Mirsad Kurtović, Ph.D., Full Professor

The manuscript is primarily intended for the population involved in agricultural consultancy (advisory services), students and any readers interested in climate change and its effect on agricultural production. This publication will thus influence the strengthening of the capacity of agricultural extension services and farmers in the implementation of measures for adaptation to evident climate change. These target groups will also be given guidance on adapting to climate change, measures for adaptation, acclimatization and the like.

This publication will make it easier for its users to make a relevant analysis of the given situations in terms of climate change as it offers appropriate methodologies, suggests the need and options for adaptation, the necessary strategies in various fields and managing the process of adaptation in the very agricultural production, and especially in organic farming which is considered to have less negative effects on climate change and the environment. The importance of organic farming in terms of mitigation and adaptation to climate change reflects in the increase of land quality, capture of CO_2 from the atmosphere and its storage into the soil, improvement of the physical, chemical and biological properties of the soil, prevention of erosion, preservation of the environment, human and animal health, etc.

Nezir Tanović, Ph.D., Full Professor

The authors have served us positive initiatives and arguments, demonstrated knowledge and used their valence toraise awareness of people who think and act for the future, especially in terms of food production. Messages of this manuscript in the projection could be summarized into several key segments:

In the context of climate change agriculture is becoming increasingly fragile and vulnerable and thus the environment.

The production of food that we used to consider as a solid support of human life on Earth is becoming a delicate segment that yields to the pressure and effects of climate change.

The agricultural activities once considered to be the common good has become questionable, and unpolluted land, clean water and air are threatening to become a costly privilege.

It is with great pleasure that I point out that this manuscript is going to successfully fill the void in this type of professional literature, and in terms of the actuality, concept, contents and the way of interpretation it can be classified as one of the best works to date. Let it be the guide to all its users orienting them towards the mutual relationship between man and naturein the context of the adaptation of agriculture to climate changes.

This manuscript deserves special attention and it is with great pleasure that I recommend it for publishing in book form.

Emir Džomba, Ph.D., Associate Professor

In terms of the concept and method, the manuscript “Adaptation to climate change in agriculture” represents a new scientific, professional and applicable reading in otherwise modest offer of similar readings in the region which reflect the sustainability of agricultural production. Challenging themes addressed by the authors as well as the identification of climate change as a global phenomenon – global not only in terms of effects on the overall life of our planet but also in terms of diversity and distribution of pathogens, is a basis on which the authors elaborate the possibilities to adapt agricultural practices with the aim of diminishing the negative effects of climate change on food production. Positioning of the Western Balkan countries on the world map of carbon footprint, given the intensity of agriculture and small share in the overall global food production is not significant, but the whole region is very susceptible and sensitive to the effects of the increase in global anthropogenic production of greenhouse gases. This was just one of a number of reasons for placing the focus of this manuscript on urgent measures for adapting the existing agricultural practices through the application of agro technical interventions (management of land and water resources, the choice of species, breeds and hybrids, the choice of production systems, technical protection measures, etc.) in order to minimize negative effects while increasing energy efficiency.Therefore, by citing the motto of the manuscript “Now is the time to act” I am highly recommending its publication as it should be read/studied by all actors in the chain of sustainable agricultural production, starting from farmers through the professional and academic communities to various governmental organizations.

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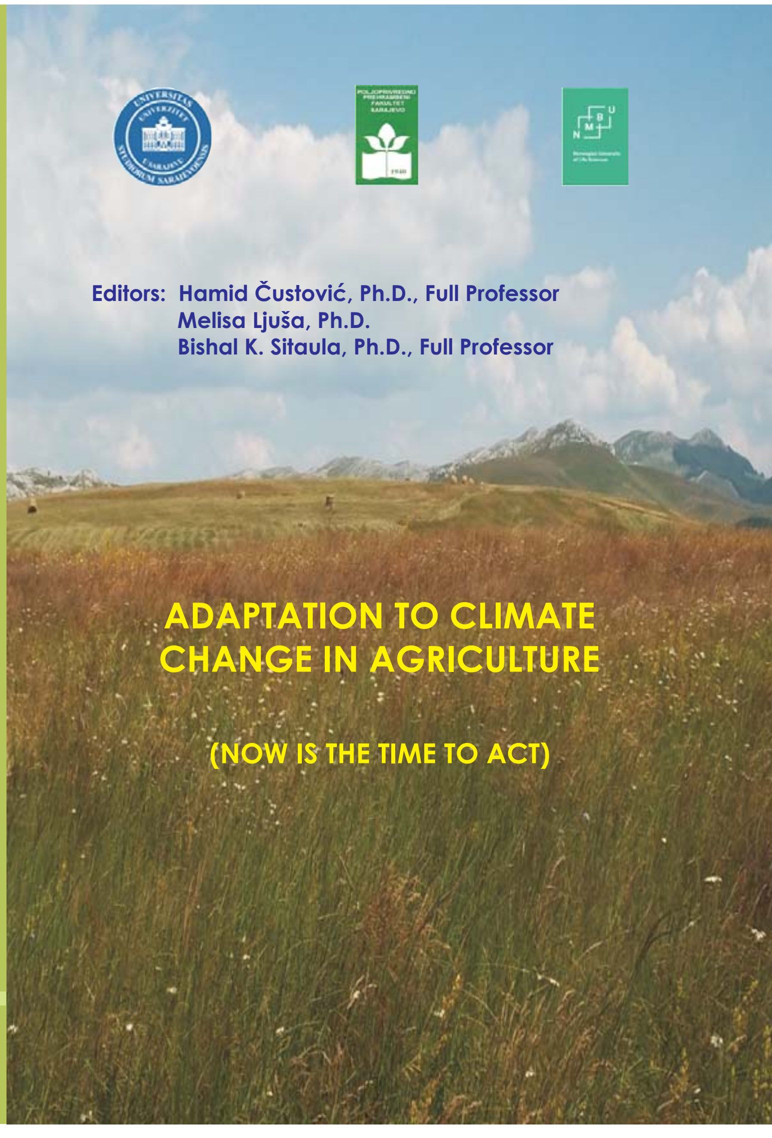

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ADAPTATION TO CLIMATE CHANGE IN AGRICULTURE

(NOW IS THE TIME TO ACT)

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CONTENT

INTRODUCTION TO UNDERSTANDING GLOBAL CLIMATE CHANGE [1]

Scientific work on climate change is very complex nowadays. There are many skeptics as well as others who interpret and experience this phenomenon in different ways. Scientific skepticism is positive. In fact, science is skeptical by its nature. Genuine skepticism involves consideration of the full body of evidence before coming to a conclusion. However, when you take a close look at arguments expressing climate 'skepticism', what you often observe is cherry picking of pieces of evidence while rejecting any data that don't fit the desired picture. This isn't skepticism. It is ignoring facts and the science.

