Food and Agriculture Organization of the United Nations

ICARDA Science for resilient livelihoods in dry areas

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Regional Initiative on Water Scarcity

Inter-Regional Technical Platform Water Scarcity

WEBINARS SERIES ON RAINWATER HARVESTING

31st May 2022 – 7th June 2022

Module n°1:

Introduction to Rainwater Harvesting

Rima Mekdaschi Studer, WOCAT, CDE, University of Bern

Boost your crop water productivity in selected farming systems: assess and adapt

WOCAT World Overview of Conservation Approaches and Technologies

What is WOCAT?

The World Overview of Conservation Approaches and Technologies (WOCAT) is a **global Network established in 1992**.

WOCAT supports the compilation, documentation, evaluation, sharing, dissemination, and application of **sustainable land management (SLM) knowledge**.

In 2014, WOCAT was **officially recognized by the UNCCD** as the primary recommended Global SLM Database for best SLM practices.

Network of organizations and individuals

Consortium Partners

Universität Bern CDE Centre for Development and Environment

ISRIC World Soil Information

ICARDA Science for resilient livelihoods in dry areas

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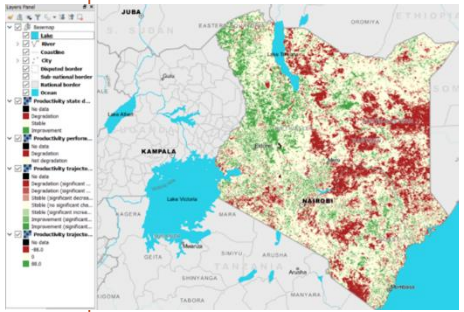
WOCAT

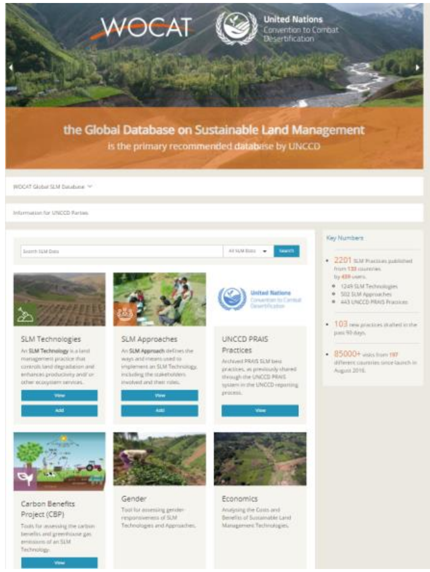
to support *innovation and decision-making in SLM* by:



maintain global, open
SLM network

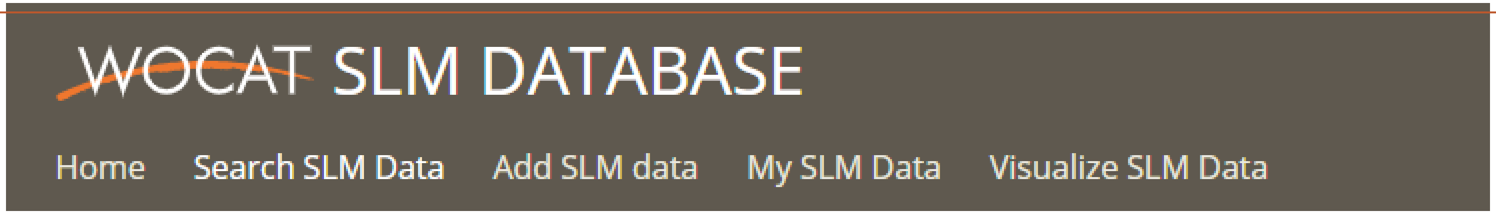
harmonize and
further develop
tools and methods
with partners

