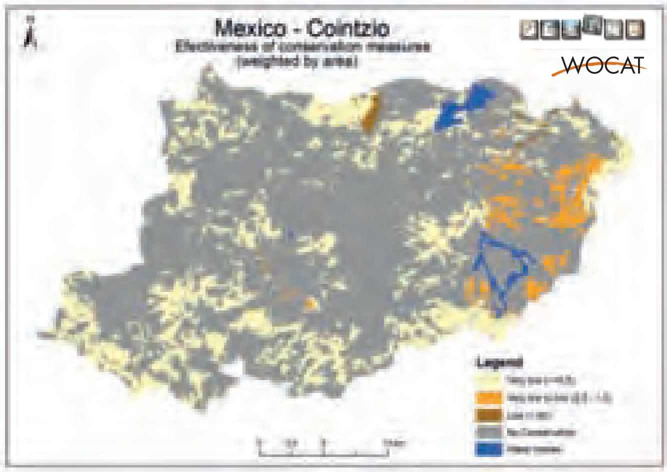
Mexico – Cointzio

The Cointzio area is characterised by a scattered pattern of cropland, forest, grazing land and shrubland. Land degradation occurs mainly in the form of soil erosion by water and wind, which is slowly increasing in the cropland, and moderately in the closed grassland and shrubland. High livestock numbers and uncontrolled grazing are the main cause of soil erosion on the grazing land. Present conservation measures include agroforestry in the closed forest and closed grassland. In the closed grassland the extent is low (<20%). The effectiveness is very low to low. There are no conservation measures in the cropland. The reclamation of degraded grazing land with native agave trees is proposed and documented in this book as one of the SLM technologies to reach sustainable land rehabilitation.



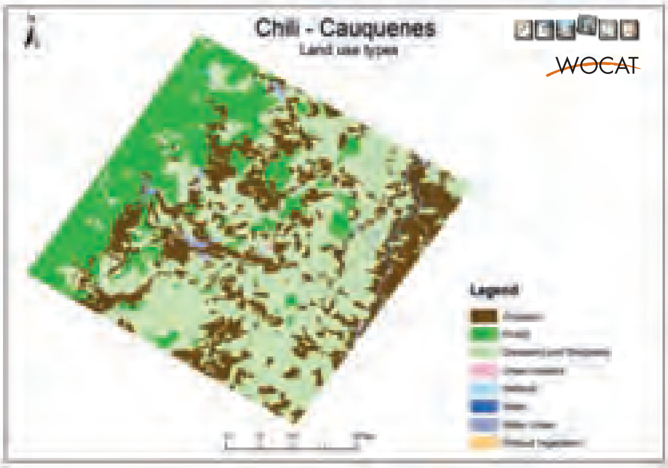


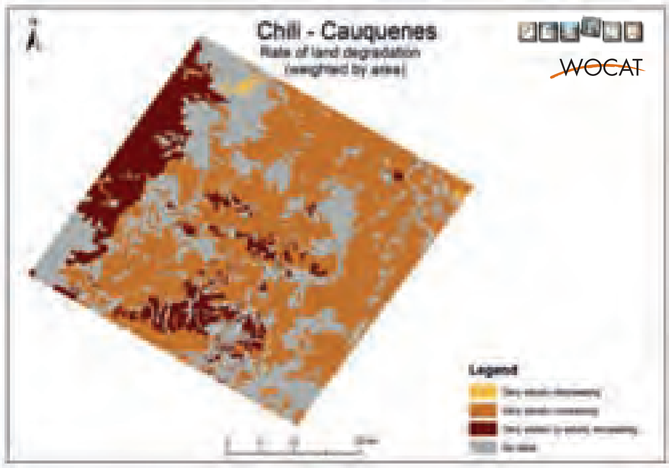


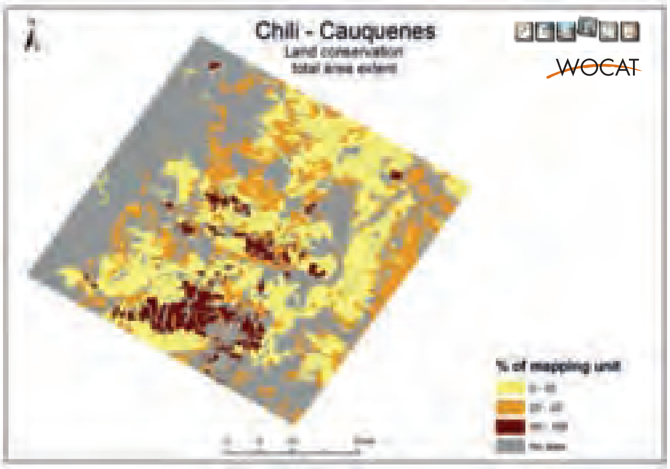


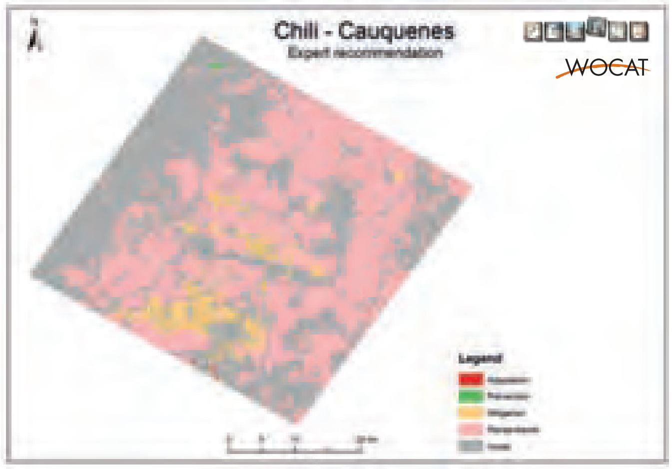
Chile – Cauquenes

The Cauquenes area has cereals, forest plantations, grass and shrubland as the main land use types. The main land degradation process, affecting all main land use types, is soil erosion by water due to inappropriate land management, soil mining, destruction of natural woodland vegetation. As a result, soil fertility depletion affects the sustainability of traditional crop production. Existing conservation measures include conservation agriculture and mulching in response to soil erosion and fertility decline in grassland and cropland. Their effectiveness is mapped as low, but with a tendency to increase. Rehabilitation of the cropland and grassland and shrubland is recommended by experts for the largest part of the degraded area. This book describes no tillage preceded by subsoiling and crop rotations with legumes as new conservation measures for the area under cropland.



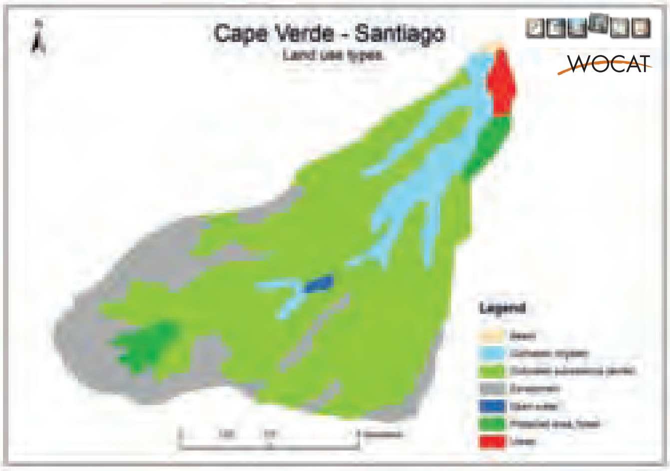


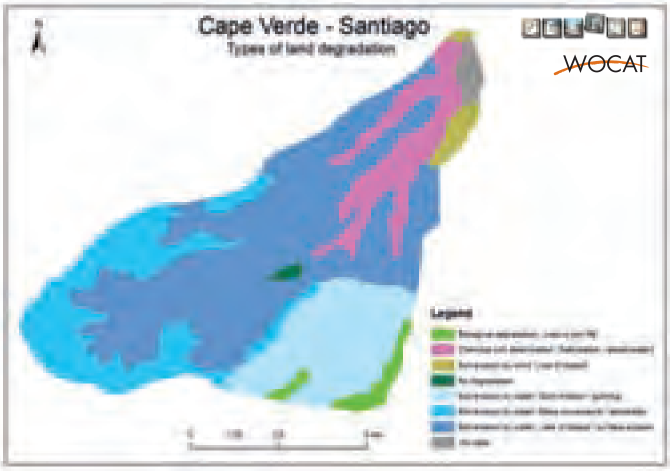


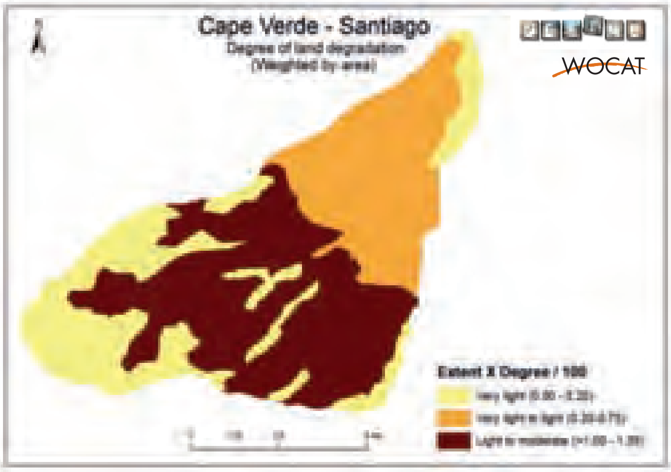


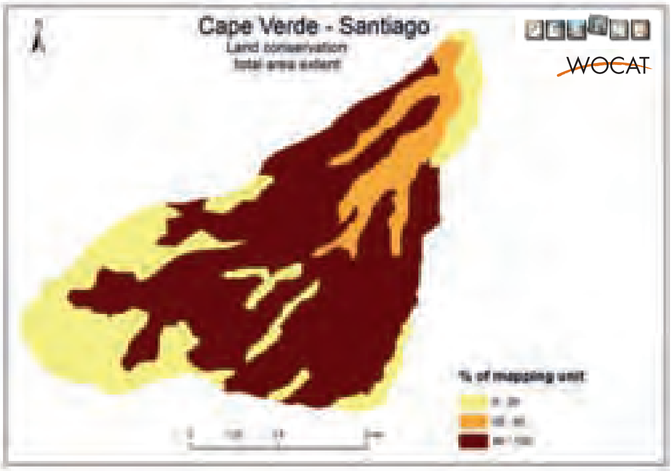
Cape Verde – Santiago

The Santiago area in Cape Verde has physical land degradation in various forms of soil erosion (surface erosion, gullying, mass movements) on land in use for rainfed subsistence agriculture, and chemical land degradation (salinisation and alkalinisation) in the cultivated land under irrigation. The degree of degradation is very light to moderate, possibly due to the large extent of land conservation measures, covering 80-100% of the cultivated rainfed area. Two examples of successful and promising conservation measures are described in this book: *Aloe vera* living barriers and afforestation.









2.3 DESIRE methodology examples

Case study of the DESIRE methodology – Eskişehir, Turkey

(This case study is structured according to the 5 steps of DESIRE approach as explained in chapter 1)

I Establishing land degradation and SLM context and sustainability goals

Socio-cultural, economic and environmental context

The Eskişehir region is situated in the inner Northwestern Anatolian region, on the north rim of the Eskişehir plain, covering an area of 90 km², and situated between 800 and 1400 m altitude. The area has been strongly influenced by agricultural and industrial activities due to its proximity to Eskişehir city. In the coming decades, urbanisation is projected to increase, as well as the demand for water for industrial, domestic and agricultural needs. At the same time the incidence of droughts is expected to increase.

Degradation problems in the area include soil erosion by water and wind, salinization, surface water pollution and groundwater depletion.

Land use is mainly rainfed agriculture (mostly cereals), irrigated cultivation (sugar beet and sunflower), pasture and man-made forests (mainly pine and oak trees).

Geology and soils: the substrate consists of metamorphic rocks with sandstones and conglomerates and alluvial deposits. Marble lenses in the metamorphic rocks are mined.

The **climate** is dry continental climate with an annual precipitation of 380 mm, with temperatures generally below 0°C during winter and possibly exceeding 40°C in summer days. Existing conservation measures: conservation measures to protect land, water and biodiversity resources are limited in the area. Crop rotation, fodder crop production and reforestation are practiced.

Socio-economic situation: the Eskişehir area has a high productivity in the agricultural and manufacturing sectors compared to other regions in the country, but the educational and income levels of the village inhabitants and farmers are low. The study site has 3040 inhabitants.

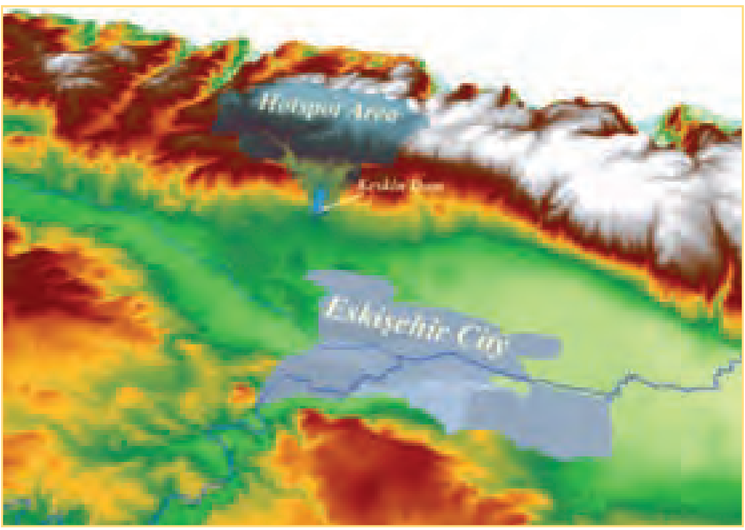
Institutional and political setting: Several state organisations and research institutes at the national and provincial level coordinate land and water management in the area. The municipality decides on land use and management within its borders. Several civil society organisations provide extension services to land users, including financial support. The national NGO TEMA is active in combating soil erosion and the restoration and protection of natural habitats. There is limited communication between stakeholders and local and national policy representatives.