"The Scientific Guide to Global Warming Skepticism" by John Cook, published on skepticalscience.com, 2010, offers a very interesting way of looking at the evidence of human contribution to global warming as well as the ways in which climate "skeptic" arguments can be misleading as they present only small pieces of the puzzle rather than the full picture. What scientists are looking for is compliance, which implies the independent lines of evidence pointing to a single consistent answer. The fill body of evidence in climate science shows us a number of distinct, discernible human fingerprints on climate change.

Measurements of the type of carbon found in the atmosphere show that fossil fuel burning is dramatically increasing levels of carbon dioxide (CO_2) in the atmosphere. Satellite and surface measurements find that extra CO_2 is trapping heat that would otherwise escape out to space. There are a number of warming patterns consistent with an increased greenhouse effect. The whole structure of our atmosphere is changing.

The evidence for human caused global warming is not just based on theory or computer models but on many independent, direct observations made in the real world.

[1] Text and figures taken from: The Scientific Guide to Global Warming Skepticism by John Cook, 2010., www.scepticalscience.com

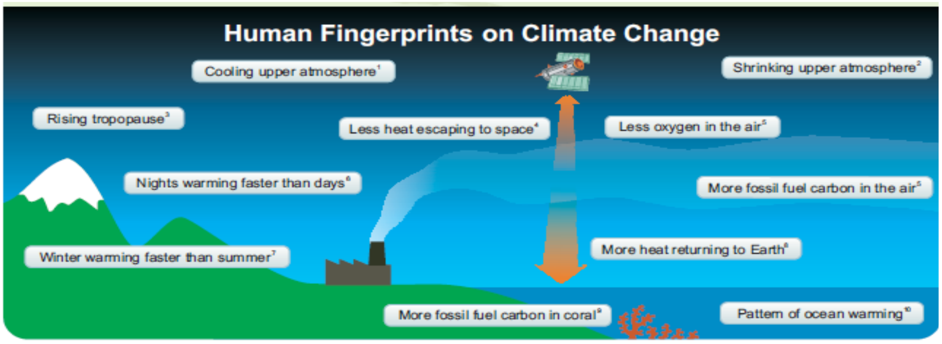


Figure 1. Human fingerprints on climate change

When you look through the many arguments from global warming “skeptics”, a pattern emerges. “Skeptics” tend to focus on small pieces of the problem while neglecting the bigger picture. A good example of this is the argument that human carbon dioxide (CO_2) emissions are tiny compared to natural emissions.

The argument goes like this: Each year, we send over 20 billion tonnes of CO_2 into the atmosphere. Natural emissions come from plants breathing out CO_2 and outgassing from the ocean (Boden et al., 2009). Natural emission adds up to 776 billion tonnes per year (IPCC, 2007). Without a full understanding of the carbon cycle, our emissions seem tiny when compared to nature's contribution. The missing part of the argument is that nature does not just emit CO_2-it also absorbs CO_2. Plants breathe in CO_2 and huge amounts of CO_2 dissolve into the ocean. Nature absorbs 788 billion tonnes of CO_2 every year. Natural absorptions roughly balance natural emissions. What we do is upset the balance. While some of our CO_2 is being absorbed by the ocean and land plants, around half of our CO_2 emissions remain in the air. Because of fossil fuel burning, atmospheric CO_2 is at its highest level in at least 2 million years (Tripati et al., 2009), and it’s still going up! The “human CO is tiny” argument misleads by only giving you half the picture.

There are different types of carbon in the air known as carbon isotopes. The most common type is Carbon-12. A heavier type of carbon is Carbon-13. Plants prefer the lighter Carbon-12.

Fossil fuels like coal or oil come from ancient plants. So when we burn fossil fuels, we’re sending more of the lighter Carbon-12 into the air. So we expect to see the ratio of Carbon-13 to Carbon-12 fall.

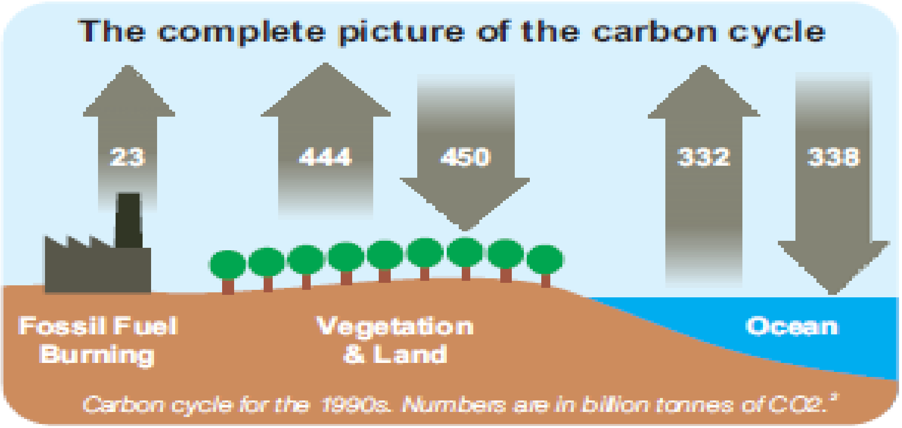


Figure 2. The complete picture of the carbon cycle

This is just what we observe, in measurements of the atmosphere (Manning and Keeling, 2006), in corals (Wei et al., 2009) and sea sponges (Swart, 2010). So we have strong evidence that the increase in carbon dioxide in the air is directly linked to human emissions. Carbon dioxide traps infrared radiation (commonly known as thermal radiation). This has been proven by laboratory experiments (Burch, 1970) and satellites which find less heat escaping out to space over the last few decades (Harries et al., 2001). This is direct evidence that more CO_2 is causing warming (Manning and Keeling, 2006).