provide open access
**global SLM data
repository**

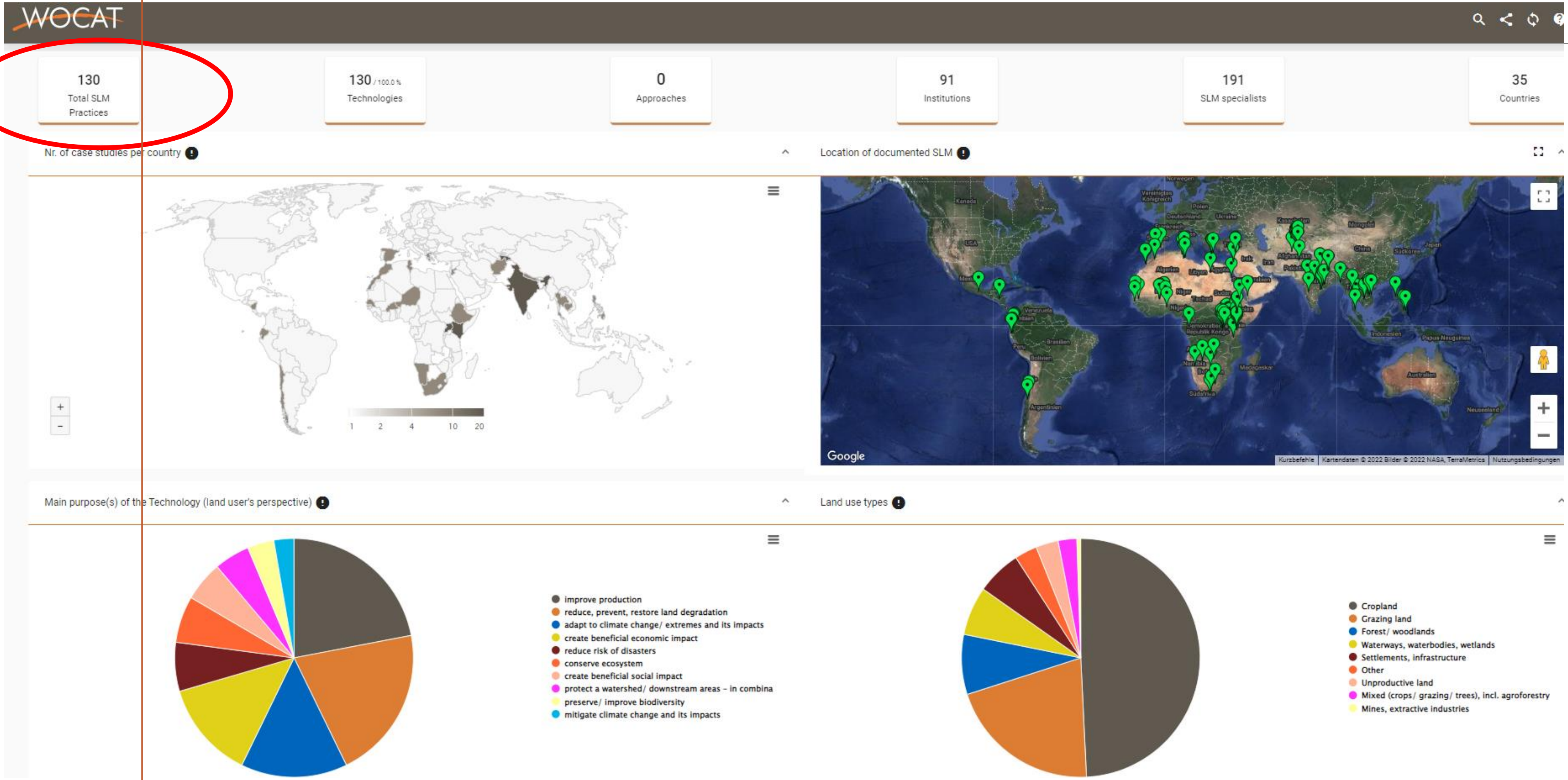


build capacities at
local, regional and
national level

World Overview of Conservation Approaches and Technologies



https://explorer.wocat.net/



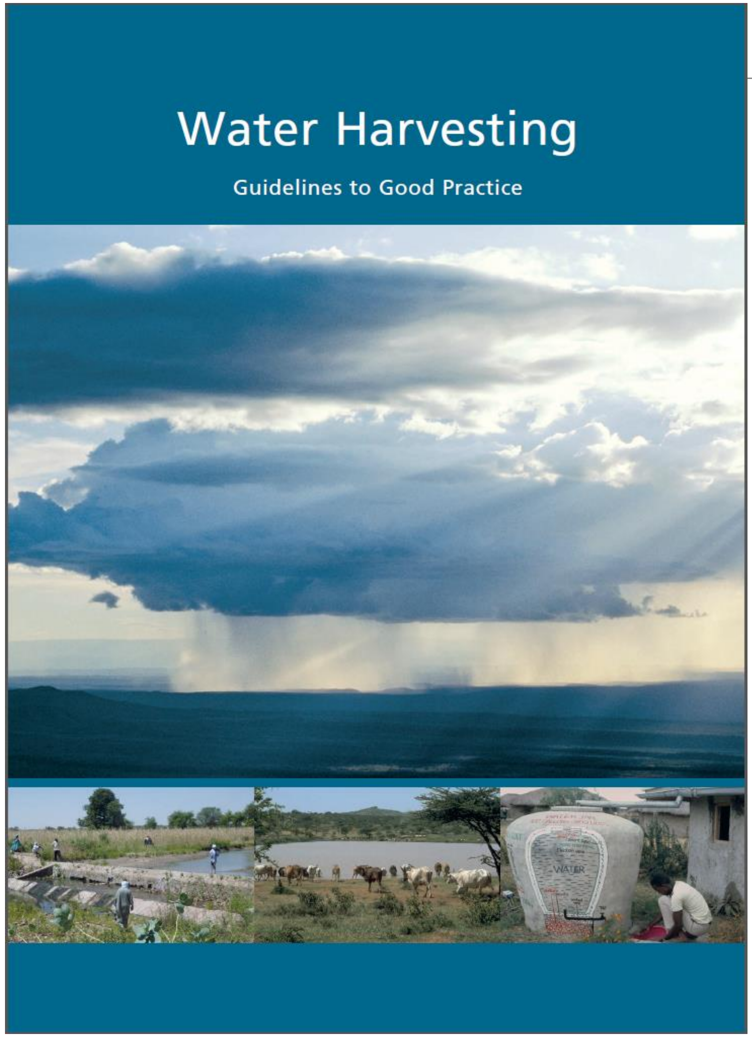
Filter for Technology group:

Water harvesting

→ **Information/data used for**: synthesis products e.g. WH guideline

linked & integrated into other platforms & tools e.g. WH explorer

Knowledge products



Water Harvesting (WH) - Guidelines to Good Practice

> concepts behind water harvesting

> harmonised classification system

> overview of 4 WH groups

> selection of good practices (standardized WOCAT format)

Rainfed farming: Challenges

Arid, semi-arid, sub-humid and even in humid regions:

- Water for production: rainfall less than crop water requirements;
- Actual yields less than the potential;
- Highly variable rainfall, long dry seasons, recurrent droughts, as well as floods (exacerbated by CC);
- Impact of variable rainfall strongly affected by the nature of the soil and the stage of the growing period;
- Water management, water losses;
- Land degradation due to soil erosion by wind and water;
- Poor management of soil fertility contributes to low rainwater use efficiency.




Water losses:

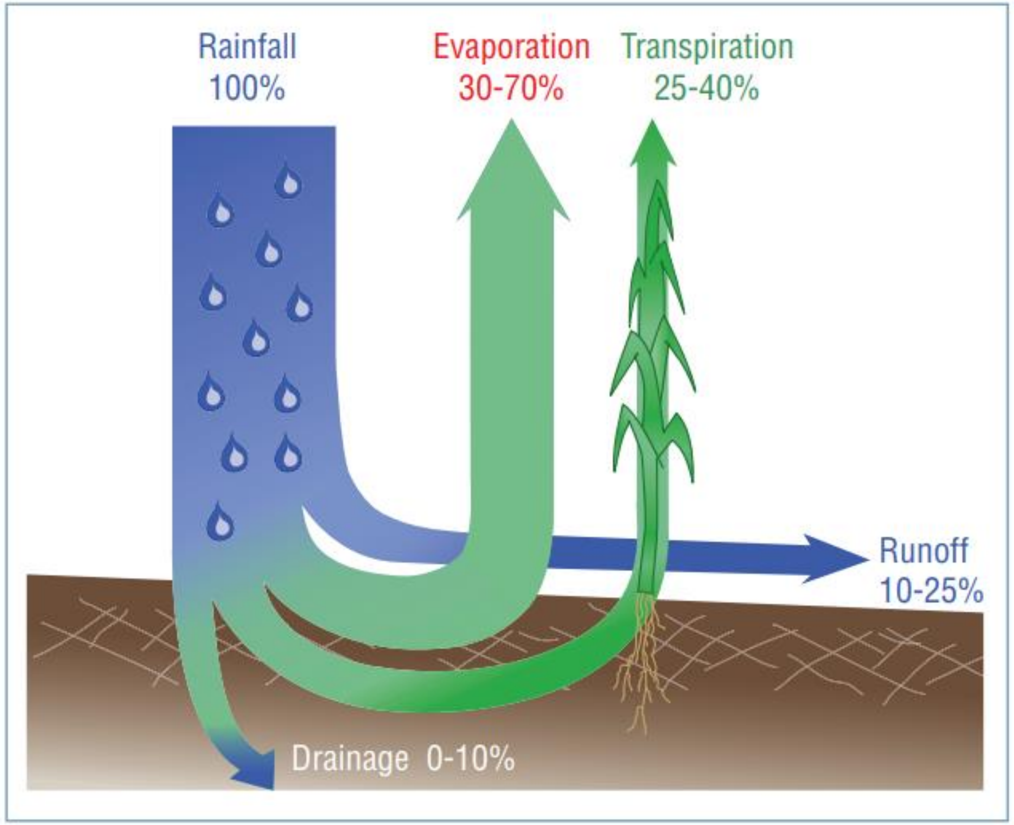


Figure 3: Productive water and losses without water conserving or harvesting measures in drylands. (Liniger et al., 2011 based on Rockström et al., 2007) Note: Water stored in the soil and used directly by plants through transpiration is termed "green water". Runoff, deep drainage, recharging of groundwater and feeding of streams is called "blue water".

Rainfall losses can be transformed into:

- productive "green water":
  - runoff feeds water harvesting systems that store water directly in the soil profile
  - soil water directly used by transpiration for plant growth
- useful "blue water":
  - water collected in water bodies and thus made available for irrigation.
  - increased groundwater availability

Rainwater Harvesting

“The greatest potential increases in yield are in rainfed areas where many of the world’s poor live and where managing water is the key to such increases” (Molden, 2007).

It is time to scale-up the ‘good practices’ of water harvesting …, after decades of almost exclusive focus on mastering fresh water flows in rivers and lakes through investments in irrigation infrastructure. Water harvesting offers under-exploited opportunities for the predominantly **rainfed farming systems** of the drylands in the developing world (IFAD, SDC 2013 preface WH publication)

East Africa and Southeast Asia are hotspots for water harvesting. “We estimate that the adoption of water harvesting in these cropland areas can increase crop production up to 60–100% in Uganda, Burundi, Tanzania and India” (Piemontese et al., 2020).

An increasing demand for Rainwater Harvesting in the regions of United States is expected to drive the market for more advanced Rainwater Harvesting. (Rainwater Harvesting Market Report 2020-2025). https://www.marketwatch.com/

Hanspeter Liniger

Rainwater Harvesting: Definition and Aim

> *"The collection and management of floodwater or rainwater runoff to increase water availability for domestic and agricultural use as well as ecosystem sustenance".*[1]

Aim: to collect water from areas of surplus or where it is not used, store it and make it available, where and when there is water shortage.

Increase water availability by either

(a) impeding and **trapping surface runoff**, and
(b) maximising water runoff **storage** or
(c) trapping and **harvesting sub-surface** water

→ deliberately reallocating water resource within a landscape, and over time
→ great potential when combined with *in situ* water management (keep RW in place) as well as improved soil and water conservation measures