Stakeholders, goals and drivers

The main stakeholder groups include the villagers holding livestock, land users of the cropland, farmer unions, the municipality, provincial directorates for infrastructure, water, environment and forestry, several research institutes and two environmental NGOs. The sustainability goals identified for the Eskişehir area reflect the needs of the livestock holders, farmers and state organizations.

The main socio-economic and environmental drivers are summarized below. Policies to protect land and water resources include a national law on soil preservation and land use.

Sustainability goals	
Goal 1	Increasing biological diversity
Goal 2	Improving productivity of fodder production on pasture lands
Goal 3	Conservation and improvement of soil fertility
Goal 4	Forest cover increase and maintenance
Goal 5	Efficient use of groundwater sources



Location of the Eskişehir study site in the Eskişehir plain.

Status of land degradation, sustainable land management and risk

The cropland in the Eskişehir site experiences land degradation in the form of surface erosion by water, sealing and crusting, and soil fertility decline and reduced soil organic matter content. Land degradation is most widespread and severe in the pasture areas close to the settlements.

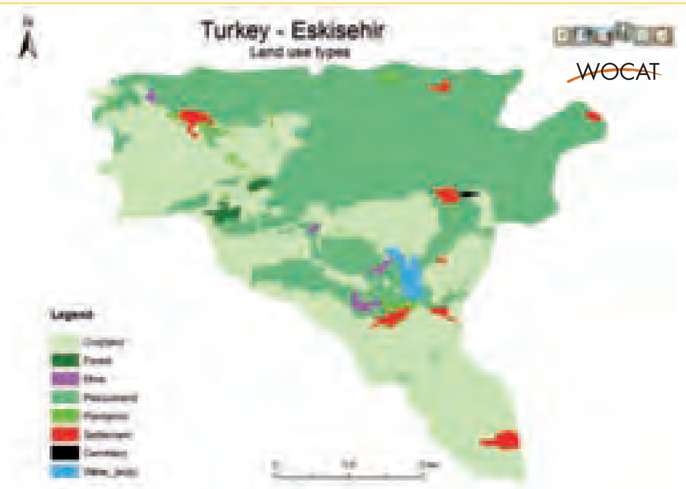
Indicators of the bio-physical, land use and socio-economic conditions in the Eskişehir site relevant to soil erosion by water were collected for 52 locations in agricultural land, for 3 locations in forest, and for 16 locations in the pasture land. Climate indicators were collected for 70 locations. Based on these indicators, and using the expert system for desertification risk assessment, a desertification risk was calculated with regard to soil erosion by water. The Eskişehir study site is subject to a very high desertification risk over almost its entire area, also in areas with currently a very light degree of land degradation.

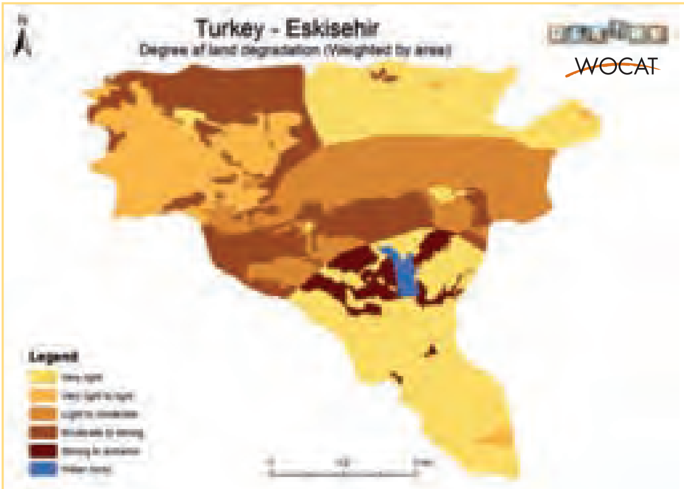
Socio-economic drivers

- Low institutional capacity cooperation
- Poor extension services, access to market difficult (also for purchase of management inputs)
- Low level of organization among farmers
- Low level of contact between stakeholders
- Large difference between farm gate price and market price: role of middle men
- Urban priorities dominate the rural region because of tourism (city to rural areas), soil excavation for bricks (urban construction)
- Land fragmentation

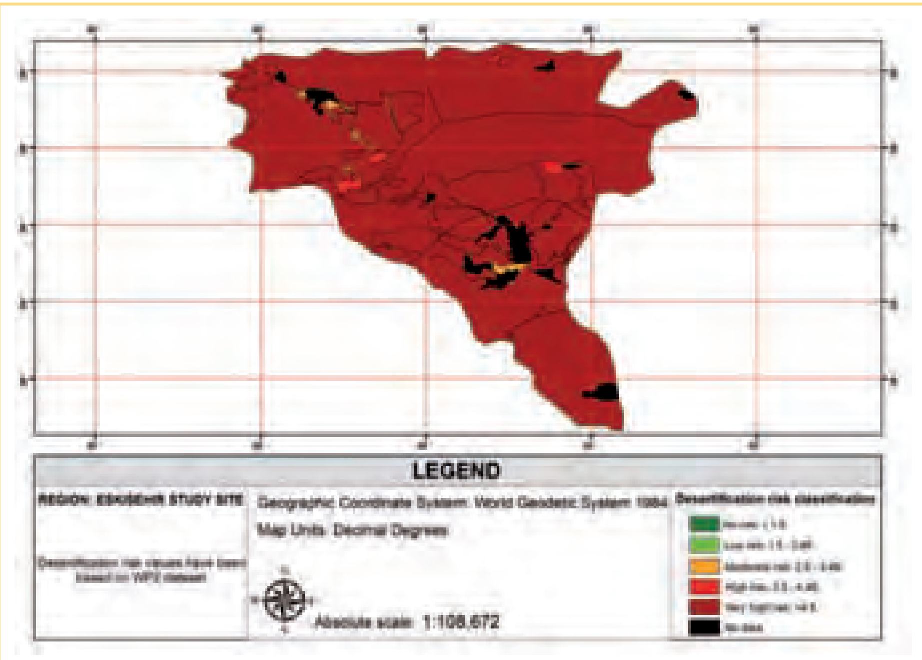
Environmental drivers

- Low vegetative cover
- Arid climate
- Deforestation
- Torrential summer and autumn rains
- Low vegetative cover
- Inappropriate tillage
- Overgrazing





Land use types (left) and degree of land degradation (right) in the Eskişehir study site, Turkey. Source: Godert van Lynden (ISRIC).



Desertification risk due to water erosion in the Eskişehir study site, Turkey. Source: AUA, Greece

II Identifying, evaluating and selecting SLM strategies

Identify, document and evaluate SLM options

The first stakeholder workshop gathered some 40 stakeholders, among whom land users, representatives of the provincial authorities on agriculture, environment and water management, researchers, the farmer and irrigation unions, NGOs and the municipality. The workshop was meant to draft an overall strategy for SLM in the area (see box), and to identify potential SLM technologies (see table). The high level of motivation of local stakeholders was evaluated as a strength of the workshop. The lack of financial aids and the lack of women in the representation of stakeholders were noted as weaknesses.

Fodder crop production was selected for evaluation and documentation with the WOCAT questionnaires both as a SLM technology and an SLM approach. The technology ‘woven wood fences’ was added to remediate soil erosion in cropland. The 4-page summaries of these technologies are available in this book.

Overall strategy

- To increase soil fertility (through crop rotation, mulching and tree planting)
- To limit water loss (through drip irrigation and improving grassland)
- To prevent water and soil loss by erosion (through terracing and check dams)

Prioritise and select remediation options

In the second stakeholder workshop, stakeholders set the objectives for SLM in the Eskişehir study site: protection of dry-farming areas from water erosion and rehabilitation of pasturelands. Remediation options corresponding to these objectives were selected from the WOCAT database on technologies. The options selected in the first stakeholder workshop based on an inventory of locally applied technologies were not selected, since they were only applicable in small areas (like gardens). Stakeholders selected economic, ecological, socio-cultural and off-site criteria to prioritise and select remediation options. The table below lists the criteria for the protection of the area for dryland farming.

Using the criteria, stakeholders scored the remediation options in groups of farmers and SLM experts. For the protection of dryland farming areas, the highest scores were obtained for the contour planting technology; for pastureland rehabilitation a vegetative measure was selected (Caragana korschinskii planting), mainly based on its benefits as fodder material. Stakeholders concluded that a combination of measures would deliver the best scores on the criteria.

The workshop revealed that leadership and authorisation of the implementation of technologies by governmental organisations is of ultimate importance. Farmers did not believe in significant contributions from governmental organisations (GOs) to the implementation. The representatives of the GOs did express the feasibility of technologies during the workshops, but were not able to grant any responsibilities to the implementation process.

Identification of disturbances in water and biomass cycles by stakeholders.

Images of the prioritisation and selection of remediation options in the stakeholder workshop in the Eskişehir study site.

Examples of potential SLM technologies for the Eskişehir study site identified by local and external stakeholders.

Local (L) or External (E) stake-holders	Technology / approach	Already applied or potential solution?	On land use type (e.g. crop land / grazing land, etc.)	Labour required (initial and mainte-nance)	Costs (initial and mainte-nance)	Impact / Effectiveness ST: short term LT: long term						Limiting factors / constraints	Overall assess-ment of the potential for the local context
						economic		ecological		socio-cultural			
						ST	LT	ST	LT	ST	LT		
L	Improving grassland	Potential	Pasture	High	High	+	+++	++	+++	0	++	Driving force, financial sup-port	Very positive
E	Improving grassland	Potential	Pasture	Medium	Medium	0	+++	++	+++	0	+	Responsibility for continual conservation	Positive
L	Fodder crops production	Partly already applied	Agricultural	Medium	Medium	+	++	++	+++	0	0	Only can be applied by a part of the farmers (livestock producers)	Positive
E	Fodder crops production	Partly already applied	Agricultural	Medium	Medium	+	++	++	+++	0	0	Only can be applied by a part of the farmers (livestock producers)	Positive

Criteria for the evaluation of SLM options in the Eskişehir study site selected by stakeholders

Protection of dryland farming areas			
Economic / production	**Ecological**	**Socio-cultural**	**Offsite**
– product diversification – fodder/animal production increase – crop yield increase – reduced risk of production failure – low expenses of inputs	– soil organic matter increase – water quantity increase – invasive alien species reduction – soil loss reduction	– food security – conservation/erosion knowledge – suitability for small/large scale land users – community institutional strengthening	– reduced downstream siltation


Sanem Açıkalın


Sanem Açıkalın

III Trialling and monitoring

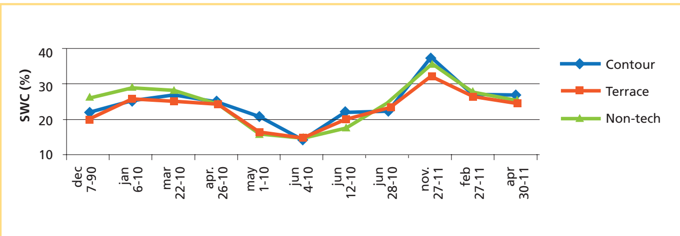
Contour ploughing and terracing and (wooden) terracing were implemented in field trials in cereal fields to increase infiltration and increase the soil moisture storage. The overall objective was to decrease surface runoff and to reduce soil loss.

Properties of the soil surface (e.g. mulch cover), the soil moisture status, germination rate, yield and income were monitored between 2009 and 2011 during three growing seasons.