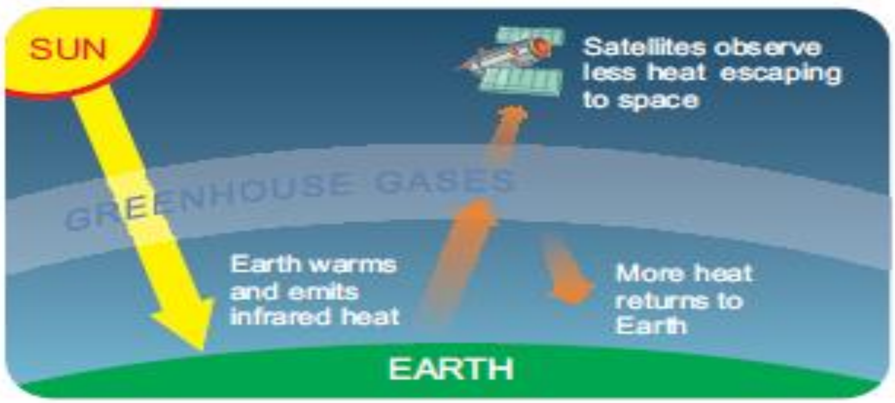


Figure 3. Human fingerprint: Less heat is escaping out to space

As well as the compelling temperature record, we have a large body of observations in many different systems that are consistent with a warming world.

Ice sheets are melting losing billions of tonnes of ice each year (Velicogna, 2009). Sea levels are rising at an accelerating rate (Church et al., 2008).

Species are migrating toward the poles and glaciers are retreating threatening water supplies for many millions of people (Image 4.) (Parmesan and Yohe, 2003; Immerzeel et al., 2010).

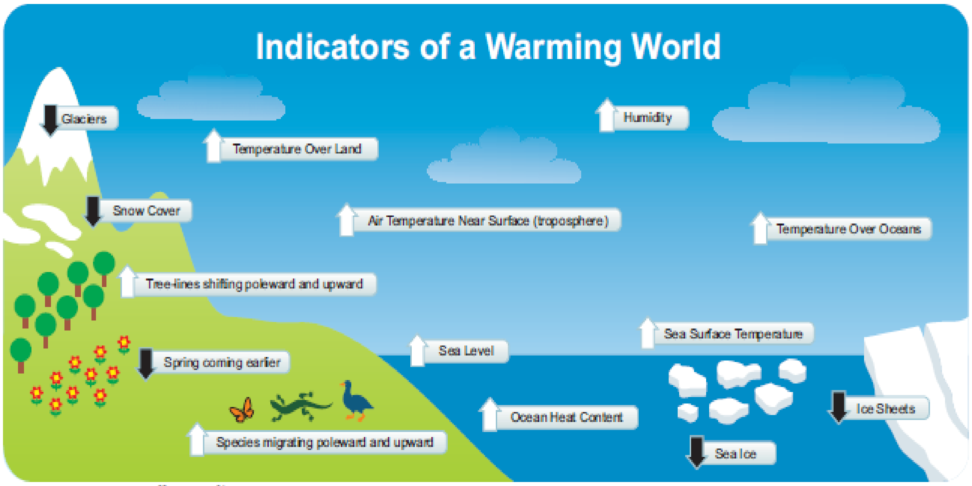


Figure 4. Indicators of global warming

An increased greenhouse effect means nights should warm faster than days. During the day, the sun warms the Earth's surface. At nighttime, the surface cools by radiating its heat out to space. Greenhouse gases slow down this cooling process. If global warning was caused by the sun, we would expect the warming trend to be greatest in a daytime. Instead, what we see is the number of warm nights increasing faster than the number of warm days (Alexander et al., 2006). A warm day is defined as the day belonging with the top 10%.

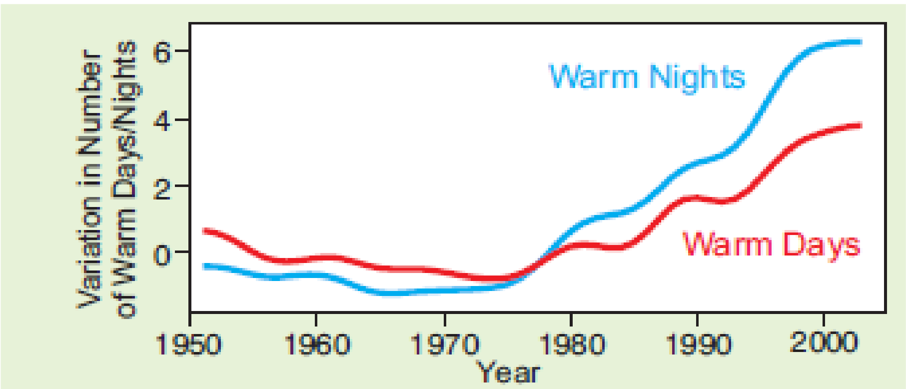


Figure 5. Long-term variation in the number of warm days (red) and warm nights (blue) per year

The book is primarily designed for employees of the agricultural advisory services and farmers, scientists and researchers in the field of climate change and agriculture, students and anyone else interested in the phenomenon of climate change and its impact on agriculture.

The handbook should contribute to build the capacity of agricultural extension services and farmers to implement measures of adaptation to climate change. To achieve this goal it is necessary for these target stakeholders to have the knowledge (on adaptation to climate change, adaptation measures and the like), skills (how to deal with uncertainty and vulnerability and how to create adaptive capacity) as well as the attitude (open to changes, acceptance of uncertainty). Ultimately, the target groups should fully understand the concept of adaptation to climate change and be able to effectively and meaningfully contribute to the debate about adaptation to climate change, both in theoretical and in a practical sense. They will strengthen their positions through these processes based on new knowledge, skills and methodologies. There are two possible ways of developing adaptation strategies: by looking into specific local or regional "hot spots" or by starting from a broader picture (global trends). For the users of this book, it should therefore be easier to achieve the following goals:

- *a) analyze the situation, including scenarios, stakeholders, institutions and policies;*
- *b) ability to adapt;*
- *c) required strategies in various fields such as institutional changes, capacities, processes, funding mechanisms, etc.;*
- *d) manage the process of adaptation.*

1 WHY CLIMATE CHANGE ADAPTATION IN THE AGRICULTURE BOOK?

Climate Change Adaptation in Agriculture is suggested as a way forward to address climate impact on Agricultutue around the world. Climate-Smart Agriculture is increasingly being promoted as one of the options for addressing the problem of food insecurity and environmental degradation, and as an adaptation to climate-related changes (Derpsch et al., 2010; FAO, 2011b; Maal, 2011; Thierfelder & Wall, 2010a). Originally applied in a larger scale in Brazil and Argentina, it is becoming increasingly popular in many other areas of the world, such as North America (zero tillage), Africa and Asia (agroforestry). Presently, conservation agriculture (CA) as an adaptive measure to climate change in agriculture is practiced in about 105 million hectares worldwide, of which 38.2% is in North America, 47.2% in South America, 1.1% in Europe, 0.4% in Africa, 11.6% in Australia and New Zealand and 2.4% in Asia (Derpsch and Friedrich, 2009). In Asia, a majority of CA is practiced in Kazakhstan and China and almost none in Southeast Asian countries. CA contributes in many ways, both direct (from reduced cultivation cost due to savings on account of fuel and labor costs) and indirect (by a way of environmental and resource sustainability).