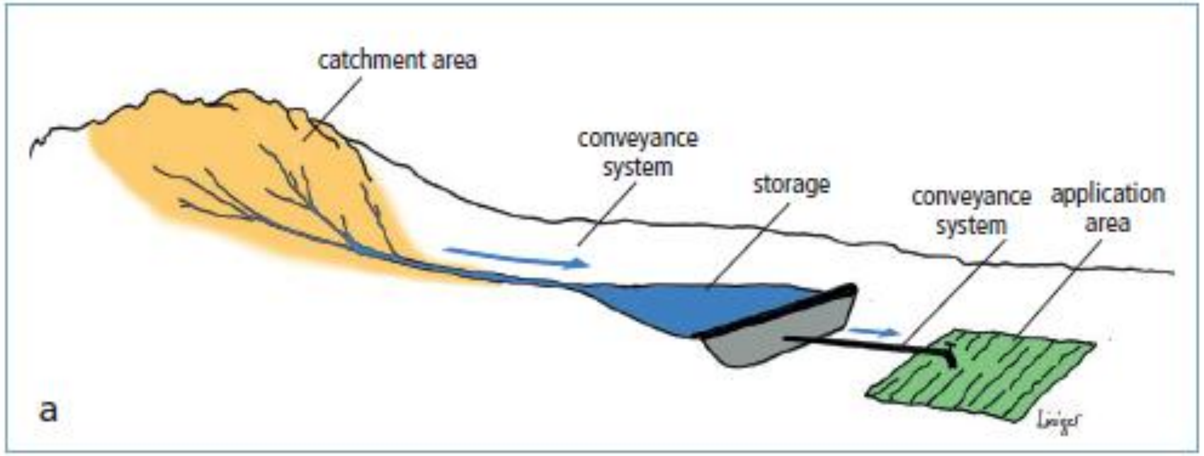


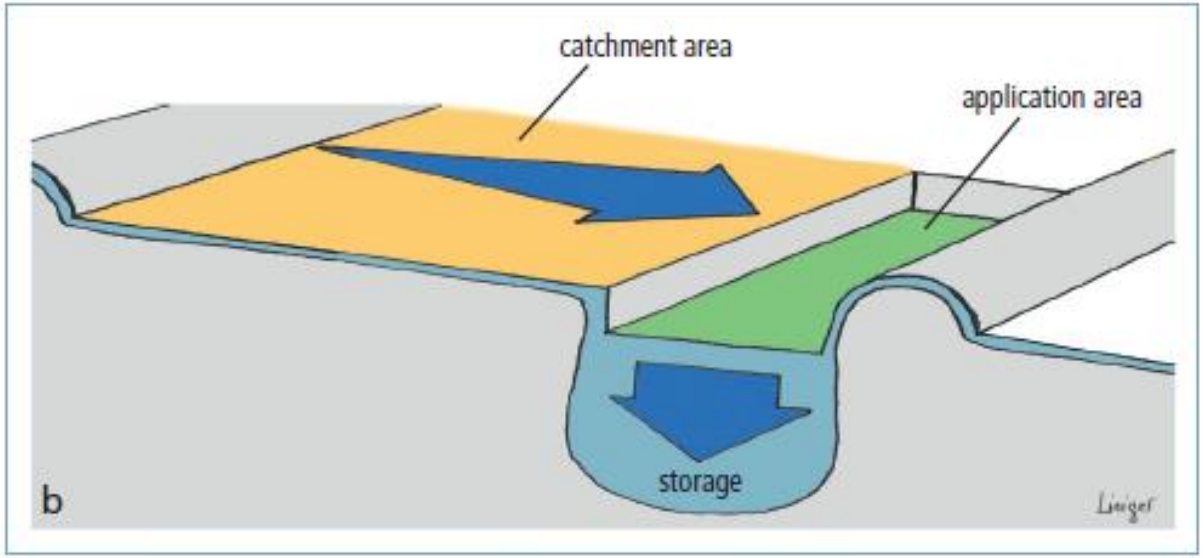

Benefits and Constraints of WH

Pros	Cons
Offers under-exploited opportunities for rainfed farming systems of the drylands	Depends on amount and variability of rainfall
Buffering water variability	Difficult to ensure sufficient quantity of water needed
Overcoming dry spells and coping with extreme events (flooding, soil erosion, siltation)	May take up productive land
Harvesting nutrients	High investment costs and labour requirements
Reducing production risks and increasing resilience	Upstream rainwater harvesting may affect downstream water availability and use
Increasing food production and security	Shared catchments and infrastructure may create rights issues (upstream-downstream, farmers and herders)
Improving access to clean and safe domestic water	Long –term institutional support may be necessary
Improving water availability for livestock	
Reducing women’s work load	
Possibility of growing higher-value crops	
Providing alternative to full irrigation	

Principle of WH

- capture precipitation falling in one area and transfer it to another, thereby increasing the amount of water available in the latter
- capture potentially damaging rainfall/ runoff and translate it into plant growth or water supply
- composed of:
  - **Catchment or collection area:** high runoff coefficients (e.g. clay or shallow soils, compacted soils, roads)
  - **Conveyance system**
  - **Storage component**
  - **Application area or target:** e.g. deep soils with high water infiltration and storage capacity
- catchment to application area ratio (C:A): degree of concentration of rainfall / runoff





Classification and categorisation

The two most frequently used criteria are catchment type and size, and the method of water storage

Table 1: Classification of water harvesting based on catchment type

	Water Harvesting			
	Floodwater	Rainwater runoff		
Group	(1) Floodwater harvesting (FloodWH)	(2) Macrocatchment WH (MacroWH)	(3) Microcatchment WH (MicroWH)	(4) Rooftop & Courtyard WH (Rooftop-CourtyardWH)
Strategy	Capture excess water from outside farm or field and spread floodwater	Trap runoff from outside farm or field	Trap localised runoff within field	Trap runoff from settlements
Agroclimatic zone	Dry sub-humid, semi-arid and arid climates; Dry areas with ephemeral watercourses and few heavy events	Dry sub-humid, semi-arid and arid climates; Where few runoff events expected per rainy season	Dry sub-humid and semi-arid climates; Where rainfall is more reliable but scattered and/or poorly distributed within the season	All climates; With dry spells and where rainfall is seasonal
Catchment	External: Large catchments or watersheds; Distinction between hilly catchment zone and cultivated fields in plain;	External: Small catchments or watersheds; Catchment and application area clearly separate;	In-field; Catchment and application area distributed evenly over field;	Household / settlement;
Annual rainfall range**	100 – 700 mm extreme runoff events, episodic floods; periodic crop water deficits	200 mm – 1,500 mm major and intense runoff events, infrequent; dry spells, water deficit during critical growth phase	200 mm – 800 mm minor runoff events lost if not harvested, relatively frequent; poor rainfall distribution within season	wide range