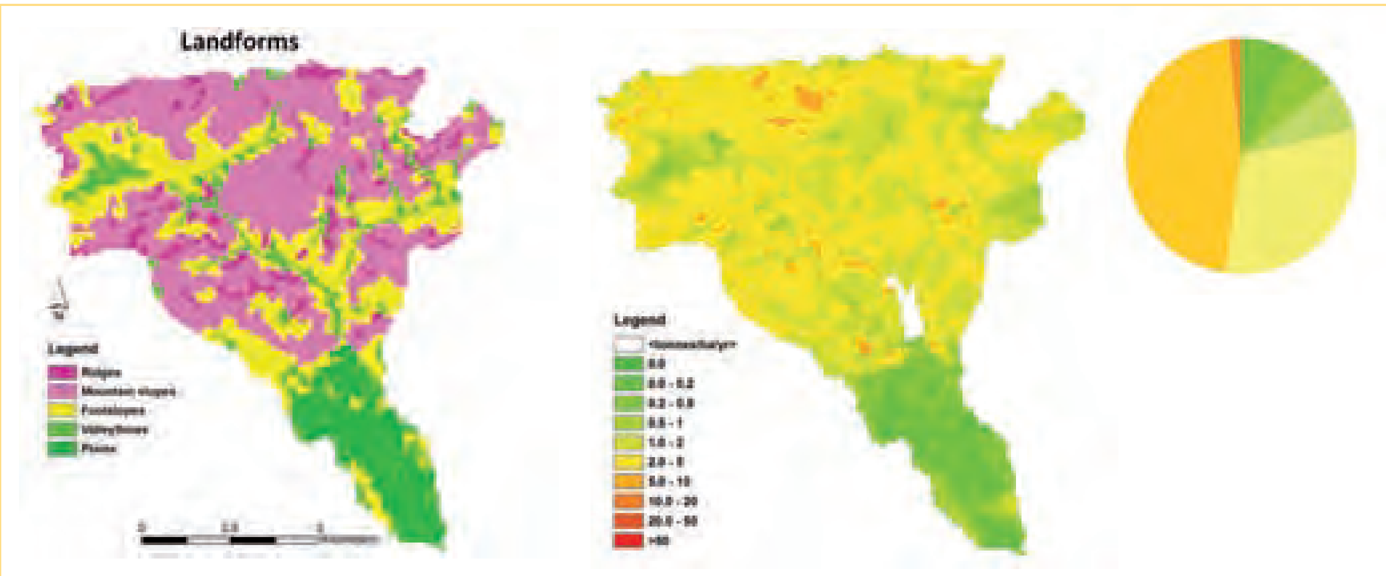
The field experiments showed that contour ploughing and terracing increased soil moisture due to reduced runoff, but this depended on the seasonal rainfall. The combination of these technologies helped to improve soil conditions and crop growth, and increased yield three times. The consultation of land users during the monitoring revealed that terracing involves additional costs and possibly loss of some land, whereas contour ploughing has only costs for fuel use. However, contour ploughing requires training on how to practice it on steeper slopes. Overall, based on the field experiments contour ploughing is considered to be applicable in wider hill slope areas of semi-arid Central Anatolia.

Experimental field for the field trials in the Eskişehir study site (top) and wooden fence (below).

Consultation with farmers on field experiments in the Eskişehir study site.



Soil water content (SWC) under contour ploughing and terracing compared to the control situation without technologies (non-tech).



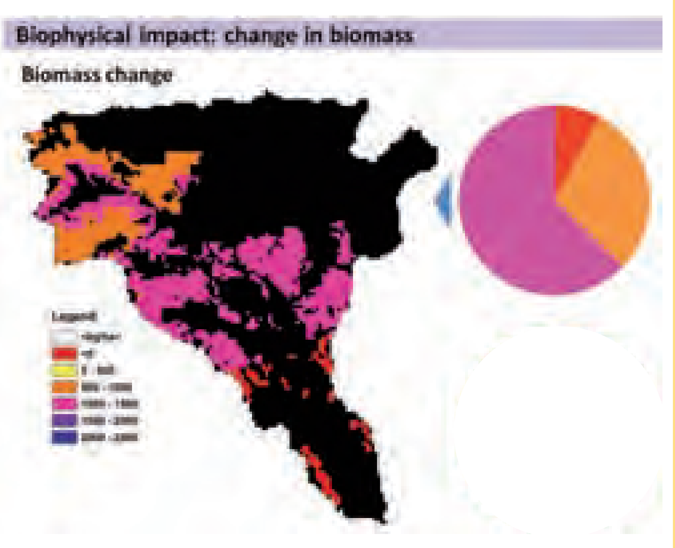
Landforms (left) and actual erosion rate (right) in the Eskişehir study site. Pie charts indicate the part of the area covered by each erosion class.

IV Up-scaling SLM strategies

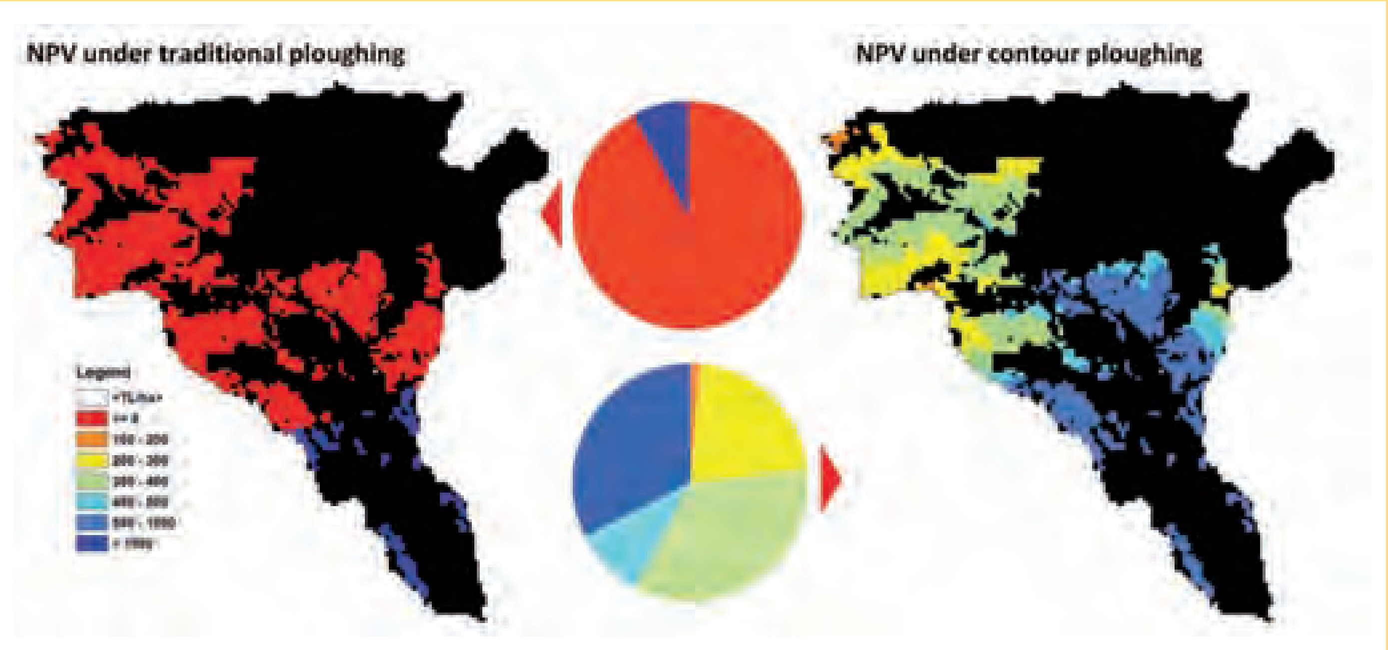
Actual erosion rate in the Eskişehir area was simulated with the adapted PESERA model for the current situation. The erosion rate appeared to be higher than 1 t/ha/y, the generally accepted tolerable level, over 80% of the area, in the slopes and ridges. The current biomass production is highest in the irrigated valley floors and plains (>3500 kg/ha), compared to 500-1000 kg/ha in the footslopes and mountain slopes with rainfed agriculture.

Simulations with the coupled PESERA-DESMICE model of the implementation of contour ploughing where applicable (on slopes between 2 and 35%) confirm the findings of the field trials that the technology would increase yield: contour ploughing would increase the biomass production by 600-1500 kg/ha, or by more than 100% in 90% of the area where it is applicable. The technology requires no additional costs, and is thus profitable everywhere where it increases productivity. The net present value of the cultivation of cereals would increase over more than 75% of the area by 200 to 1000 TL/y.

Stakeholders evaluated the model results in a third stakeholder workshop. They preferred woven fences over contour ploughing based on increased crop yields observed in the field experiments. In addition, they were concerned that contour ploughing would not be effective under high intensity rainfall. The modelling results support the idea that contour ploughing is not very effective in areas with high erosion rates. Stakeholders acknowledged the investment costs of woven fences.



Change in biomass production due to contour ploughing.

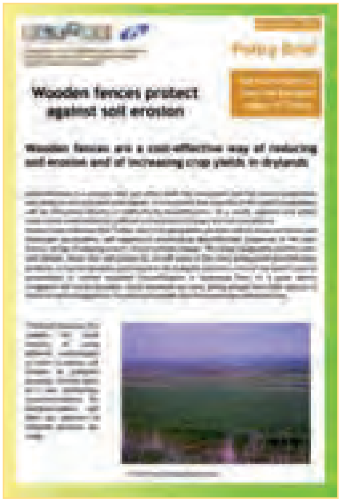


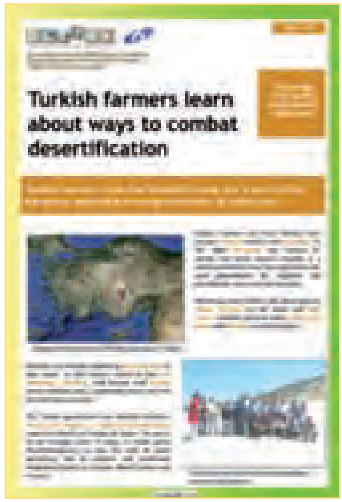
Net present value of cereal cultivation under traditional ploughing and contour ploughing.

V Disseminating the information

The Turkish research team from Eskişehir Osmangazi University, Turkey, used various communication formats to disseminate the results of the DESIRE project to three main stakeholder groups: the local and provincial authorities and policy makers, farmers and the general public. An example of communication to policy makers is the policy brief on the wooden fences technology. In this policy brief, stakeholders and the DESIRE project experts recommended state-funded subsidies for installing fences and the setup of training courses for the technology, as crucial preconditions for the adoption of the technology by farmers. See the DESIRE Harmonised Information System content for the Eskişehir study site dissemination products, including the policy brief on wooden fences, at http://www.desire-his.eu/en/eskiehir-turkey.

The research team organised an exchange visit between farmers from the Eskişehir and Karapinar study sites, aiming at exchanging knowledge on ways to reduce water and wind erosion (a problem in the Karapinar site), and to save water. The workshop was supported by the Turkish Ministry of Forests and Water, which has a dedicated Directorate General to Combat Desertification. The team reported on the exchange visit in a leaflet, that was disseminated among land users, local and regional authorities, and through the DESIRE Harmonized Information System (www.desire-his.eu/en/eskiehir-turkey/599-exchange-visits-between-farmers-from-turkish-study-sites).





Policy brief on wooden fences technology (left) and leaflet on farmers' exchange visit in the Turkish DESIRE study sites (right) (by Faruk Ocakoğlu et al.).

In order to reach the general public, the research team published various articles in local and regional newspapers, and figured in TV Broadcasts. These can be visited at http://tinyurl.com/88ba3zz (papers) and http://tinyurl.com/3y442hx (TV broadcasts).

Article in a local newspaper reporting on the DESIRE project and starting screen of TV Broadcast


'Çölleşmeye Karşı Küresel Bir Girişim-DESIR' projesi

Case study of the DESIRE methodology – Yan River Basin, China

(This case study is structured according to the 5 steps of DESIRE approach as explained in chapter 1)

I Establishing land degradation and SLM context and sustainability goals

Socio-cultural, economic and environmental context

The Yan River catchment is situated on the Chinese Loess Plateau and covers an area of 7680 km^2.

Degradation problems: mainly water erosion (severe), also wind erosion and vegetation degradation. Erosion and water shortage are the main limiting factors.
Land use: arable farming, cash crops, grass, secondary forests and vegetables
Geology and soils: mainly loess
Climate: semi-arid with about 500 mm per year
Existing conservation measures: mainly dams, terraces and tree planting
Socio-economic situation: population density about 70 people/km^2, income about 1600 Yuan (about 200 Euro) per person. Mostly small farmers with increasing amount of off-farm work.
Institutional and political setting: importance of policies like 'Grain for Green Project', which aim to replace cropland on steep slopes with other land uses such as forest, grassland or orchards.

Location of the Yan River Basin.

Stakeholders, goals and drivers

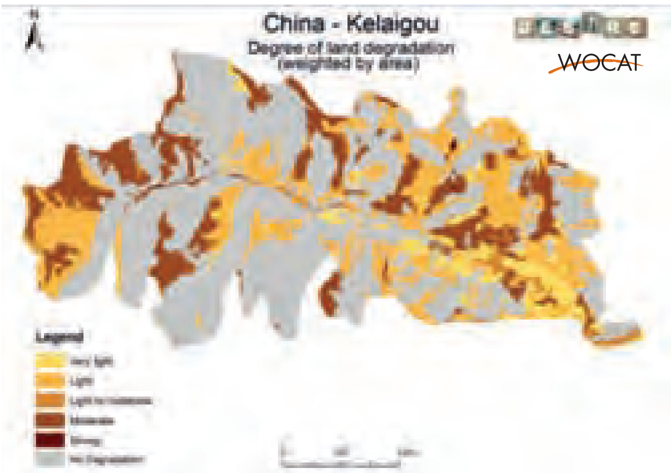
The main stakeholder groups include government/project staff, public administration, research centres and universities, schools and land users. Eight sustainability goals were defined, some examples are presented on the right.