Changing farming practices and adopting various coping strategies is determined by the prevailing conditions, their previous experience and their access to resources. Farmers are finding it increasingly difficult to cope in the face of rapid change and the occurrence of events that they have not previously experienced. Climate change and variability is not a stand-alone hazard but rather a multiplier of risk, interacting with existing and future hazards to produce unusual situations that might not have been previously experienced. As many research proved that farmers are already experiencing production problems related to current climatic constraints, as well as facing the prospect of coping with greater uncertainty, we need a sustainable approach to secure future agricultural production.

Adapting to the capacity of the environment will contribute to better and safer lives of people in the long run. Such strategies allow farmers better adaptation and safety in food production in the conditions of climate-change uncertainty.

In order to be able to deal with current hazards, farmers need to be empowered to analyze and understand what is happening. They need to be aware of these impacts on their production. In addition, farmers need access to reliable information about the weather and the climate. Meteorological data, along with weather forecasts can help an informed farmer to bring decision when it comes to agricultural production.

Agricultural systems are human-dominated ecosystems and therefore, the vulnerability of agriculture to climate change is strongly dependent not just on the biophysical effects of climate change but on the reaction of the man to these changes. These reactions may be planned (on a local, regional or state level) or individual (reactions of individual farmers).

UNDERSTANDING CLIMATE CHANGE 2

2.1. Climate change at a global level

Climate change will have a wide range of effects on the environment and socioeconomic and related sectors, such as water resources, agriculture and food security, human health, terrestrial ecosystems and biodiversity and coastal zones (WMO & UNEP, 1992). However, climate change is global by its nature, potential changes are not expected to be globally uniform and this differnec may be dramatic (USAID, 2007). Crop yield was found to have a statistically significant sensitivity to climate variables, mainly temperature and precipitation. The majority of impacts are expected to be driven by trends in temperature than in precipitation, although both affect the yield significantly. A 1°C rise tends to lower yields by up to 10%, except in high-latitude countries, where rice in particular gains from warming (Lobell et al., 2011).

Several studies suggest that South Asia and Africa are comparatively vulnerable than any other regions in the world (Nelson et al., 2009). The distribution of climate impacts and the sectoral vulnerabilities to these impacts are also quite diverse (Table 1). Southeast Asia is also deemed to be seriously affected by the adverse impacts of climate change since most economies are relying on agriculture and natural resources.

This area is regularly affected by some of climate extremes, particularly floods, droughts and tropical cyclones, while large areas of the region are highly prone to flooding and influenced by monsoons (IPCC, 2007). In economic terms, the data are, however, scanty in Southeast Asia, some estimates show that the impacts of climate change could vary from a small benefit to a loss of 37% of agricultural GDP by 2100 (Mendelsohn, 2005). It may definitely influenceto Southeast Asian countries, where agricultural contribution of GDP ranges from 8.7% in Malaysia and 10.7% in Thailand to 42% in Lao PDR and 57% in Myanmar (MoF, 2006; Nabangchang and Srisawalak, 2008). Available projections, however, show that the mountainous part of Southeast

Asia is expected to gain from increasing temperature (Lacombe et al., 2012), climate change will have other impacts, importantly sea-level rise, a result of which could lead to salinization of 80% of the deltaic areas in the region.

In Table 1, some studies started to appear elsewhere suggesting negative impacts of climate change on total net revenue from agriculture in India; crop yield loss in South Africa, west African countries and Tanzania due to intense warming; switch of crops as a result of anticipated climate change in South America; and increased negative impact on agriculture through increased drought and flood in Kenya and other parts.

Molua (2009) reports that the current climate variation is already altering the types, frequencies and intensities of crop and livestock pests and diseases, the availability and timing of irrigation water supplies, and severity of erosion in Cameroon.

Table 1. Climate change impact on agriculture

No.	Climate change variable	Impact	Country/ Region	Reported by
1	2°C temperature increase	Crop yield loss by 13% in Maize and 8.8% in Sorghum and 7.6% in Rice	Tanzania	Rowhani et al., 2011
2	3.5°C temperature rise and 20% reduction in precipitation	61% net revenue loss/hectare for medium and low potential agro climate zones 13% net revenue loss/hectare for high potential agro climate zones	Kenya	Mariara and Karanja, 2007
	4°C temperature rise and 20% reduction in precipitation	69% net revenue loss/hectare for medium and low potential agro climate zones 18% net revenue loss/hectare for high potential agro climate zones		
3	2^0C temperature increase and 8% precipitation increase	12% decreases in net revenue from Agriculture	India	Sanghi and Mendelsoh, 2008
		20% net revenue decrease	Brazil	
4	7% decrease in precipitation	Net revenue loss of US $2.86 billion from crops	Cameroon	Molua, 2009
	14% decrease in precipitation	Net revenue loss of US$3.48 billion from crops		
	2.5°C warming	Net revenue loss of US$0.79 billion from crops		
	5°C warming	Net revenue loss of US$1.94 billion from crops		

No.	Climate change variable	Impact	Country/ Region	Reported by
5	Combined result of 16 published paper	Median crop yield loss of 11%	West Africa	Roudier et al., 2011
6	Impacts of the IPCC A2 and B2 climate scenarios	Food production shortfall frequency to double from current figure of 1-3 years/decade Population experiencing food shortfall to grow from present 50 million to 82-139 million in 2070s	Russia	Alcamo et al., 2007
7	Based on review of past studies on effects of climate change on agricultural productivity in Europe	The effects of global change are on the whole likely to increase productivity of European agricultural systems, because increasing CO_2 concentration will directly increase resource use efficiencies of crops, and because warming will give more favorable conditions for crop production in Northern Europe.	Europe	Olesen and Bindi, 2002

* Authors' own compilation

Despite some information exist, it is important to understand that the exact magnitudes of impact on agriculture are uncertain because of the complex interactions and feed back processes in the ecosystem and the economy (World Bank, 2006).