Classification and categorisation

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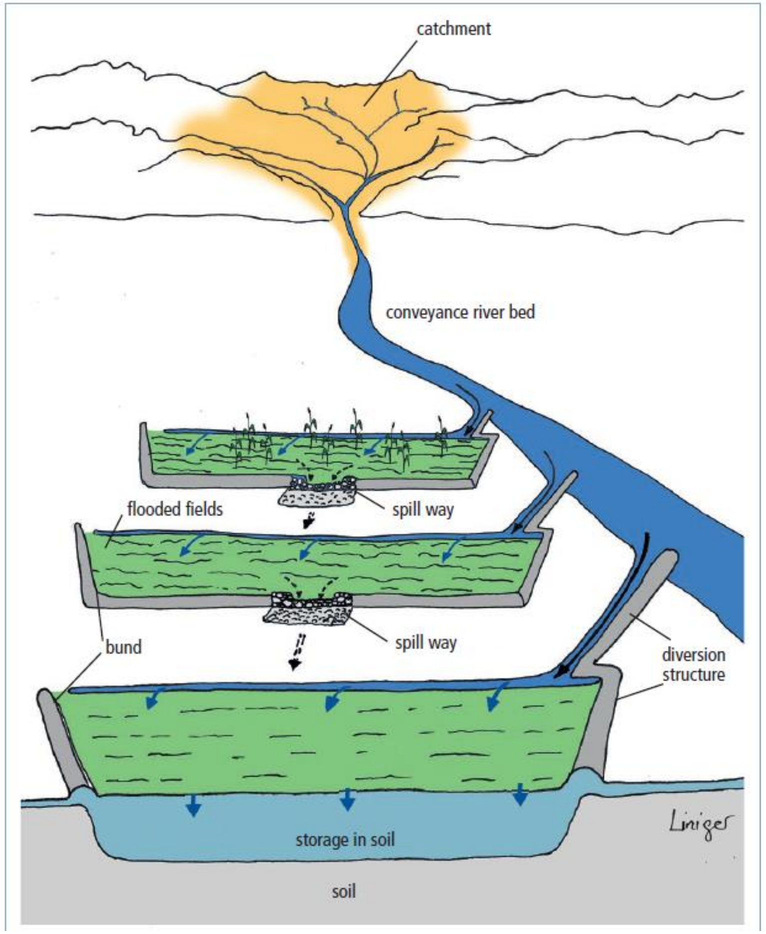
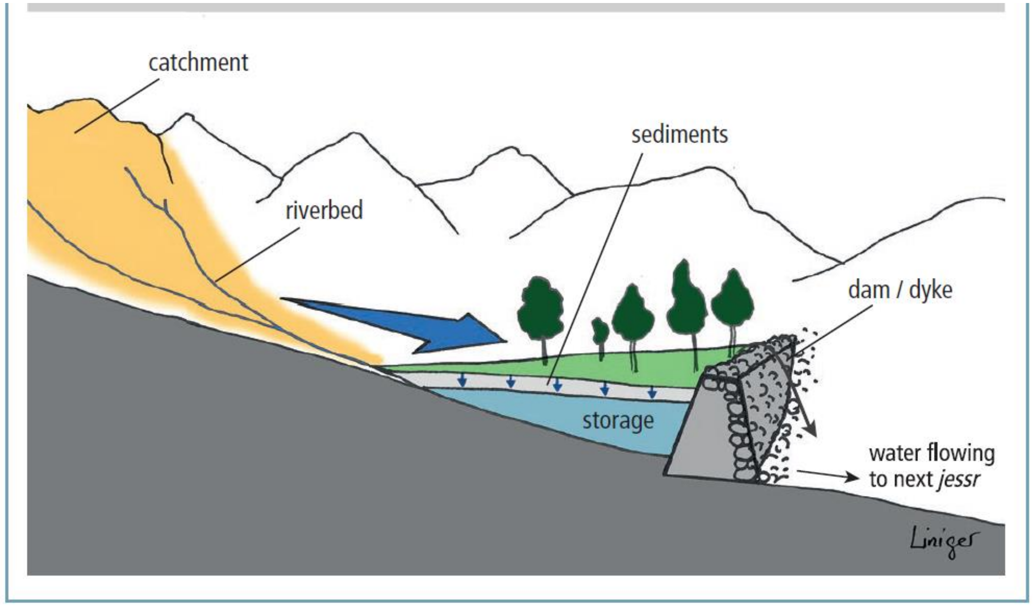
Runoff water	Channel flow with more or less well-defined course	Sheet and rill flow (turbulent overland runoff), short channel flow	Sheet and some rill flow	Sheet flow from rooftops and sealed surfaces
Storage	Soil moisture in root zone; Groundwater recharge	Soil moisture in root zone; Groundwater recharge; Reservoirs: dams and ponds; Tanks (surface and subsurface)	Soil moisture in root zone; Pits, trenches and bunds for planting	Tanks (surface and subsurface)
Use of water	Crop production: Supplementary irrigation, high groundwater recharge, improve soil moisture	Multiple use: domestic use, water for livestock, crop production: improve soil moisture, groundwater recharge and water storage for supplementary irrigation	Crop, fodder and tree production: improve soil moisture, limited groundwater recharge	Multiple use: domestic use, water for livestock, small-scale crop and horticultural tree production: water storage for supplementary irrigation of kitchen gardens / backyard crops; agro-processing no groundwater recharge
Management	Large communities or local authority, integrated watershed management	Community or individual	Individual or community	Individual or community

Floodwater Harvesting



Floodwater diversion / off-streambed system

channel water either floods over the river/ channel bank onto adjacent plains (wild flooding) or is forced to leave its natural course and conveyed to nearby fields (spate irrigation)



Floodwater harvesting within streambed

water flow is dammed and as a result, is ponded within the streambed. The water is forced to infiltrate and the accumulated soil water is used for agriculture

Floodwater Harvesting

Principles:

- Floodwater captured from outside farm or field, large watersheds (no control over catchment area)
- Dry areas with ephemeral watercourses and few heavy rains
- Water/ runoff stored in soil or groundwater
- One system with one catchment area (large distant catchment)
- Catchment: application area ratio 100:1 – 10,000:1
- Often ‘self-fertilizing’ through sediment build-up
- (Traditional) engineering skills needed
- Integrated watershed management (local authority & large communities)
- Defined water usage rules

Practices:

Flood recession farming, spate irrigation, water spreading weirs/ bunds, ‘warping’ dams, jessour, tabia and rock dams


Spate irrigation in Yemen. (spate-irrigation.org)


C. Studer


View of an area with a number of *jessours* in Tunisia. (M. Ben Zaied)

Floodwater Harvesting


Eritrea

Spate irrigation
A traditional water diversion and spreading technique under which seasonal floods of short duration are diverted from ephemeral rivers (*wadis*) to irrigate cascades of levelled and bunded fields in the coastal plains.

p 45


Ethiopia

Runoff and floodwater farming
Flood water and runoff from ephemeral rivers, roads and hillsides is captured through temporary stone and earth embankments for growing vegetables, fruit trees and high value crops.

p 49


Spain

Water harvesting from concentrated runoff for irrigation purposes
Small earthen- or stone-built bunds divert flood water from intermittent streams towards cultivated fields with almond orchards and/or cereals.

p 53


Chad

Water-spreading weirs for the development of degraded dry river valley
Structures that span the entire width of a valley to spread floodwater over the adjacent land area.

p 57


Tunisia

Jessour
An ancient runoff water harvesting technique widely practiced in the arid highlands.