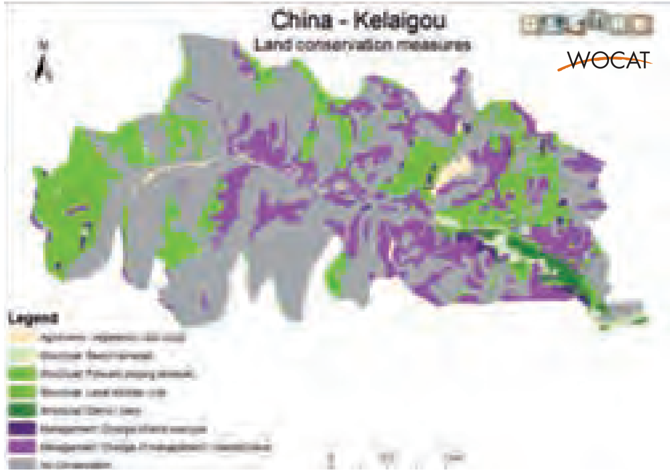
Sustainability goals	
Goal 1	Reduction of soil erosion and runoff losses;
Goal 2	Improvement of the water use efficiency of precipitation;
Goal 6	Improvement of local socio-economic condition;
Goal 7	Reduction of sediment load of the Yellow River;

Examples of identified drivers, their impact and the response

Protection of dryland farming areas			
Drivers	**Impact**	**Responses**	**Policies**
Easily eroded soil	Soil erosion	Revegetation, reforestation, terracing, reduction of local population	Regulations on the Protection of Basic Farmland (1998-12-27), Regulations on Conversion of Farmland to Forests (2003-1-20)
Inappropriate land management (agriculture on steep slopes)	Soil erosion and land fragmentation	Prohibit planting slopes steeper than 25 degree and impose a fine on actions that provoke erosion	Flood Control of The People's Republic of China (1998-1-1), Law of the People's Republic of China on Prevention and Control of Desertification (2002-1-1)
Climate change	Water loss and shortage of soil water	Terrace	Law of The People's Republic of China on Water and Soil Conservation (1991-6-29 issued, and 2010-12-25 revised)

Status of land degradation, sustainable land management and risk





WOCAT maps on degree of land degradation and on land conservation measures.

Status of land degradation, sustainable land management and risk

Two results from the use of the WOCAT mapping methodology are presented above.

150 indicator questionnaires were completed, 30 for each of the land uses settlement, forest, orchard, grazing land and cropland.

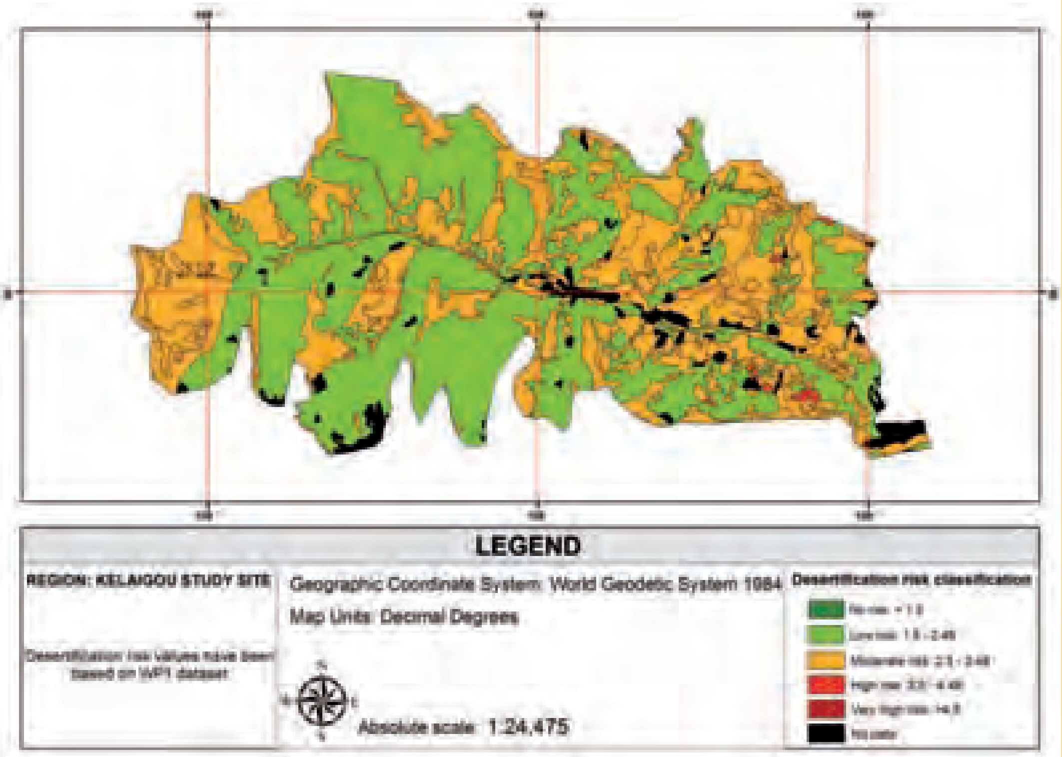
The expert system to estimate desertification risk based on indicators was applied using data collected in the indicator questionnaire and also using data from the WOCAT mapping questionnaire.

Distribution of estimated desertification risk

Study site	Distribution of land desertification risk classes (%)				
	No risk	Slight	Moderate	High	Very high
Yan River Basin, Loess Plateau, China	22.8	21.7	16.5	21.3	17.7

Desertification risk due to water erosion in the Kelaigou study site, China

Source: AUA, Greece



II Identifying, evaluating and selecting SLM strategies

Identify, document and evaluate SLM options

The first stakeholder workshop gave the following main results. Separate evaluations of SLM technologies were performed by local and external stakeholders. Below the assessment made by the **local stakeholders**:

Examples of potential SLM technologies for the China study site identified by local stakeholders

Technology / approach	Already applied or potential solution?	On land use type	Labour required (initial and maintenance)	Costs (initial and maintenance)	Effectiveness (long-term)	Limiting factors / constraints	Overall potential for local context
Building dam	applied	cropland	high	high	+	funds are limited	hard but beneficial
Building terraces	applied	cropland	high	high	++	much funds and labour needed	good
Planting trees	applied	forest	medium	medium	++	survival of trees	good
Closed for grazing	applied	grazing	low	low	+	education level	good
Interplanting	applied	cropland	low	low	+	soil fertility	good but takes more effort

Interview to complete the WOCAT questionnaire.

The following technologies were selected to be evaluated: 1. Planting trees, 2. Building dam, 3. Building terraced field, 4. Closure against grazing and 5. Interplanting. The WOCAT SLM technology description of the progressive bench terrace is described in this book.

Prioritise and select remediation options

In the second stakeholder workshop the main technologies selected earlier were considered, as well as a few new ones from the WOCAT database. Criteria were defined to evaluate the technologies with respect to economics/production, ecology and socio-cultural issues.

Two groups of stakeholders, local or external participants, performed the evaluation. The final score represents the average of the scores of different stakeholder groups. The scoring of options is shown in the table below for some of the criteria. The results were entered into the Facilitator software.

Criteria for the evaluation of SLM options in the China study site selected by stakeholders

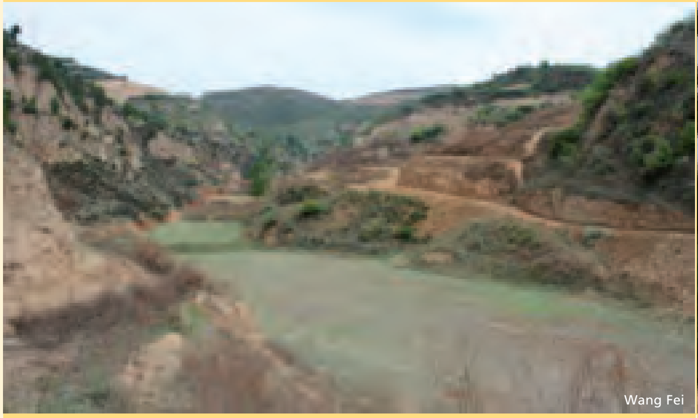
Protection of dryland farming areas		
Economic / production	**Ecological**	**Socio-cultural**
cost effectiveness	effectiveness in reducing runoff	reduce conflicts over water
Increase yield	reduce evaporation	suitability for smallholders
little financial inputs required for maintenance	reduce siltation downstream	no increase of woman workload
resilience to hazards	improve drinking water quantity and quality	—

SLM technology options

Level bench terrace

Reforestation

Check dam land



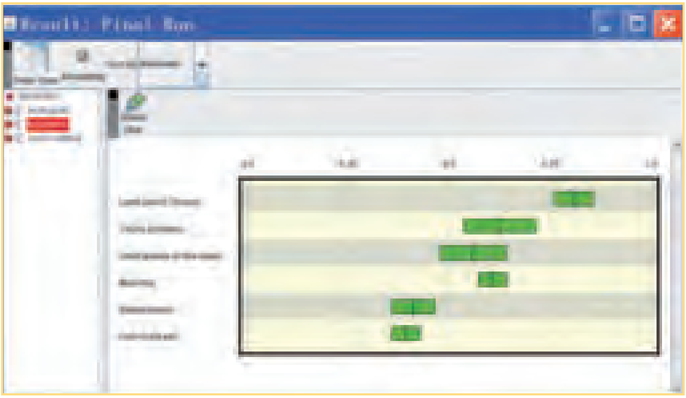
Contour ridging

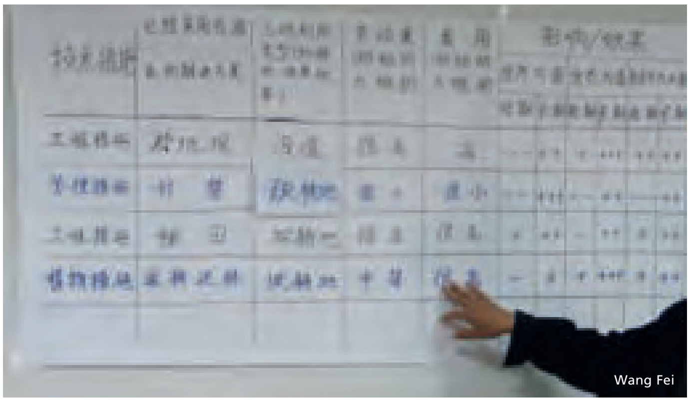
Fish-scale pits

Mulching

Option	Effectiveness in reducing runoff	Reduce evaporation	Reduce siltation downstream	Improve drinking water quantity and quality	Cost effectiveness	Increase yield	Water
Level bench terrace	7	3	6	4	6	7	7
Reforestation	5	1	4	2	4	1	2
Check dam land	7	1	7	7	3	4	4
Contour ridging	5	4	5	3	4	5	6
Fish-scale pits	4	3	3	2	2	1	2
Mulching	4	5	5	4	6	5	5

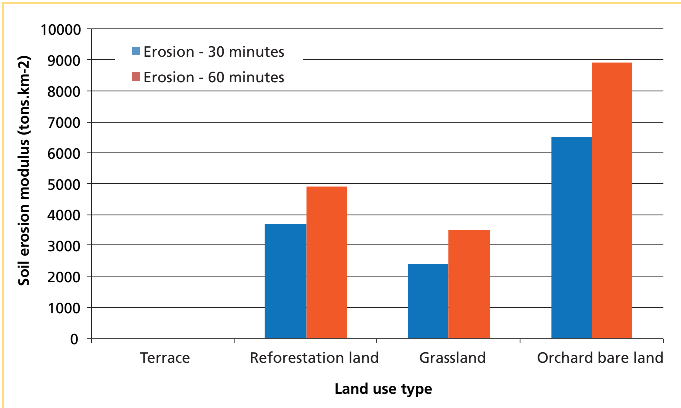
The results showed that the best option in this area is check dam land, then level bench terrace and reforestation. Constructing check dams requires design and great financial input. It was therefore not possible to implement it in DESIRE. Therefore level bench terrace and reforestation have been selected for implementation.





III Trialling and monitoring terraces

Experiments were carried out to monitor soil moisture and soil loss in different land use types in sloping areas and also in terraced land. High intensity rainfall was generated with a rainfall simulator, and data were collected for rain events lasting 30 and 60 minutes. Soil samples were collected to determine soil moisture level. Runoff samples were collected to determine sediment content and soil loss.



Results

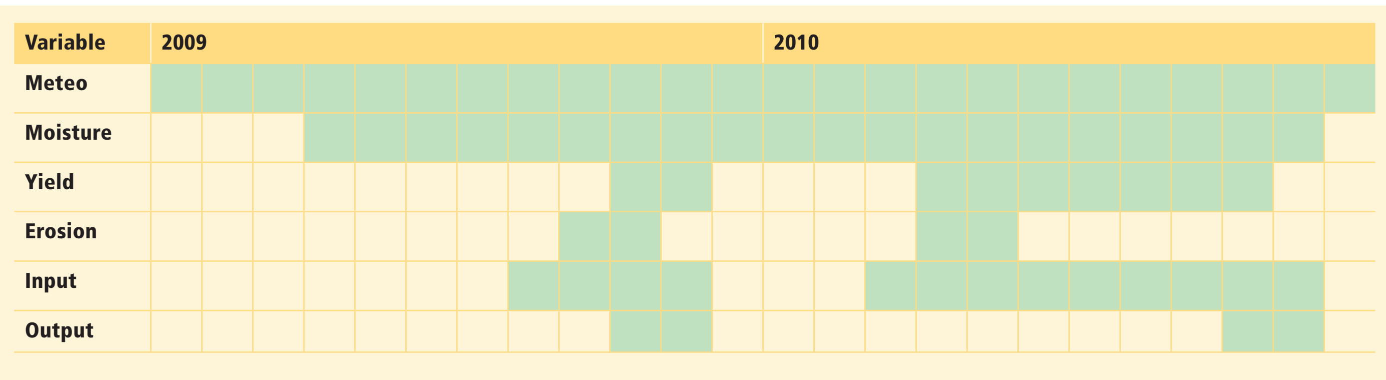
Results showed that soil loss was different for different land use types: no soil loss was observed on terraces, while orchards had very high soil loss. Results also showed that the longer rainfall event caused more erosion than the shorter one, but not twice as much as might have been expected based on the difference in duration.