2.2. Climate change at the local level

Climate change could affect agriculture and food production through diverse ways, such as by changing overall growing conditions (general rainfall distribution, temperature regime and carbon); by inducing more extreme weather, such as floods, drought and storms; and by increasing extent, type and frequency of infestations, including that of invasive alien species (Nellemann et al., 2009). There is also the need to consider the impact of inter-annual and seasonal climate patterns as these are observed to have an increasing variability within the long-term shift of climate baselines (Crane et al., 2011).

Current projections of climate change impacts on tropical crop yields, even though on average negative, remain largely uncertain. There is a need for more consistent large-scale, quantitative assessments (Berg et al., 2012). While there is a continuous need for increasing understanding of the link between climate change and its impact on agriculture elsewhere including in Southeast Asia due to lack of information and uncertainties of available information, the concerns on this issue cannot be ignored by not pursuing in the lack of information and uncertainties.

This kind of thing should not happen,because food insecurity and climate change are, more than ever, the two major global challenges humanity is facing today, and climate change is increasingly perceived as one of the greatest challenges for the food security (HLPE, 2012), and thus agriculture sector. In this time of increasing degradation and loss of ecosystems, including various types of degradation of agricultural lands in the region compounded by the uncertainties of climate change impact, meeting food demand is a huge challenge as there is limited scope for expansion of arable land in the future.

Agricultural activities, including indirect effects through deforestation and other forms of land conversion account for about one-third of total Global Warming Potential from GHG emissions (IPCC, 2007). Moreover, agriculture is also one of the major anthropogenic activities affecting climates through production of greenhouse gases accounting for an estimated emission of 10-12% of total anthropogenic emissions of greenhouse gases (Smith et al., 2007). In Southeast Asia, a substantial proportion of population is engaged in agriculture, and these are mostly smaller and poorer farm households that have limited resources.

Climatic changes will severely threaten the livelihood of poor people dependent on agriculture with limited adaptive capacity in developing countries (Bohle et al., 1994; WMO & UNEP, 1992). Thus, reducing the direct and indirect emissions from agriculture, sequestering emission through agricultural practices and most importantly climate change adaptation in agriculture to maintain or enhance agricultural production and ecosystem and thereby protecting a livelihood of small farm holders from the anticipated risk of climate change impact are urgent (McCarthy et al., 2011).

Climate-Smart Agriculture (CSA), a relatively new term, emphasizes to increase agricultural productivity in an environmentally and socially sustainable way, strengthen farmers' resilience to climate change, and reduce agriculture's contribution to climate change by reducing greenhouse gas emissions and increasing carbon storage on farmland. Sustainable Land Management (SLM) is one of key CSA elements, which further includes those innovative practices related to the climate's role in agriculture, such as better weather forecasting, early warning systems and climate risk management of droughts, floods and erratic weather patterns on agriculture. This also includes not only the technologies being available and adopted by the farmers but also development of new technologies, such as drought or flood tolerant crops to the changing climate.

Climate-Smart Agriculture is not only closely related to technological solutions, but also to creating conditions and the political environment that makes room for the adaptation of such technology.

Climate-Smart Agriculture includes also proven practical techniques and approaches, such as SLM, that can help achieve a triple win for food security, adaptation and mitigation. Climate-smart agriculture gives attention to landscape approaches to ensure synergies among various elements of ecosystems that connect each other are captured (World Bank, 2012). This is essential for reducing emissions from land cover change and deforestation, and to balance food, energy and climate considerations in the face of greater land and water scarcity. CSA specifically aims at the following:

- Integrated planning of land, agriculture, forests, fisheries and water at local, watershed and regional scales, to ensure synergies are properly captured.
- Promoting activities that increase carbon storage, combine livestock farming and trees with food production, and encourage improvement of soil fertility.
- Reducing a variety of emissions from agriculture, such as nitrous oxygen from fertilizer application, methane emissions from livestock and rice cultivation.
- Exploring carbon finance as a “lever” to promote sustainable agricultural practices that have many other direct benefits for smallholder farmers and the environment.
- Developing resistant genetic traits of crops and diversifying income to help farmers hedge against an uncertain climate.
- Developing sound risk insurance and risk management strategies as well as resilience building strategies, including safety nets that reach the poorest farmers of society.
- Developing and adopting an adaptive management that disseminates timely climate information to farmers and monitors the local outcomes of different actions, builds on the traditional knowledge of farmers, and tailors techniques to shifting climatic conditions without harming ecosystems.

Adoption of good agricultural practices, such as SLM, generates both positive local benefit of increased household income and public benefit of GHG mitigation.

However, the adoption of such practices has been very slow in general due to a number of reasons (McCarthy et al., 2011). One of the main challenges is that many of these activities (e.g. water management) include public goods and, therefore, requirelocal collective actions complicating the situation. Secondly, public-goods benefits generated through these activities are not generally compensated to the farmers leading to slow adaptation of new practices or their absence. Such explanations are directly related to the issues of financing and risk (McCarthy et al., 2011). The same author further states that there are five broader categories/barriers identified in the literature associated with the adoption of SLM practices and investments. These are:

1. investment costs (e.g. equipment and materials),
2. variable and maintenance costs (seeds and fertilizers),
3. opportunity costs of household assets (e.g. crop residue as livestock feed vs mulch),
4. transaction costs (time needed to find information on best practices), and
5. risk costs (uncertainty of likely benefits).

Key elements when it comes to adaptation to climate change in agriculture and the implementation of the Climate-Smart Agriculture are as follows:

A) Strengthening research for enhancing adaptive capacity

1. assessing climate change impacts on crops, livestock, fisheries, pests, and microbes, and emission mitigation/adaptation potential of various farming systems,
2. improving collection and dissemination of weather-related information,
3. establishing early warning system for climatic risks,
4. develop climate-tolerant genotypes.

B) Intensifying food production systems

1. bridging yield gaps in crops by sustainable intensification,
2. increasing efficiency in livestock and fisheries' productivity,
3. recycling nutrients and minimizing waste.