p 63


Tunisia

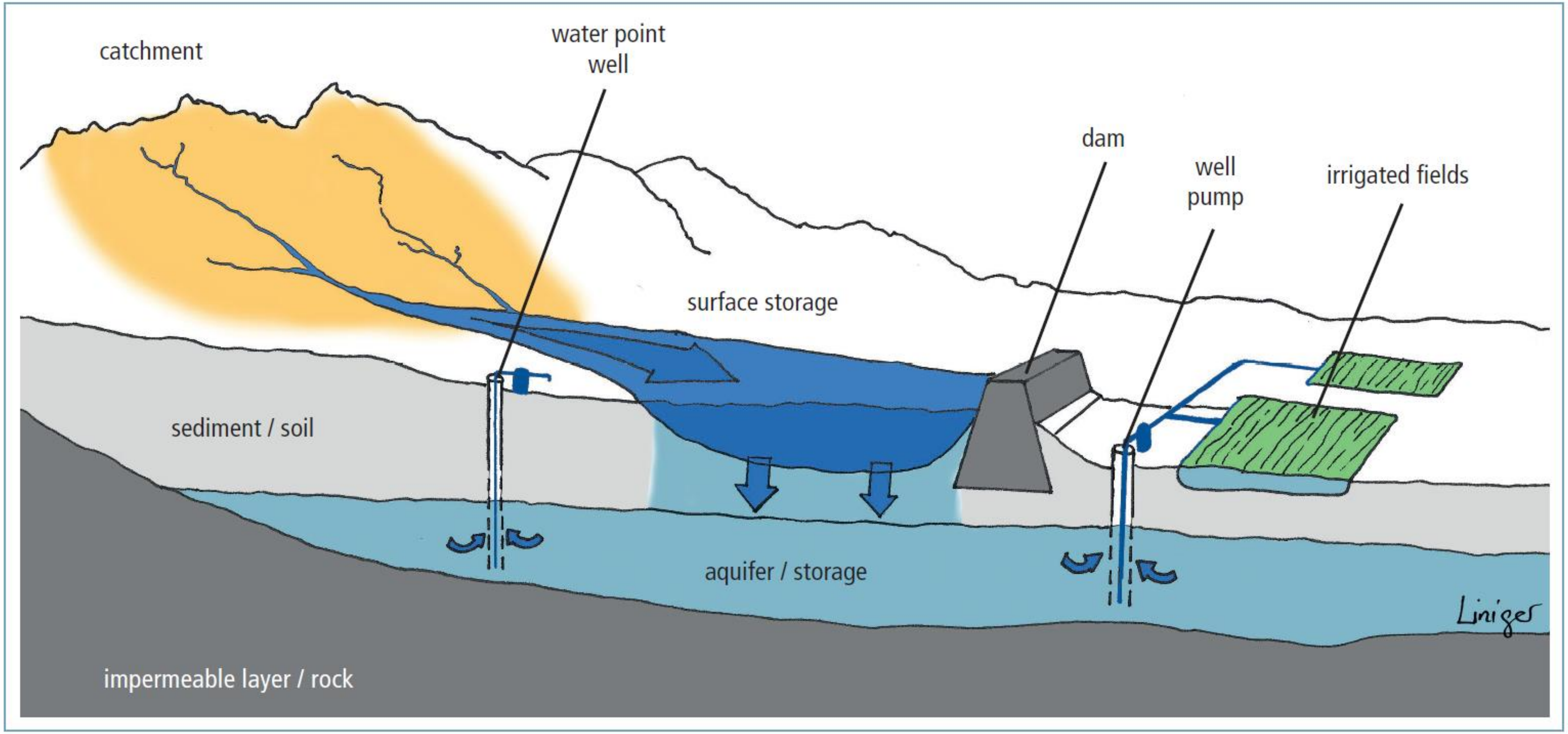
Tabia
The *tabia* earthen dyke is a water harvesting technique used in the foothill and piedmont areas.

p 67

Case studies floodwater

Macrocatchment cross-section

Harvesting runoff water from a natural catchment such as the slope of a mountain or hill



Macrocatchment WH

Principles:

- Runoff (overland or rill flow) trapped from outside farm or field, small watersheds (no control over catchment area)
- Runoff collected from shallow soils or sealed and compacted surfaces, overland flow directed and spread, runoff collected through barriers and storage facilities
- Few runoff events per rainy season
- Suitable for annual and perennial crops tolerant of temporary waterlogging or rapidly maturing on residual moisture
- Water stored in reservoirs, root zone & groundwater recharge; multiple water use
- One system with one catchment area
- Catchment: application area ratio 10:1 100:1
- Nutrients harvested from accumulated sediments and animal droppings
- Managed by community or individually

Practices:

Hillside conduit, large semi-circular bunds, road run-off, gully reclamation, ponds, pans, dams (surface, sand and percolation dams), wells

Kanda rock catchment, Afghanistan., C. Studer

Small check dam, Rajastan India. (HP. Liniger)

Sand dam Embu, Kenya. (HP. Liniger)

Macrocatchment Water Harvesting

India

Sunken streambed structure
Excavations in streambeds to provide temporary storage of runoff, increasing water yields from shallow wells for supplementary irrigation

p 91

Zambia

Small Earth Dams
Water harvesting and storage structures, constructed across narrow sections of valley, to impound runoff generated from upstream catchment areas.

p 95

Kenya

Sand dams
A sand dam is a stone masonry barrier across a seasonal sandy riverbed that traps rainwater and sand flowing down the catchment.

p 99

Tunisia

Recharge well
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 105

Case studies macrocatchment

Microcatchments

Collecting surface runoff/ sheet (and sometimes rill flow) from small catchments of short length

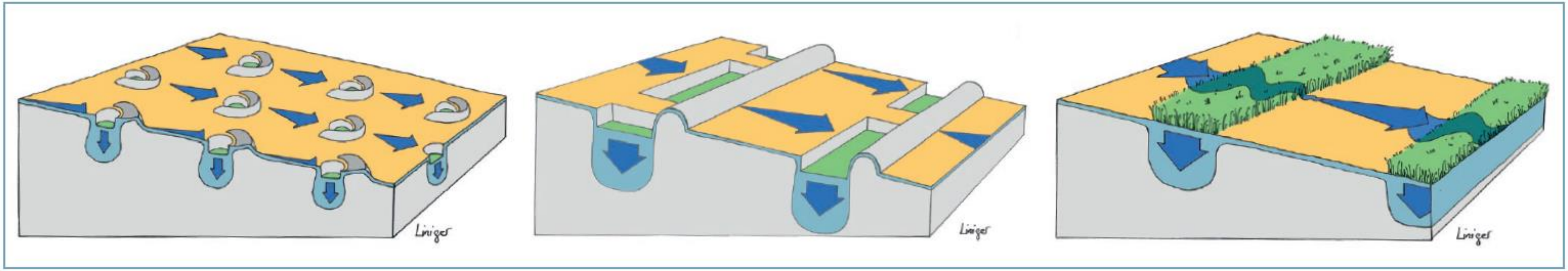


Figure 8: Microcatchment water harvesting: (left) planting pits e.g. cholola, zai, tassa; *(centre) contour bunds with trenches e.g. tied* fanja chini; *(right) vegetative barriers e.g. grass strips.*
Yellow: indicates bare or compacted catchment area; light blue: storage of water in soil; green: application area with crops, trees, etc.; dark blue arrows: indicate direction of water flow.