The results were also evaluated from a production, socio-cultural and economic point of view, using the part of the WOCAT system that evaluates conservation technologies (www.wocat.net). The bars in the figure on the next page express the estimated or measured effect compared to the reference situation (untreated plots). This change can be positive (blue) or negative (red). Overall, the results were positive.

Main conclusions

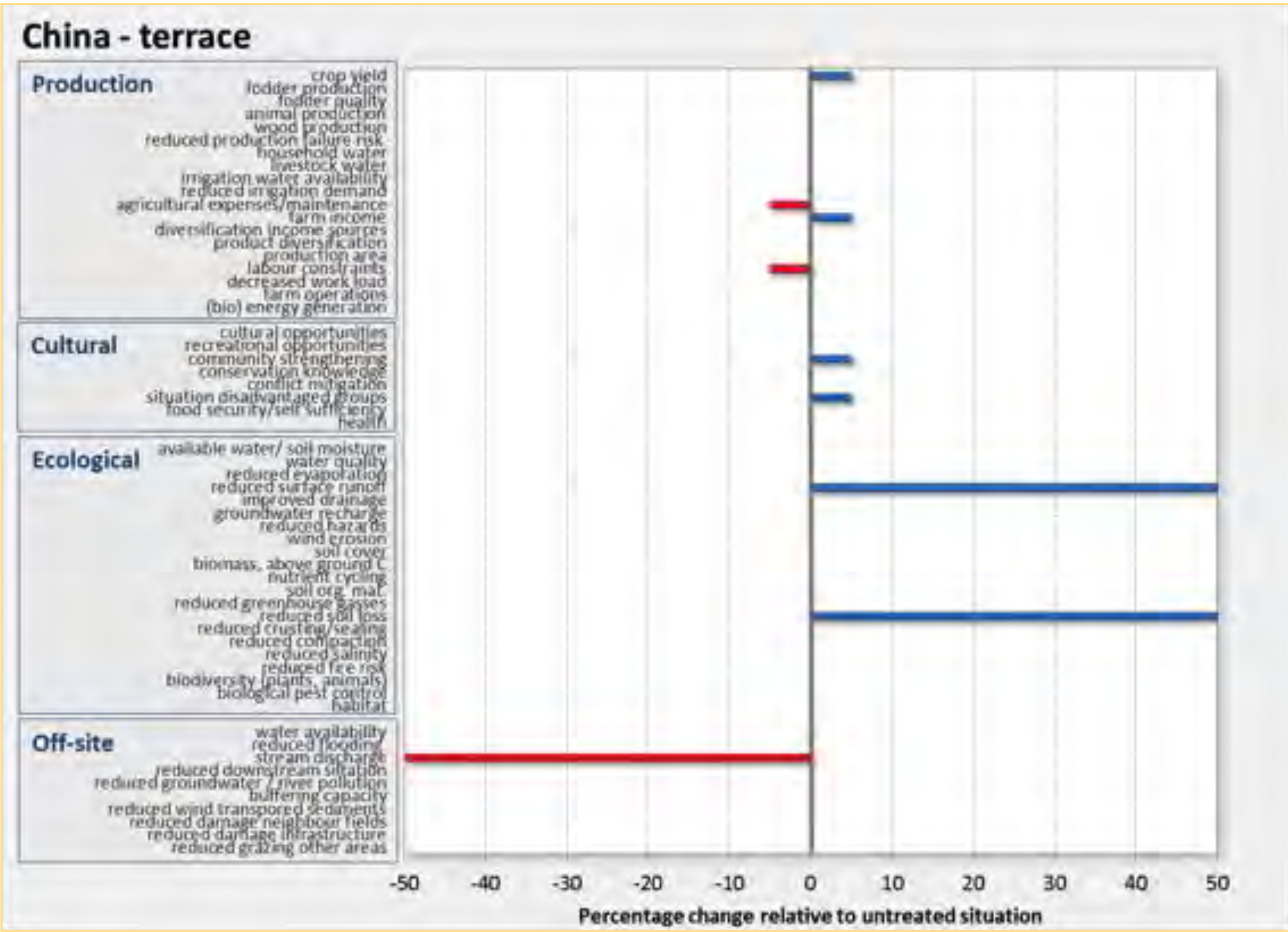
– Terracing improves soil moisture condition, controls soil erosion and increases agricultural production.

– The farmers are convinced that soil and water conservation practices help to protect the land from degradation, but they do not think that it is possible to get more income from the land. They hope that the results of DESIRE influence local government to invest more to build terraces.




Wang Fei

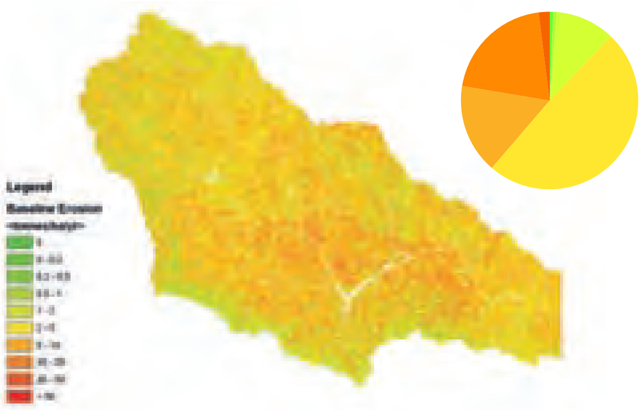

Wang Fei


China - terrace
Production
crop yield
fodder production
fodder quality
animal production
wood production
reduced production failure risk
household water
livestock water
irrigation water availability
reduced irrigation demand
agricultural expenses/maintenance
farm income
diversification income sources
product diversification
production area
labour constraints
decreased work load
farm operations
(bio) energy generation
Cultural
cultural opportunities
recreational opportunities
community strengthening
conservation knowledge
conflict mitigation
situation disadvantaged groups
food security/self sufficiency
health
Ecological
available water/ soil moisture
water quality
reduced evaporation
reduced surface runoff
improved drainage
groundwater recharge
reduced hazards
wind erosion
soil cover
biomass, above ground C
nutrient cycling
soil org. mat.
reduced greenhouse gasses
reduced soil loss
reduced crusting/sealing
reduced compaction
reduced salinity
reduced fire risk
biodiversity (plants, animals)
biological pest control
habitat
Off-site
water availability
reduced flooding
stream discharge
reduced downstream siltation
reduced groundwater / river pollution
buffering capacity
reduced wind transported sediments
reduced damage neighbour fields
reduced damage infrastructure
reduced grazing other areas
-50
-40
-30
-20
-10
0
10
20
30
40
50
Percentage change relative to untreated situation

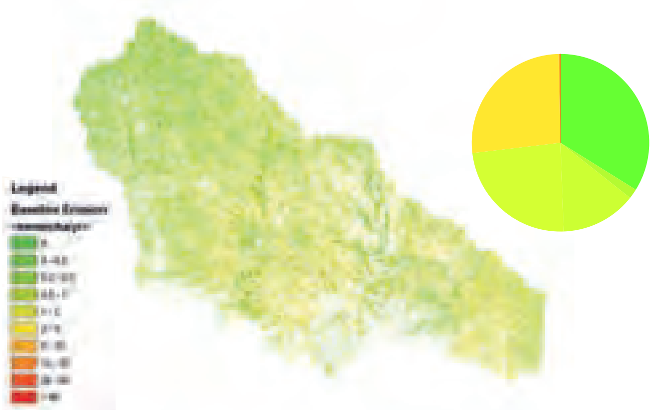
IV Up-scaling SLM strategies

Some results for year-after-year terraced land.

The technology is applicable on land under arable or tree crops on slopes higher than 2%.

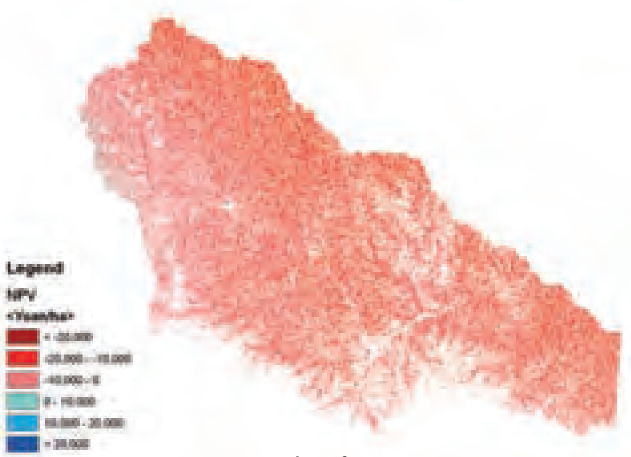


Without technology



Initial years of implementation of the technology

The maps above show soil erosion and indicate that even in the initial years of application, erosion is reduced (although the level remains fairly high). In the long term erosion would decrease further when ground cover is improved. The figure below shows that the technology is not profitable in the short term (up to at least 10 years). However, the technology was found to be profitable in the area in the long term (20 years).



Net present value after 10 years

V Disseminating the information

Evaluation of remediation options with stakeholders

The workshop was held with two sessions. The first session was held on 22 June 2011 with local farmers, including six village heads. The farmers who carried out monitoring of soil erosion and soil water and conducted an economic survey were also present. The second half of the workshop was conducted with policy makers at the county level on 23 June 2011. Additional interviews are planned with selected Government departments and experts in the following months to further disseminate project findings.

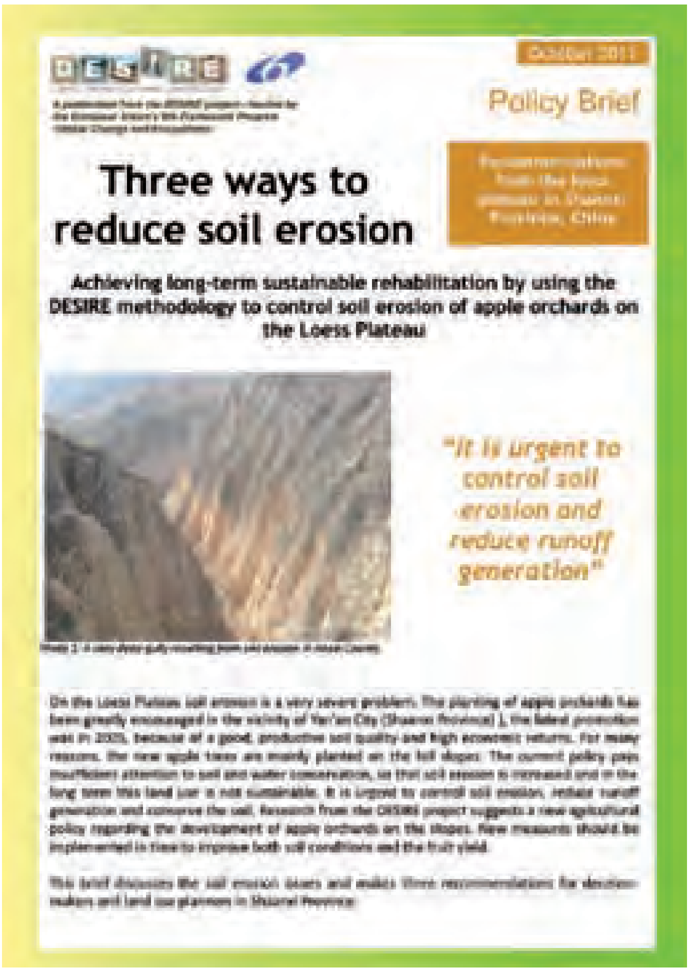
Priority remediation strategies selected in the initial stakeholder workshop were ranked in the same order after participants had been presented with evidence from field trials and modelling. The three strategies prioritised during the initial workshop are clearly the most important options in this region given their benefits in relation to ecological, economic and socio-cultural criteria. This was supported by field trial results.

Examples from the dissemination plan

China participated in several dissemination products, such as DESIRE newsletters, DESIRE factsheets, DESIRE HIS (Harmonised Information System – www.desire-his.eu/en/yan-river-basin-china) and scientific papers.

A policy brief was also written about ways to reduce erosion in apple orchards (see www.desire-his.eu/en/yan-river-basin-china/738-policy-brief). The policy brief recommended the use of terraces, mulching and grass cover to decrease erosion rates in orchards. In this policy brief it is also recommended that policies should cover three components:

– Actions to improve the awareness of SLM need to be communicated and initiated with the full range of stakeholders, from local farmers to administrative managers;
– SLM should be planned, designed and implemented at the same time as planting new trees on the slopes;
– Financial subsidies could be paid to households as an incentive to implement and maintain the SLM practices that have resulted from DESIRE.


Policy Brief

Three ways to reduce soil erosion

Achieving long-term sustainable rehabilitation by using the DESIRE methodology to control soil erosion of apple orchards on the Loess Plateau

"It is urgent to control soil erosion and reduce runoff generation"

Policy brief on ways to reduce erosion (by Wang Fei et al.).