C) Improving land, water and forest management

1. implementing ecosystem approach,
2. implementing strategies for water conservation and use efficiency,
3. increasing the dissemination of best practices in agriculture,
4. promoting cooperation through community management of natural resources, including the rational use of genetic resources at the global level.

D) Enabling policies and regional cooperation

1. integrating adaptation perspectives in policy considerations,
2. providing incentives for resource conservation,

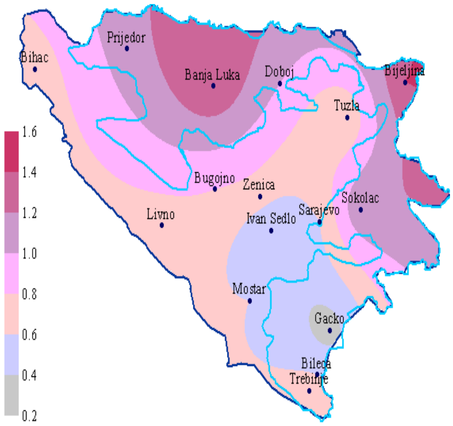
3. securing finances and upscale technologies for adaptation, particularly to small farmer holders,
4. promoting insurance for climatic risk management.

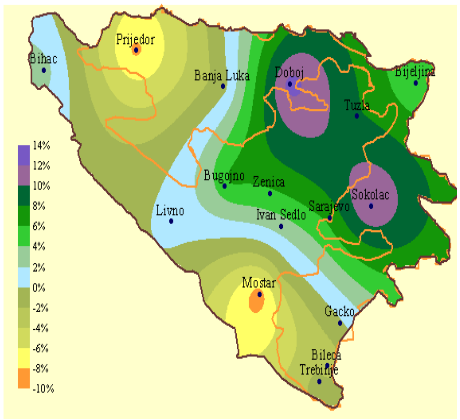
2.3. The Western Balkans Region: trends and predictions of climate change

According to Čustović et al. (2013), for the assessment of climate change in the territory of the Western Balkans countries, different climatic scenarios were used, some of which will be presented in this section for the three countries in the region: Bosnia and Herzegovina, Montenegro and Serbia.

By using EH5OM[2] global model, it was projected that temperature in BiH will increase from 0.7 to 1.6°C, namely between 1 and 2°C along the coast, and between 2 and 3°C in the interior part of the country. The highest increases will occur in summer and in inland areas (UNDP BiH, 2009). When it comes to precipitation, the result will be a drier climate during the summer (June-August). A reduction by 50-100 mm (up to 10 percent) is expected. From the seasonal point of view, maximum effects are expected in the fall, where the level of precipitation will significantly decrease-up to 25%. Changes in the precipitation regime will also be reflected in the timing, frequency and intensity of extreme phenomena-floods and droughts. This means an increased evapotranspiration and more pronounced extreme minimums in the watercourses' regime. On the other hand, the increasingly frequent precipitation of extremely high intensity will cause rapid runoff, often in the form of flooding. All of this will lead to an even more pronounced unevenness in water runoff in Bosnia and Herzegovina (BiH). On the one hand, the availability of water resources during the vegetation season, when the requirements are the largest, will generally decrease, while, one the other hand, the risk of flooding will become higher. BiH is highly vulnerable to climate change and will be considerably exposed as it is extremely sensitive to such threats due to the fact that the economic role of the "climate-sensitive" sectors such as agriculture and forestry, has a significant secondary effect.

[2] EH5OM global model developed at the Max Planck Institute for Meteorology, Hamburg, Germany





Source: Initial National Communication of BiH under the United Nations Framework Convention on Climate Change, 2009

Figure 6. Increase in average annual temperature in the last decade (1990-2000) compared to the reference period (1961-1990) in BiH expressed in °C

Figure 7. Spatial distribution of annual surplus/deficit of rainfall in the last decade (1999-2008) compared to the reference period (1961-1990) of BiH

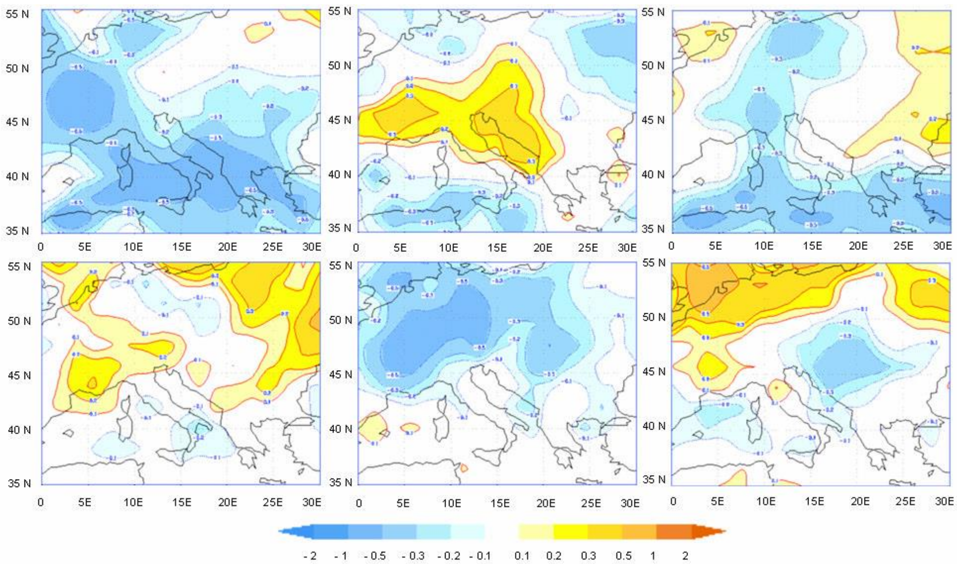
P a v i č e v i ć (2012) states that an increase of average annual temperature; more frequent dry periods during the summer; and, intense rainfall with potential flooding in the winter, are to be expected in Montenegro. According to the projections, a significant reduction of precipitation, up to-50% in the southern parts of Montenegro in the summer, and a slight increase of precipitation, up to 5%, also during the summer, in the central parts, and in the north-western part (border with BiH) in the spring season, are expected. The largest temperature increase is expected in the northern part of Montenegro in the summer, with the occurrence of warm and cold waves, drought, desertification of land, avalanches and hurricanes. Extreme weather events will mostly affect the poor population (especially in the north), whose livelihood largely depends on agriculture.