Microcatchment WH

Principles

- Localized runoff trapped within field (catchment and application areas alternate within same field)
- Rainfall more reliable but scattered/ poorly distributed in season
- Catchment area generally bare with sealed, crusted and compacted soils
- Water stored in soil within field; plant production
- System replicated many times identically and evenly over field
- Catchment: application/storage area ratio 1:1: 10:1
- Needs fertility management
- Managed individually or by community

Practices

Planting pits, micro-basins/trenches (Vallerani), small semi-circular/ triangular bunds, eyebrow terraces, vegetative strips, contour bunds and ridges, trenches, stone lines


Microcatchments with eyebrow terraces, Orissa, India. (HP. Liniger)


Down-slope contour bunds in Cape Verde (HP. Liniger).

Microcatchment Water Harvesting

Niger

Planting pits and stone lines

Rehabilitation of degraded land through manured planting pits, in combination with contour stone lines.

p 123

Syria

Furrow-enhanced runoff harvesting for olives

Runoff harvesting through annually constructed V-shaped microcatchments, enhanced by downslope ploughing.

p 127

Burkina Faso

Vallerani system

A special tractor-pulled plough that automatically constructs water-harvesting catchments, ideally suited for large-scale reclamation work.

p 131

Kenya

Fanya juu terraces

Fanya juu terraces comprise embankments (bunds), which are constructed by digging ditches and heaping the soil on the upper sides to prevent loss of soil and water.

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Case studies microcatchment

Rooftop/Courtyard WH

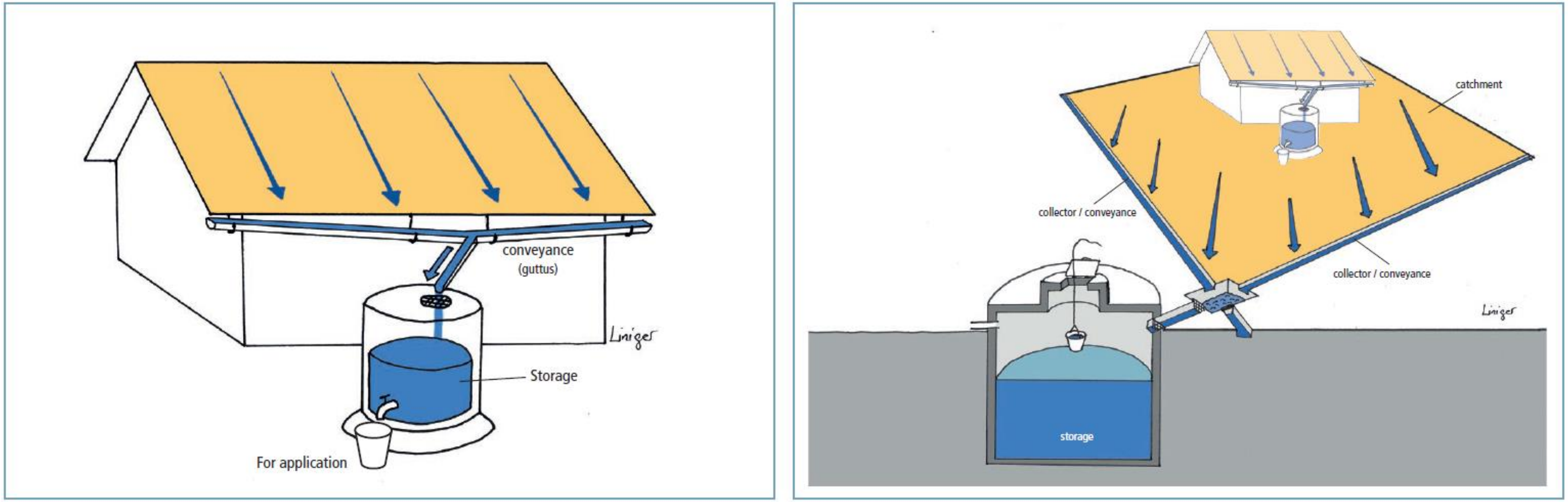


Figure 9: (left) water harvested from roofs used for drinking, domestic purposes and irrigation of kitchen gardens; (right) rooftop and courtyard water harvesting for irrigation of kitchen gardens and domestic use.

Volume captured: effective area of the roof and local annual rainfall. Between 80 – 85 percent of rain can be collected and stored

The slope and permeability affects the amount of rainwater that can be collected.

Rooftop/Courtyard WH

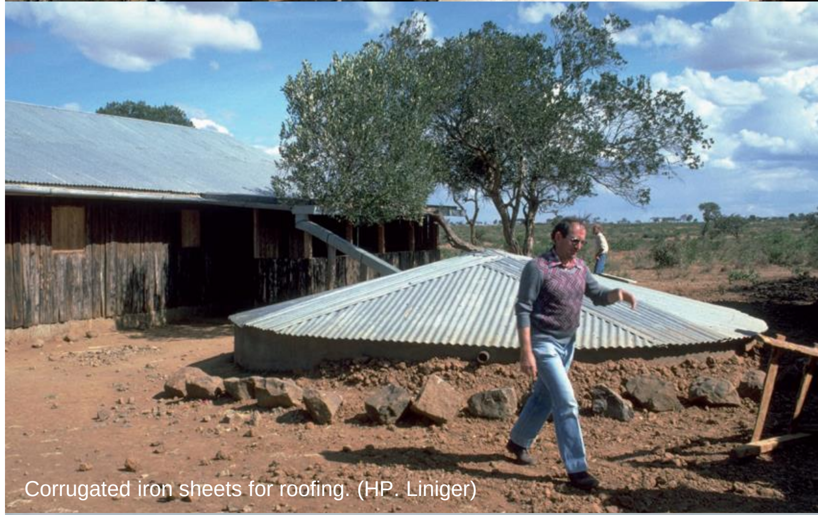
Principles:

- Runoff trapped from settlements (roofs or compacted/ paved courtyards)
- Seasonal rainfall and with dry spells (bimodal rainy season). Tropical and sub-tropical countries (rainfall between 200 and 1000 mm)
- Multiple water use (incl. drinking)
- One system with one catchment
- Surface and subsurface tanks
- May recharge groundwater if an infiltration well is built
- Managed individually or by community

Practices:

Roof catchments of different materials (sheets, tiles, organic roofs), courtyard catchments of compacted/ paved surfaces


Water tank, Nepal. RAIN


Corrugated iron sheets for roofing. (HP. Liniger)


Courtyard water harvesting, Palestine. (N. Harari)

Case studies rooftop & courtyard

Rooftop and Courtyard Water Harvesting

Botswana

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

p 159

Nepal

Rooftop rainwater harvesting system
A water harvesting system in which rain falling on a roof is led through connecting pipes into a ferro-cement water collecting jar.

p 163

Tajikistan

Roof top rainwater harvesting stored in a polyethylene lined earth retention tank
The use of an earth tank lined with a polyethylene sheet to retain rainwater collected from the roof of the house.

p 167

Tajikistan

Roof Top Rain Water Harvesting – Concrete Tank
The roof top rain water harvesting system using a concrete tank was designed to improve household access to water for irrigation of kitchen garden plots during the hot and dry summer months.