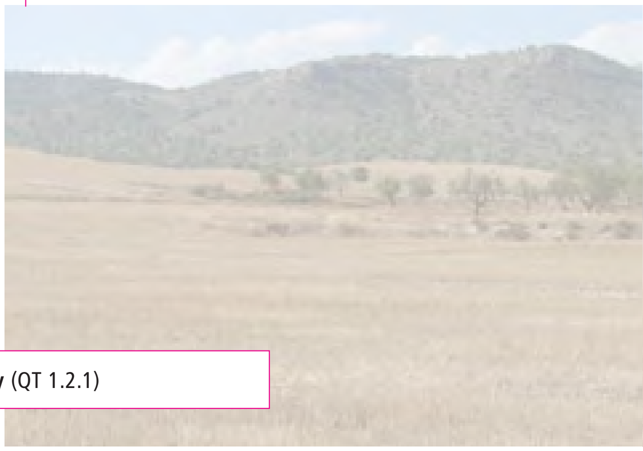
Target audience	Location of target audience	Message	Reduce siltation downstream	Improve drinking water quantity and quality	Cost effectiveness
1 Soil and water conservation office of Yan River Basin	Yan River Basin, Yan'an City, Ansai County	Benefit analysis of different practices; Recommendation of soil and water conservation;	– Paper and report – Policy brief	Poster and discussion	– To think more about SLM; – Agreement on SLM of DESIRE
2 Local farmers	Ansai County	Suggestion on the land management of orchards	– Presentation – Poster	– At meetings – Hand out to villages	– Knowledge of SLM

Annex

Explanation pages of case studies: SLM technologies

QT: refers to Questionnaire on Technologies and its related database

Two photographs are included here to provide – ideally – an overview and detail of the technology: from QT 2.1.3



Name of Technology (QT 1.2.1)

Reduced contour tillage of cereals in semi-arid environments

Spain - *Labranza reducida de cereal en contra de la pendiente en ambientes semi-áridos (Spanish)*

Country – local name of technology (QT 1.2.2)

Above left: Crop r… that were harveste… will remain like this… when it will be plou… (Photo: Joris de Ve…
Above right: Cere… Joris de Vente)

Above left: Photo caption and name of photographer(s)

Above right: Photo caption and name of photographer(s)

Reduced contour tillage in a rotational system of winter cereals and fallow land

A summarised definition of the technology in one sentence: from/based on QT 2.1.1

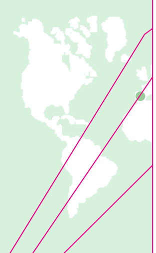
This technology is a type of conservation tillage with minimal economic effort and is … tillage is reduced to a maximum of three times … rs with a disc- or a chisel-plough. The disc-plough … se weed or crop residue cover. The disc-plough … than the chisel-plough, while the chisel tends to plough slightly deeper (~30cm) than the disc-plough (~20cm). The advantage of the chisel-plough is that it leaves a higher surface roughness and is less destructive to soil aggregates. Under conventional tillage, fields are ploughed up to five times every two years, once with a mouldboard plough. In both systems, cereals are cropped in a … Cereals are sown in autumn (October) and … low year. Under reduced tillage the crop residues … utumn and winter periods. This provides increased … age is performed on fallow land in early spring … sowing in October. With conventional tillage, fields … ough in autumn. Traditional sowing machinery can … ded in specialised equipment. Tillage is performed … event rill and gully formation. No herbicides are … mixed with the upper soil layer during ploughing. … ontent and a better infiltration capacity, soil water … d crop yields will increase within 3-5 years after …

A concise description of the technology, based on QT 2.1.2, standardised by editors, usually including information on:
- the overall purpose
- establishment and maintenance procedures
- natural and human environment including land use, and land degradation problems
- costs (from QT 2.6)
- how long the technology has been practised
- `supportive technologies/measures' – those that add extra effectiveness or value to the main technology (where relevant; QT 2.8).

This section should give the reader a descriptive overview of the technology, which is then supplemented by data in the rest of the case study.

… ease the soil organic matter content by retaining it … erosion by water and tillage. The higher infiltration … th crop residues in autumn and winter protects the … soil erosion by over 50% and runoff by 30%. In … ontent increases overall soil quality in terms of soil … acity. Compared to traditional multiple tillage … h, under reduced tillage, tillage erosion is reduced … but also through tillage of fallow land resulting in … ondary tillage operations of already loosened soil. … leading to a reduction of 40% in production costs … he studies showed that in first 2-3 years after … enser and have a lower infiltration capacity than … Yet, when the organic matter content and soil … rates are higher than under traditional ploughing and result in increased soil water content and crop yields.

The technology is applied on loamy soils with a calcareous substrate, of shallow to medium depth, and slopes are gentle to moderate (5-15%). The climate is semi-arid with a mean annual rainfall of around 300 mm. Droughts, centred in summer commonly last for more than 4-5 months. Annual potential evapotranspiration rates greater than 1000 mm are common. The production system is highly mechanised and market oriented but depends strongly on agricultural subsidies.



Location: Murcia
Region: Guadalentín…
Technology area: 1…
Conservation meas…
Stage of interventio… degradation, mitigatio… degradation
Origin: Land Users… Experiments - recent
Land use: cropland
Climate: semi-arid, s…
WOCAT database r…
Related approach: … programme (QA SPA…
Compiled by: Joris d…
Date: 12th Jun 2008

Location / region: location, district, country: from QT 1.3.1
Technology area: in km² indicating the particular site studied; from QT 1.3.1
Conservation measure: agronomic/ vegetative/ structural/management or combination: from QT 2.2.2.2
Stage of intervention: from QT 2.2.2.3
Origin: from QT 2.3.1
Land use: cropland/grazing land/ forest/woodlands/mixed/other: from QT 2.2.2.1
Climate: humid/subhumid/semi-arid/ arid: from QT 2.5.2
WOCAT database reference: QT code
Related approach: name and code of approach: from QT 1.2.5
Compiled by: for original and updated versions (if these differ) name and address of main author QT 1.1
Date: of original data collection and update – month and year

Land use problems: This brief description of the major land use problems – without SWC – in the area is derived from the specialists' and the land users opinions combined, both of which questions fall under QT 2.2.1

Classification

Land use problems: There is a lack of ... dryland farming. A lack of water availabi... The relatively high soil erosion rates ca... gully formation and reduced soil depth).

Land use: Here there is a choice between cropland/ grazing land/ forest or woodland/ mixed and 'other' with various subcategories
Climate: The choice here is between humid/ subhumid/ semi-arid/ arid: taken from QT 2.7.2
Degradation: The types of soil degradation addressed by the technology are given here: water erosion/ wind erosion/ chemical deterioration/ physical deterioration/ water degradation/ vegetation degradation – with further specification where relevant: from QT 2.2.2.4
SWC measures: The relevant SWC category/ies is/are given; the choice is between agronomic/ vegetative/ structural/ management with possible combinations: from QT 2.2.2.2. There should be further specification of measures according to the SWC categorisation system given in Annex T4
Supportive measures **(supp.)** are desirable but not essential measures for the functioning of SWC.
Optional measures **(opt.)** indicate additional choices.
For definition of **pictograms** refer to page 272.

Land use | Clima...

annual | semi-ar... subtrop...

Stage of intervention: from QT 2.2.2.3

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land u...
Experi...
Extern... introduced.

Origin: from QT 2.3.1

Level of technical knowledge

Agricultural advis...
Land user

Level of technical knowledge: from QT 2.3.2

Main causes of land degradation:
Direct causes - human induced: soil management, disturbance of water cycle (infiltration / runoff)
Indirect causes: inputs and infrastruc...

Main causes of land degredation: from QT 2.2.2.5

Main technical functions:
- control of raindrop splash
- control of dispersed runoff: retain / t...
- control of dispersed runoff: impede / retard
- control of concentrated runoff: impede / retard
- improvement of ground cover

Secondary technical functions:
- increase of surface roug...
- increase in nutrient avai...

Secondary technical functions: from the same question (QT 2.2.2.6); those appearing lower down the rank are listed here

Main technical functions: here the question was 'what are the main means by which the technology achieves its impact?': QT 2.2.2.6 gives multiple categories, and these have are ranked in terms of importance

Avg. annual rainfall (mm): QT 2.7.1 / **Altitude (m):** QT 2.7.6 / **Landform:** QT 2.7.7 / **Slope:** QT 2.7.8

Environment

Natural Environment

Average annual rainfall (mm)	Altitude (m a.s.l.)	Landform	Slope (%)

Natural environment ranked in the charts below: ■ very important/most common; ■ important; ■ less important. Note that within the technology area there can be a range of environments. In some cases, even where the area is small, the annual rainfall (for example) may be on the boundary between two categories – or not exactly known – thus both categories may be given a rank in that situation.

Average annual rainfall (mm)	Altitude (m a.s.l.)	Landform	Slope (%)
750-1000	1000-1500	valley floors	steep
500-750	500-1000		very steep
250-500	100-500		
< 250	<100		

Soil depth (cm)

0-20

Soil depth before SLM applied: from QT 2.7.9

Growing season(s): 220 days (Nov - Jun)
Soil texture: medium (loam)
Soil fertility: low
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: poor (eg sealing /crusting)

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: for agricultural use only
Biodiversity: low

Tolerant of climatic extremes: seasonal rainfall increase, heavy rainfall (intensities and amount), wind storms / dust storms, floods, decreasing length of growing season.
Sensitive to climatic extremes: temperature increase, seasonal rainfall d...
If sensitive, what modifications were made / are possible: The crop typ... arid conditions.

Growing period: how many seasons and the duration; from QT 2.7.4
Soil fertility: very high / high / medium / low / very low (QT 2.7.11)
Soil texture: coarse (sandy) / medium (loam) / fine (clay) (QT 2.7.10)
Topsoil organic matter: high (> 3%) / medium (1–3%) / low (<1%) (QT 2.7.12)
Soil drainage/infiltration: good / medium / poor (QT 2.7.13)
Soil water storage capacity: from QT 2.7.14
Ground water table: from QT 2.7.15
Availability of surface water: from QT 2.7.16
Biodiversity: from QT 2.7.18

Tolerant or sensitive to climatic extremes:
Under which climatic regime the technology is tolerant or sensitive, if sensitive, what modifications were made/are possible (from QT 2.7.5).

Cropland (or grazing land, mixed land, forest land) per household*
Table (size of land per household in hectares): ranked ■ (very important/ most common): ■ (important): ■ (less important); dependent on what form of land use where the SWC is implemented: whether QT 2.8.8 (cropland); 2.8.9 (grazing land); 2.8.10 (forest/ woodland)
*Note: title of this box will change depending on land use

Land user: from QT 2.8.1
Population density: from QT 2.8.2
Annual population grow: from QT 2.8.3
Land ownership: state / company / communal/village / group / individual – not titled / individual – titled; QT 2.8.4
Land-/water use rights: open access (unorganised) / communal (organised) / leased / individual; QT 2.8.4
Relative level of wealth: from QT 2.8.5
Importance of off-farm income: from QT 2.8.6: <10% / 10–50% / >50% of all income
Comment regarding off-farm income: especially source of that income
Access to service and ifrastructure: from QT 2.8.7
Market orientation: QT 2.8.8.1/ QT 2.8.9.1/ QT 2.8.10.1/QT 2.8.11.1
(answer chosen from list below depends on land use system) subsistence (self-supply) / mixed / commercial (market)
Mechanization: from QT 2.8.8.2
Livestock grazing on cropland: from QT 2.8.8.5

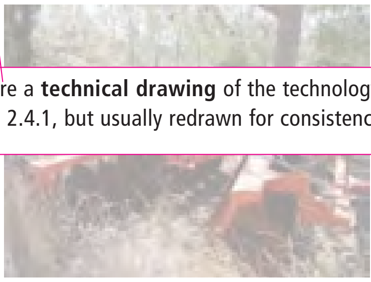
Human Environment

Cropland per household (ha)

	<0.5
	0.5-1
	1-2
	2-5
	5-15
■	15-50
■	50-100
	100-500
	500-1,000
	1,000-10,000
	>10,000

Land user: Individual and common small scale land users, mainly men
Population density: 10-50 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, titled
Land use rights: individual (all cropland is privately owned)
Water use rights: individual. Water use is organised by permits to water extraction from aquifers on an individual basis. Water rights are provided and controlled by the water authority of the Segura river basin.
Relative level of wealth: average, which represents 80% of land users; 75% of the total land area is owned by average land users

Technical drawing:
Top: Photo of the disc-plough used for superficial ploughing (~20cm depth) where there i[s] perennial vegetation. Bottom: Chisel-plough (Photos: Joris de Vente)



Here a **technical drawing** of the technology (if available): originally from QT 2.4.1, but usually redrawn for consistency

Implementation activities, inputs and costs

Initial investment

Establishment activities
The **establishment** activities for the SLM measures (whether agronomic, vegetative, structural and/ or management) are described here in sequence: 1. / 2./ 3./ 4.; etc. Information is added on source of energy, equipment used, timing of operations etc. Taken from the questions: QT 2.5.1.2; QT 2.5.2.2; QT 2.5.3.2; QT 2.5.4.2. The duration of the establishment phase is given (usually either within one year – or a number of years)

Establishment inputs and costs per unit

Inputs	Costs (US$)
Equipment - tools	7[illegible]
TOTAL	7[illegible]

Establishment inputs and costs per ha
Input amounts and costs taken from QT 2.6.1: remarks may be added on specifications / how costs were calculated (e.g. for line structures: meter of gullies, etc)
Where inputs are 'free' to the land users (e.g. stone, manure etc) quantities are given, but no cost allocated unless there is a market value locally – in which case that value is quoted

Maintenance/recurrent inputs and costs per ha

Inputs	Costs (US$)		
Labour		[illegible]	[illegible]
Equipment - machine use (tractor & fuel)		50	100
TOTAL		[illegible]	

Maintenance / recurrent activities
The annual **maintenance** (upkeep/ repair) or **recurrent** (regular annual operations) activities for the SLM measures (whether agronomic, vegetative, structural and/ or management) are described here in sequence:
1. / 2./ 3./ 4.; etc.
Information is added on source of energy, equipment used, timing of operations, frequency etc
Taken from the questions: QT 2.5.1.2; QT 2.5.2.2; QT 2.5.3.2; QT 2.5.4.2

Maintenance/ recurrent inputs and costs per ha per year
Annual input amounts and costs taken from QT 2.6.1:
Where inputs are 'free' to the land users (e.g. stone, manure etc) quantities are given, but no cost allocated unless there is a market value locally – in which case that value is quoted

...factor affecting the costs. The costs are indicated per ha of land wher... ...t assuming an average farm size of 10 ha, this means a per ha cost of $...