According to the W W W report (2012), in the past 50 years in almost entire territory of Serbia there was an increase of mean annual temperature up to 0.04°C per year, whereas in some areas in the east and southeast of the country, a negative trend was recorded, up to -0.05°C per year. The highest increase of temperature occurs in autumn period. At the same time, there is a positive trend in precipitation in most parts of the territory, while in the eastern and southeastern part of Serbia precipitation was reduced. According to the projections for A1B1 temperature increase scenario[3], a relatively uniform increase is expected throughout the country, with a somewhat more pronounced positive trend in the eastern parts,

[3] 2001-2030

along the Danube, and in the southwest. Situation with precipitation is alike, where a slight negative trend is expected in the north of Vojvodina and in some areas in the east and southeast. According to Lalić et al. (2011), in the area of Vojvodina, the increase of mean annual air temperature from 1.1 to 1.5°C can be expected. A reduction of the number of frost days and an increase of summer and tropical days are also expected. Substantial extension of the period between the last spring and the first autumn frost should be an important characteristic of the thermal regime in Vojvodina in the coming decades, which could ultimately have a significant effect on the sowing date and the dynamics of work in the field. When it comes to the vegetation dynamics, all the models indicate a significant increase of the sum of active air temperatures above 10°C, which will considerably accelerate vegetation of not only all grown crops, but also weeds and pests. As for the precipitation, a reduction of quantity is expected, though it will not be uniform, but is expected to increase the number of dry days during the summer and autumn, and a decrease during the spring.

For the whole region, it can be generally stated that the duration of dry periods, the frequency of torrential flooding and soil erosion intensity are expected to increase over the next century. Additionally, an increase in the occurrence of hail, windstorms, thunderstorms and maximum wind speed is projected, which can pose a serious threat to all forms of human activity, and certainly the agriculture.



Source: Initial National Communication of BiH under the United Nations Framework Convention on Climate Change, 2009

Figure 8. Projected regional changes in precipitation from the EH5OM

AGRICULTURAL PRODUCTION - THE VICTIM AND THE CAUSE OF CLIMATE CHANGE

3

3.1. Emission from agriculture

According to Rosenberg and Izaurralde (2000), the annual increase of CO_2 concentration amounts to 3.4 Gt (billion tonnes) C. The sources of extra carbon emission caused by human impact include: deforestation in the tropics with 1.6 Gt C yr^{-1}, changes in land use with 1.1 Gt C yr^{-1} and burning of fossil fuels with 6.4 Gt C yr^{-1}. Storage places for this extra emitted carbon are the terrestrial ecosystems of the temperate zone with 2.0 Gt C yr^{-1}, oceans with 2.0 Gt C yr^{-1} and "unknown" with 1.7 Gt C yr^{-1}.

The main sources of greenhouse gas emissions from agriculture are: a) the mineralization of soil organic matter and emission of CO_2 caused by tillage and other types of soil disturbance relating to agricultural activities, b) emission of CO_2 due to soil erosion and erosion-induced soil degradation, c) natural levels of emission of N_2O and NO_x from soil and emissions from nitrogen fertilization, d) methane emissions from rice fields, wetlands, landfills of organic materials and livestock production in general.

It is estimated that to date the loss of carbon from agricultural land amounts to 78 ± 12 Gt C at the global level, and that a large portion of that carbon ends up in the atmosphere. The losses of carbon from agricultural land are the most intense in the first decade after cultivation. Over time, the level of loss decreases due to the decrease of available carbon for decomposition and gradual improvement of soil management practices. Consequently, most of the agricultural land is now neutral in terms of CO_2 emissions, meaning that it neither appears as a source of anthropogenic emission of CO_2, nor as a storage place for CO_2 from the atmosphere. Two approaches are used to determine the impact of land management on carbon storage: a) measurement of the content of C in soils under different management methods, and b) measurement of soil CO_2 flux.

The leading causes of declining amount of carbon in soil include various processes of soil damage such as erosion, compaction, disturbance of soil structure, mineralization or oxidation organic matter. These degrading processes in soil are a result of human activities (poor soil management) which include plowing, burning of biomass, drainage of wetland soils, inadequate grazing, depletion of soil fertility due to low-productivity agricultural practices.

The available information on the effect of soil cultivation on the organic matter content and the accessibility of N indicate that: *i)* all types of plowing lead to the reduction of the content of organic C and N in soil compared to natural soils; plowing generally increases the amount of oxygen in the soil air and exposes the protected soil organic matter to microbiological activity; the more the soil is plowed the greater the losses of organic matter. *ii)* incorporation of crop residues in the soil in comparison to their movement normally increases organic matter content in the soil; *iii)* leaving the crop residues on the soil surface leads to the accumulation of organic matter and total N on the soil surface; *iv)* burning of crop residues often produces different effects on the amount of soil organic matter, depending on the depth of the soil, the tillage practices, the level of burning, the weather and other conditions; *v)* an increase in frequency of making land fallow generally increases the loss of organic matter in the soil.

In general, the farming systems returning the majority of carbon into the soil usually show a minimum loss of soil organic matter.

It is estimated that the cultivation reduces the amount of soil organic matter by half compared to the pre-cultivation period. The majority of data on the impact of conservation tillage on the amount of organic matter show a higher content of carbon in soils under conservation tillage.

3.2. Emissions from livestock production

In recent years, animal production has been in focus regarding the subject issue. Research (F A O , 2011) indicates that the market demand for animal products in 2050 will increase by 73% (meat) or 58% (milk), compared to the demand in 2010. Intensification of animal production and conversion of farms to factories for the production of meat, milk and eggs have made livestock production a significant competitor for natural resources among other sectors. The rapid growth of animal sector, driven by market demands, has a negative impact on the environment manifested through increased emission of greenhouse gases, soil and water pollution and reduced biodiversity. As the gases from the animal production account for 7.1 gigatons CO_2-eq per year or between 7 and 18% (I P C C , 2007; F A O , 2013) in the total greenhouse gases' emission, the concern and increased public interest in the identification of critical points in gas emissions in the chain of animal production as well as in finding adequate solutions to reduce these emissions, become understandable.