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WH part of integrated water resource management

Water management strategies:

1. Management of excess water from rainfall or seasonal flooding through controlled drainage and water storage for future use; suitable for sub-humid conditions as well as semi-arid and arid conditions (*floodwater harvesting*).

2. Increasing rainwater capture and availability, making use of surface runoff; suitable for dry sub-humid to arid conditions (*rainwater harvesting*).

3. *In situ* water conservation: improving direct water infiltration and reducing evaporation; soil and water conservation practices (e.g. conservation agriculture, mulching, composting, terraces); suitable for sub-humid to semi-arid conditions.

4. Increasing *water use efficiency* (e.g. good agronomic practice, including use of best-suited planting material and fertility management).

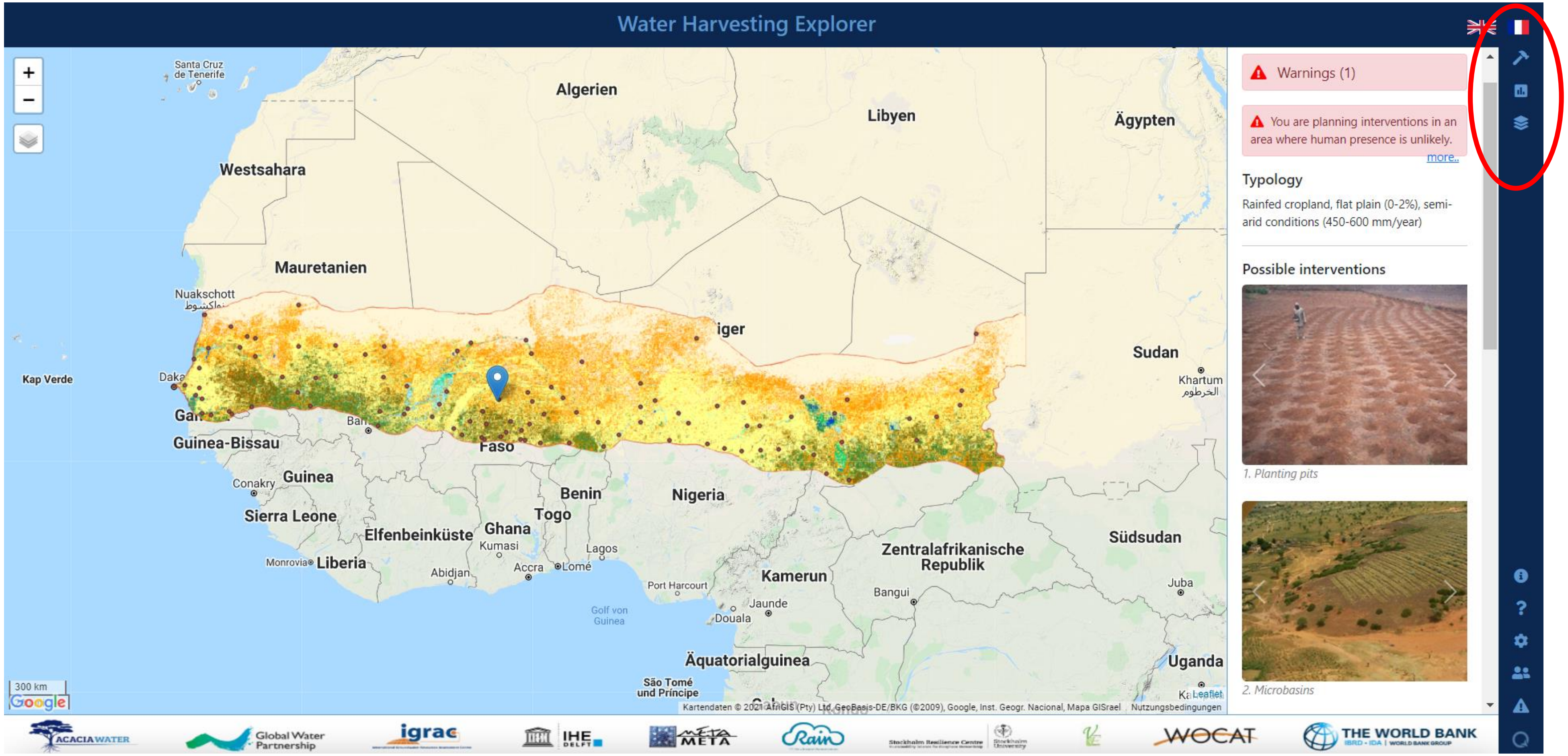
Key reading material

Mekdaschi Studer et al. 2014. Diagnostic and evaluation of the agricultural potentials and examples of good soil and water conservation and soil defence and restoration practices adapted to the MENA (Middle East and North Africa) desert zones". Report mandated by OSS (Sahara and Sahel Observatory) and MENA-DELP (Desert Ecosystems and Livelihoods Programme) and funded by the World Bank. https://www.wocat.net/library/media/56/

Mekdaschi Studer, R. and Liniger, H. 2013. Water Harvesting: Guidelines to Good Practice. Centre for Development and Environment (CDE), Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), Rome. https://www.wocat.net/library/media/25/

Water Harvesting Explorer

A decision support webtool for small scale water storage intervention planning in the Western Sahel, available in EN and FR; https://sahel.acaciadata.com/



Intervention inspector: click on the map to show possible interventions

Survey: Assess the enabling conditions identify possible hindering factors

Layers: e.g. land cover, average annual precipitation, river network

The WOCAT cases show successful implementation examples at precise locations.

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Thank you for your attention

Boost your crop water productivity in selected farming systems: assess and adapt