Remarks
Here a comment is added on how, and for what situation, the inputs and costs were calculated. For example what was the original land slope? That can make a large difference to the costs of terraces or vegetative strips. What other assumptions have been made? Is it based on measurements or broad estimates? Any extra information that may be useful to shed light on the calculations is added here. Taken from question 2.6.2

Impacts of the technology: This information is asked of the specialist under questions QT 3.1.2 – QT 3.1.5. Categories are then ranked (+=little, ++=medium, +++=high), listed according to rank and additional comments/specifications given in brackets where available e.g. crop yield increase (maize +200%; beans +150%).

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+ increased crop yield	+ increased expenses on agricultural inputs
+ increased farm income	

Socio-cultural disadvantages

Ecological disadvantages

Off-site disadvantages

Acceptance / Adoption
The information below relates to the spread of the technology. Within the area covered by the case study (the 'technology area': see box on page one) we are considering only those people who have applied the technology (though often this means all/ nearly all the households). The infomation below refers to how the spread has occured/ is still occuring – with a special focus on the role of incentives. The following details are given:

- % land users / number of families who accepted the technology with incentives; from QT 3.3.1.1
- % land users / number of families who accepted the technology without incentives (spontaneous adoption); from QT 3.3.2.1
- which groups accepted with/ without incentives? What were these incentives and what were their reasons for adoption? From QT 3.3.1.2 and QT 3.3.2.2
- is there a trend towards growing spontaneous adoption? comments here from QT 3.3.2.2

Benefits/costs according land user
Short-term / long-term categories: the land users' view of how beneficial the technology is with respect to establishment and to maintenance activities, and in the short- term and the longterm for each. Note: this is essentially a qualitative question, having seven possible answers ranging from 'very negative' through 'neutral/ balanced' to 'very positive'. Another consideration is that when incentives are used for establishment, land users may view the benefits for establishment as 'positive' relating the benefits to the incentives rather than the impact of the SWC technology.

Farm income may increase with up to12%. There is no known effect on education, health etc. The subsidies applied for cereal production in a rotation system of fallow & for contour ploughing contribute to improved livelihood of most farmers.

for establishment: QT 3.2.1

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	slightly negative	slightly positive
Maintenance/recurrent	slightly positive	slightly positive

for maintenance/ recurrent: QT 3.2.2

When a disc-plough was not already used in normal farming operations, th… …ring establishment.

Acceptance/adoption:
There are no subsidies for reduced tillage. Nevertheless, 100% of land user families have implemented the technology with external material support since there are subsidies for parts of the technology such as contour ploughing and rotational farming allowing a fallow period (1-2 years) after harvest. Practically 100 % of farmers use these subsidies; still reduced tillage is implemented 100% voluntary. There is a little trend towards spontaneous adoption of the technology. There seems to be a growing public awareness of the fact that frequent deep rotational ploughing is not always necessary and results in higher production costs.

Concluding statements

Concluding statements:
The answers to QT 3.4.1 and 3.4.2 summarise the technology's strong and weak points and how these could be, respectively, sustained/ improved or overcome. The questions were divided into two: the author's opinion and the land user's' viewpoints. The answers (which often coincided and were seldom contradictory) have been combined in this table.

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
This is a low-cost technology that requires limite… equipment and potentially results in a slightly in… as well as a decrease in land degradation and a… quality and water-holding capacity → In some h… sufficient rainfall, the technology might be adap… tillage with direct sowing, reducing the tillage op… However, this implies an important investment i… level of organisation at the agricultural cooperat…	…ess of this technology is that it does …m income and so may not be …ers to apply → Provide information …od soil management that include …uding floods, reservoir siltation, etc.) …uced tillage will lead to less work for …profit.
An increased soil surface cover throughout autu… provides a good protection against soil erosion … formation → Sometimes a field is left fallow for t… but it is still ploughed between them. This ploug… as well.	…es for cereal cultivation in a rotation … are obliged to plough after each …ds, even when two consecutive … This is considered unnecessary → It … the need for this and look for …ng.

Key reference(s): López-Fando, C., Dorado, J. and Pardo, M.T., 2007. Effects of zone-tillage in rotation with no-tillage on soil properties and crop yields in a semi-arid soil from central Spain. Soil and Tillage Research, 95(1-2): 266-276; Ozpinar, S., 2006. Effects of tillage systems on weed population and economics for winter wheat production under the Mediterranean dryland conditions. Soil and Tillage Research, 87(1): 1-8; Holland, J.M., 2004. The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agriculture, Ecosystems & Environment, 103(1): 1-25
Contact person(s): Joris de Vente, EEZA-CSIC, Spain, Joris@sustainable-ecosystems.org

Key reference(s)
References to literature are specified here: not just taken from the questionnaire annex 1, but in some cases added to by the editors. Many technologies have not been documented before.

Contact person(s)
The name and contacts of the author(s) so that specific interests/ question from readers can be followed up, taken from annex 1.

Explanation pages of case studies: SLM approaches

QA: refers to Questionnaire on Approaches and its related database

Two photographs of approach activities are included here: from QA 1.3.3 or from the WOCAT photographic database

Above left and right: D... on the usefulness of soi... and the need for agricul... Joris de Vente).

Above left and right: Photo caption and name of photographer(s)

Name of Approach (QA 1.2.1)

Regional rural development programme

Spain – *Programa de desarrollo rural de la región de Murcia (Spanish)*

Country – local name of approach

Regional development programme to protect natural resources and stimulate rural economies.

A summarised definition of the approach in one sentence: from/ based on QA 2.1.1.1

Aim / objectives: The objective of the Rural Development Programme (RDP) is to ...ficult environmental conditions (drought, steep ...ctices either in the implementation phase or for ...ied out to: 1) improve the socio-economic ... abandonment, and 3) prevent on-site and off-site damages caused by land degradation and erosion. To achieve these objectives, the RDP identifies different lines of action: 1) compensate for difficult natural conditions; 2) fight against erosion; 3) reduce farming intensity; and 4) promote ecological agriculture.

Methods: The main method used in the RDP is through subsidies of farming practices following a cross-compliance principle. Each line of action implies a combination of conservation measures that are subsidised, but only when applied in combination. Hence, single conservation measures outside of these lines of action are not subsidies.

Role of stakeholders: The level of the subsidy is based on estimated implementation and maintenance costs and possible loss of productivity caused by the conservation measures. These values were obtained after consultation of various stakeholder groups including farmer organisations with agricultural cooperatives. However, because of limited resources, not all farmers will receive subsidies for the conservation measures. Priority is given to: 1) farmers who have 50% of their land within the Nature 2000 network, a European wide network of protected areas for the preservation of ...mers with >50% of their land in unfavourable ...e subsidy in previous RDPs.

...ore than 20% are not subsidised in this ...at no agriculture takes place in these areas. ...ubsidised. RDPs are developed for a period of ...RDP is defined and priorities and levels of ... is valid for the period 2007-2013.

This body of text constitutes a concise description of the approach, usually including the overall purpose, specific objectives, methods (including incentives), stages of implementation, role of participants, project description, donors, project dates (where relevant). It is based on the answer to QA 2.1.1.2: 'summary of approach with main characteristics'. The intention is that this section should give the reader a descriptive overview of the approach, which is then supplemented by data in the rest of the case study.

Location: Murcia, Guada...
Approach area: 11,313 k...
Type of Approach: proje...
Focus: mainly on conser... activities
WOCAT database refere...
Related technology(ies)... tillage in semi-arid enviro... Vegetated bench terraces... Ecological agriculture of a... using green manure (QT... tillage of almonds and oliv...
Compiled by: Joris de Ve...
Date: 12 May 2009

Location: location, district, country: from QA 1.3.1
Approach area: in km² indicating the particular site studied; from QA 1.3.1
Type of approach: from QA 2.1.1.3
Focus: from QA 1.2.4
WOCAT database reference: QA code
Related technology: name of related technology given in related QT
Compiled by: for original and updated versions (if these differ) name and address of main author
Date: of original data collection and update – month and year

Problem
A list of the main problems addressed by the approach, in order of importance: from QA 2.1.3.1, intended to indicate what gaps the approach was intended to fill, so that the associated technologies could be effectively implemented.

Problem, objectives and constraints

Problems:
The main problems addressed by the ... abandonment, and erosion and land deg...

Aims / Objectives: 1) improve the soci... off-site damage caused by land degrada...

Objectives
Description of the main objectives of the approach: text taken directly or summarised from QA 2.1.4.1

Constraints addressed

	Constraints	Treatments
Financial	Many technologies require an investment and ...	A subsidy equal to the loss of productivity and ...maintenance costs.
		...ing by the regional extension ...ners organisations.
		...vegetation types to use and ...implementation costs.

Constraints addressed
This is a list of the specific constraints 'hindering the implementation of the SWC technology' and an indication of 'the treatment offered by the approach' to overcome these. These are grouped under 'major' and 'minor' categories, such as 'social', 'financial' and 'legal': from QA 2.1.3.2. The intention here was to highlight those problems that arose, especially after the approach was put into practice, and how these were tackled.

Stakeholders / target groups

Approach costs met by:
International
Government
local government (district, cou... municipality, village, etc.)
Total

US$> 1,000,000

Approach costs met by
The various donors/ contributors listed in QA 2.3.1.1, based on figures or estimates

Target groups
Meaning those identified to be addressed through the approach – from QA 2.2.1.1.
For definition of **pictograms** refer to page 272.

Decisions on choice of the Technology(ies): mainly by SLM specialists
Decisions on method of implementing the Technology(ies): by politicians / leaders
Approach designed by: national spec...
Implementing bodies: international, g...

Decisions on choice of the technology: Categories here are specified in QA 2.1.5.1, and comments allowed
Decisions on method of implementing the technology: Categories here are specified in QA 2.1.5.2, and comments allowed
Approach designed by: Taken from QA 2.1.6.1: where the four options of 'national specialists', 'international specialist', 'land users' and 'others' are specified

Land user involvement

Phase	Involvement	
Initiation/motivation	Self-mobilisation	Land users were sporadically consulted through farmers organizations, and participated in protest meetings against initial versions of the RDP that they considered insufficient regarding payments for the agricultural sector
		Land users implemented SLM technologies themselves with help from technicians of regional government and farmers organisations

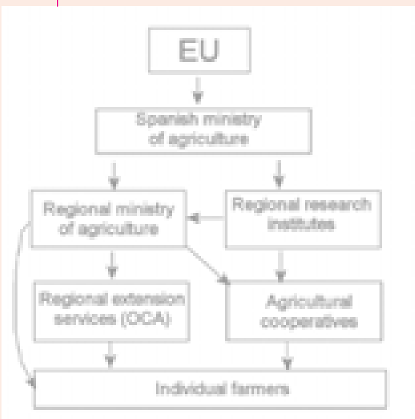
Land user involvement
This table below is based on a mix of answers to questions QA 2.2.2.1 and QA 2.2.3.2
phase / Involvement* / activities
* either 'none' 'passive' 'payment/ incentives' 'interactive' or 'self-mobilisation'

...**of men and women:** Yes, moderate. Traditionally land users and agricultural activities are

Involvement of disadvantaged groups: Yes, little. The focus of the approach is on the socio-economic situation of farmers with a relatively low income and under marginal conditions.

Differences in participation between men and women: Taken from question QA 2.2.2.2 this is a summary of the different roles played by women and men under the approach, with reasons for these differences explained where possible.
Involvement of disadvantaged groups: from QA 2.2.2.3

Here appears an organogram – if available from the answer to QA 2.1.2: where this is not the case, for example in an approach which is basically a tradition, a drawing or a photograph is included in its place



Organogram
To be fit for purpose, since 2007 the RDPs are designed at the regional level using advice from scientific institutes. The boundary conditions regarding the overall environmental and economic obje... finances are received from the European and national... extension services have a role in the dissemination of information and control of correct implementation of measures by farmers.

Caption

Technical support

Training / awareness raising: Trai... farmer to farmer. Training focused on... and from the extension services.
Advisory service: Name: agricultural... Key elements: 1. Control 2. advice
Currently, the extension system is str... awareness building required for land u... of the farmers organisations but not at...
Research: Yes, moderate resear... Results from national and internationa... national research institutes such as th... national research council (CSIC).

Technical support
Training: A short piece of text, formulated from the answers to QA 2.4.1.2 and QA 2.4.1.3 (the subjects and form/ method of training) and from QA 3.2.4.1 where the effectiveness of training ('poor', 'fair', 'good' 'excellent') on different specified target groups is rated.
Advisory service: A similar piece of text here, formulated from QA 2.4.2.1 which asks for the 'name of extension approach' and its 'key elements' and a description of the adequacy of extension services to continue SWC activities in the future (QA 2.4.2.5) supplemented by a rating of effectiveness of extension ('poor', 'fair', 'good' 'excellent') on different target groups with an explanation – from QA 3.2.4.2
Research: Was applied research part of approach? QA 2.4.3.2 asks this basic question and requires an overall rating of 'not', 'low', 'moderate' or 'great'. It further asks for a list of topics researched. The text here goes on to describe and explain impact of the applied research on the effectiveness of the approach – taken from QA 3.2.4.3

External material support / sub...

Contribution per area (state/private...
Labour: Land users implement measu...
Input:
- Agricultural (seeds, fertilizers, etc.): seeds, partly financed; fertilizer and biocides, fully financed
- Construction material (stone, wood, etc.): stones, fully financed
- Productivity loss: Fully financed

Credit: Credit was not available.
Support to local institutions: Yes, little support with training. Information to agricultural cooperatives.

Monitoring and evaluation

Monitored aspects	Metho...
bio-physical	*Ad hoc* ... *param...*
technical	*Ad hoc* ... *measu...*
economic / production	*Ad hoc...*
area treated	Regula...
no. of land users involved	Regula... progra...

Changes as result of monitoring and... are evaluated and redefined every 7 years...

Incentives
Labour: This section answers the question of whether labour for implementation was voluntary, or rewarded with incentives. If it was rewarded, specifications of those incentives for land user's labour input are given. It is taken from QA 2.5.1.1
Inputs: Under this heading there is the answer to QA 2.5.1.2 which seeks to find out whether inputs were provided, and if so, what inputs and whether financed. And if financed, under what conditions and what terms?
Credit: The answer to QA 2.5.2.1 forms the basis for this information: whether credit was provided for activities under the approach, and if so whether the interest rate was equal to, or lower than, the commercial market rate.
Support to local institutions: Here is a sentence or two, taken from the answer from QA 2.5.3 which asks whether local institutions were specifically supported under the approach, to what extent and in what way. Naturally some projects or programmes focus strongly on institution-building, other not so.

Monitoring and Evaluation
Monitored aspects: Taken from QA 3.1.1.1 with aspects that had been monitored under the approach, including methods and indicators.

Impacts of the Approach

Improved sustainable land management: Yes, moderate. Awareness and motivation to apply SLM amongst land users has increased due to the approach.
Adoption by other land users / projects: Yes, many. RDPs are dev
government and from the EU.
Improved livelihoods / human well-being: Yes, little. Because of the
Improved situation of disadvantaged groups: Yes, moderate. B
marginal areas is slightly improved.
Poverty alleviation: Yes, little. Because of the approach the economi
Training, advisory service and research:

Training effectiveness
(There is strong lack of training of land users.)
Land users - poor
SLM specialists - fair
Agricultural advisor / trainers - good

Advisory service
Land users - poo
Politicians / decis

Land/water use rights: None hindered the implementation of the app
Long-term impact of subsidies:
Positive (moderate) long-term impact. The subsidies are there during
disappear or change considerably. This introduces a level of uncertain
Main motivation of land users to implement:
Rules and regulations (fines) / enforcement
Payments / subsidies
Environmental consciousness, moral, health
SLM Sustainability of activities:
It is uncertain whether the land users will be able to sustain the approa

Impacts of the approach
Improved sustainable land management: A very brief assessment and grading of what improvements to SLM, if any, were adopted by land users as a result of the approach. Taken from QA 3.2.1.1.
Adoption of the approach by other projects/land users: Taken from question QA 3.2.2.1: whether the approach had spread to other projects or been institutionalised.
Improved livelihoods / human well-being: Taken from question QA 3.2.2.2
Improvement situation of disadvantaged groups: Taken from question QA 3.2.2.3
Poverty alleviation: Taken from question QA 3.2.2.4
Training, advisory and research: Taken from question QA 3.2.3.1; QA 3.2.3.2
Land/water use rights: Taken from question QA 3.2.4.1
Long-term impact of subsidies: Taken from question QA 3.2.5.1
Main motivation of land users to implement: Taken from question QA 3.3.1.1
SLM Sustainability of activities: Taken from question QA 3.3.1.2

Concluding statements

Strengths and →how to sustain/impro | **o overcome**

The approach is an effort to provide an
SLM can be achieved. Therefore, no se
complete SLM plan at the farm level →
measures in the approach.

All implementation and maintenance co
productivity are subsidised → There sho
for all farmers willing to apply the meas
continuity between new versions of the

participation in the design, implementation
h → Organise stakeholder meetings,
ainings for land users.

ncy in communication → Farmers'
extension services should have a more
tivities and communication

ion amongst land users → Farmers'
extension services should have a more
activities and communication.

Concluding statements
The answers to QA 3.3.2 and QA 3.3.3 summarise the approach's strong and weak points and how these could be sustained/improved or overcome. The questions were divided into two: the author's opinion and the land users' viewpoints. The answers (which often coincided and were seldom contradictory) have been combined in this table.

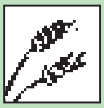
Key reference(s): CARM 2008. Programa de D
http://www.carm.es/neweb2/servlet/integra.serv … D=c431$m1219
Contact person : Joris de Vente, EEZA-CSIC, Joris@sustainable-ecosystems.org

Key reference(s)
References to literature are specified here: not just taken from the questionnaire annex A1, but in some cases added to by the editors. Many approaches have not been documented before.

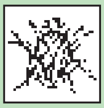
Contact person(s)
The name and contacts of the author(s) so that specific interests/ question from readers can be followed up, taken from annex A1.

Pictograms SLM technology

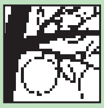
Land use types



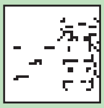
Annual cropping: land under temporary/ annual crops usually harvested within one, maximally within two years (eg maize, rice, wheat, vegetables)



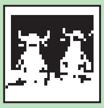
Perennial (non-woody) cropping: land under permanent (not woody) crops that may be harvested after 2 or more years, or only part of the plants are harvested (eg sugar cane, banana, sisal, pineapple)



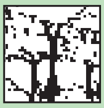
Tree and shrub cropping: permanent woody plants with crops harvested more than once after planting and usually lasting for more than 5 years (eg coffee, tea, grapevines, oil palm, cacao, coconut, fodder trees, fruit trees)



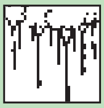
Extensive grazing land: grazing on natural or semi-natural grasslands, grasslands with trees/ shrubs (savannah vegetation) or open woodlands for livestock and wildlife



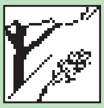
Intensive grazing land: grass production on improved or planted pastures, including cutting for fodder materials (for livestock production)



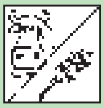
Natural forests: forests composed of indigenous trees, not planted by man



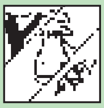
Plantations, afforestations: forest stands established by planting or/and seeding in the process of afforestation or reforestation



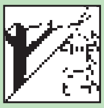
Agroforestry: crops and trees (mixed)



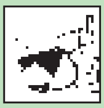
Agropastoral: cropland and grazing land (mixed)



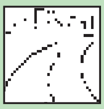
Agrosilvopastoral: cropland, grazing land and forest (mixed)



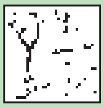
Silvopastoral: forest and grazing land (mixed)



Mines and extractive industries

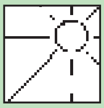


Settlements, infrastructure networks: roads, railways, pipe lines, power lines

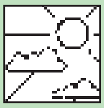


Wastelands, deserts, glaciers, swamps, etc

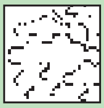
Climate



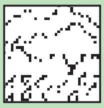
Arid: length of growing period (LGP) 0–74 days



Semi-arid: LGP 75–179 days



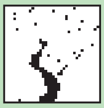
Subhumid: LGP 180–269 days



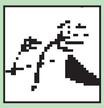
Humid: LGP >270 days

The length of growing period (LGP) is defined as the period when precipitation exceeds 50% of the potential evapotranspiration and the temperature is higher than 6.5° C.

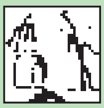
Degradation



Water erosion: loss of topsoil by water; gully erosion; mass movements; riverbank erosion / coastal erosion; offsite effects: deposition of sediments, downstream flooding, siltation of reservoirs and waterways, etc

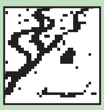


Wind erosion: loss of topsoil by wind; deflation and deposition; offsite effects of wind erosion: Covering of the terrain with windborne sand particles from distant sources ('overblowing')



Chemical deterioration: fertility decline and reduced organic matter content; acidification; lowering of the soil pH; soil pollution; salinisation/alkalinisation

Physical deterioration: soil compaction; sealing and crusting; waterlogging; subsidence of organic soils; loss of bio-productive function due to other activities (eg construction, mining)

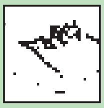


Water degradation: aridification/soil moisture problem; water quality decline (pollution of water bodies by chemicals and eroded sediments); water quantity decline (groundwater, surface water).

Vegetation degradation: reduction of vegetation cover; quality and species composition decline; quantity decline (loss of vegetative production)

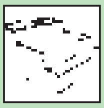
Pictograms SWC technology continued

SWC measures

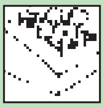


Agronomic measures: measures that improve soil cover (eg green cover, mulch); measures that enhance organic matter/ soil fertility (eg manuring); soil surface treatment (eg conservation tillage); subsurface treatment (eg deep ripping)

Vegetative measures: plantation/reseeding of tree and shrub species (eg live fences; tree rows), grasses and perennial herbaceous plants (eg grass strips)



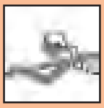
Structural measures: terraces (bench, forward/ backward sloping); bunds, banks (level, graded); dams, pans; ditches (level, graded); walls, barriers, palisades



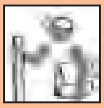
Management measures: change of land use type (eg area enclosure); change of management/intensity level: (eg from grazing to cut-and-carry); major change in timing of activities; control/ change of species composition

Pictograms SWC approach

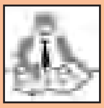
Targed groups



Land users

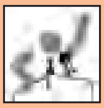


SWC specialists/extensionists



Planners

Teachers/students



Politicians/decision makers

Acronyms

CAP	EU Common Agriculture Policy
DESIRE	Desertification Mitigation and Remediation of Land
DESMICE	Desertification Mitigation Cost Effectiveness model
DSS	Decision support system
EU	European Union
FAO	UN Food and Agriculture Organisation
GEF	Global Environmental Facility
GLASOD	Global Assessment of Soil Degradation
HIS	DESIRE Harmonised Information System
LADA	Land Degradation Assessment in Drylands
LUS	Land Use System
LUT	Land Use Type
NGO	Non-Governmental Organisation
NRM	Natural Resource Management
PESERA	Pan-European Soil Erosion Risk Assessment
QT	WOCAT questionnaire on SLM technologies
QA	WOCAT questionnaire on SLM approaches
QM	WOCAT questionnaire for mapping land degradation and SLM
SIP	Site Implementation Plan
SLM	Sustainable Land Management
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environmental Programme
WOCAT	World Overview of Conservation Approaches and Technologies

Logos of partners

Desire for Greener Land

Options for Sustainable Land Management in Drylands

Desire for Greener Land compiles options for Sustainable Land Management (SLM) in drylands. It is a result of the integrated research project DESIRE (Desertification Mitigation and Remediation of Land - A Global Approach for Local Solutions). Lasting five years (2007–2012) and funded within the EU's Sixth Framework Programme, DESIRE brought together the expertise of 26 international research institutes and non-governmental organisations. The DESIRE project aimed to establish promising alternative land use and management strategies in 17 degradation and desertification sites around the world, relying on close collaboration between scientists and local stakeholder groups. The study sites provided a global laboratory in which researchers could apply, test, and identify new and innovative approaches to combatting desertification. The resulting SLM strategies are local- to regional-scale interventions designed to increase productivity, preserve natural resource bases, and improve people's livelihoods. These were documented and mapped using the internationally recognised WOCAT (World Overview of Conservation Approaches and Technologies) methodological framework, which formed an integral part of the DESIRE project.

The DESIRE approach offers an integrated multidisciplinary way of working together from the beginning to the end of a project; it enables scientists, local stakeholders and policy makers to jointly find solutions to desertification. This book describes the DESIRE approach and WOCAT methodology for a range of audiences, from local agricultural advisors to scientists and policymakers. Links are provided to manuals and online materials, enabling application of the various tools and methods in similar projects. The book also includes an analysis of the current context of degradation and SLM in the study sites, in addition to analysis of the SLM technologies and approaches trialled in the DESIRE project. Thirty SLM technologies, eight SLM approaches, and several degradation and SLM maps from all the DESIRE study sites are compiled in a concise and well-illustrated format, following the style of this volume's forerunner *where the land is greener* (WOCAT 2007). Finally, conclusions and policy points are presented on behalf of decision makers, the private sector, civil society, donors, and the research community. These are intended to support people's efforts to invest wisely in the sustainable management of land – enabling greener drylands to become a reality, not just a desire.

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