The intensity of the GHG[4] emissions, expressed per unit of animal product, is not uniform in terms of either different production units or similar production systems. The use of different production practices on farms, as well as the management of procurement, is the main reason for the variations. In ruminants, the most significant sources of emissions are ruminal fermentation and animal feed production. In the production of meat and milk, the higher level of emissions is linked to the low-productivity production systems. The reasons for this are primarily related to the lower digestibility of feed, inadequate management of herd and poor reproductive performance of animals. In poultry and pig production, the major sources of emissions are the feed production and storage of manure. Smaller emissions are linked to the better feed conversion, i.e. lower feed consumption per unit of product. Compared to other animal productions, the lowest emissions are linked to the production of poultry meat and eggs.

In the total GHG emissions from animal sector, production of beef accounts for 41%, milk 20%, pork 9% and eggs 8% (Chart 1).

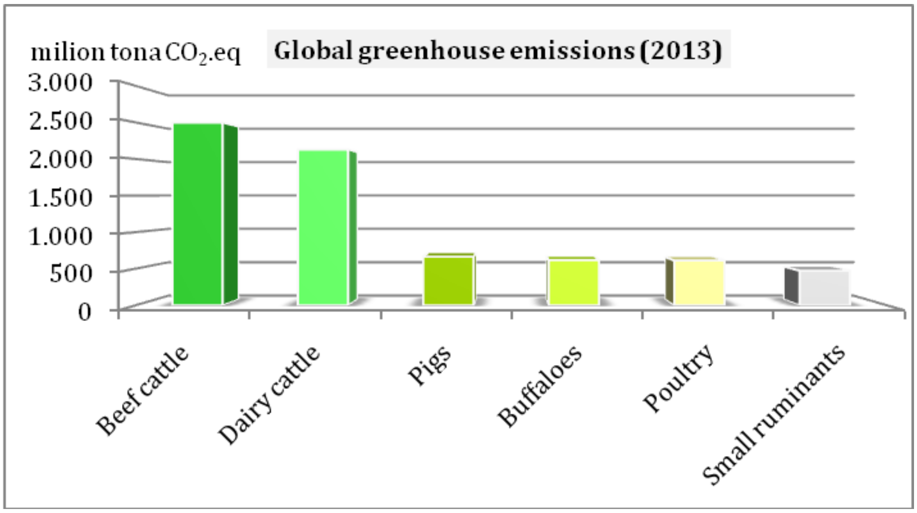


Chart 1. *Global gas emissions by animal species (FAO, 2013)*

The two main sources of emissions are the production and processing of animal feed and ruminal fermentation in ruminants, whose share in the total emissions

[4] GHG – greenhouse gas (emission of greenhouse gases)

amounts to 45% and 39% respectively. Manure with 10% is in the third place. Other sources include the processing and transportation of animal products.

When it comes to the production of animal feed, 9% emissions result from deforestation used to increase pasture and arable land. Fossil fuel consumption in the entire chain of animal production is the source of 20% emissions. When it comes to emissions from animal sector, they primarily include CH_4, N_2O and CO_2. Methane is the most represented with 44%, while the emissions of N_2O and CO_2 are roughly the same 29% and 27%.

Reduction of emissions originating from animal production is based on the application of technologies and practices that increase productivity of animals and production units. These include feeding animals with more quality fodder and balancing meals in a way that reduces the production of emissions from digestion and manure. Ensuring better conditions for keeping animals and taking better care of their health (thus reducing the number of animals excluded from production) and provision of optimum circulation of nutrients and energy from manure represents an indispensable part of any strategy to reduce gas emissions.

Additionally, there is the use of different additives in animal nutrition as well as animal selection.

3.3. Major sources of greenhouse gas emissions from animal production

CH_4-The largest amounts of methane are formed as a by product of digestion of ruminants. Methane is generated also by microbial fermentation of food in the rumen of ruminants and decomposition of complex carbohydrate molecules, in addition to those easily digestible to animals. Meals that contain larger amounts of fibers have the effect of increasing the quantity of methane compared to meals with more digestible nutrients. Since the nutrition of ruminants is based on meals, which must have a voluminous component in their composition as well as due to the specificity of their digestion, methane generation in cattle, buffalo, sheep and goats is significantly higher than in monogastric animals. Methane is also generated in the intestinal tract of pigs, but in a significantly lower concentration. Another significant source of methane is manure. Methane is released through anaerobic decomposition of the organic matter in manure. This is particularly evident in the storage of liquid manure in deep lagoons or tanks. Production of rice for animal feed is also a significant source of methane emissions.

N_2O-The main source of N_2O in animal production is nitrogen from manure. During storage of manure, nitrogen is mainly released into the atmosphere in the form of ammonia (NH_3) which is subsequently transformed into N_2O, which means that this is an indirect emission. Production of animal feed which implies the use of organic and synthetic fertilizers represents the next important link in the emission of N_2O. Stay of animals on pasture and decomposition of animal feed residues also cause N_2O emissions. The amount of N_2O depends on the temperature and humidity at the time of application of fertilizers.

Source: S. Čengić-Džomba, 2014

Figure 9. Diffuse source of pollution from animal production

CO_2-Emission of CO_2 from animal production is primarily related to the energy consumption in all stages of production. Speaking about the production of animal feed, the use of energy (fossil fuels) is linked to the production of fertilizers, the use of machinery in the production of field fodder crops (sowing, harvesting, processing, transportation). Energy is directly used for various mechanical operations at the farm (ventilation, heating) or indirectly for the construction of facilities and equipment. Transport of animal feed, animals and the like, as well as processing of animal feed and animal products also require energy and thus affect the emission of CO_2. Global increase in CO_2 emissions is the result of deforestation aimed at increasing the area of land for growing animal feed (pastures and arable land).

3.4. Land degradation

Different forms of degradation processes and pressures on land have affected almost all the countries of the world, primarily due to the unsustainable way of exploitation in the production of biomass, change of land use and various forms of destruction and permanent loss of fertile land. The processes of land degradation are manifested in different forms such as reduced yields of crops, reduced productivity of natural pastures, etc. Likewise, the degradation takes place in areas under crops or grass associations that are irrigated, forests and forest land as a result of exploitation and way of use by man.

There is an increasing concern of the international community, particularly the UN, that the land is becoming one of the limiting factors for the development of civilization of the 21st century, given the increasing growth of the population and the reduction of arable land for the production of sufficient quantity of food needed to feed the population at the global level.

The role of soil in the natural and anthropogenic environment is manifold and multifunctional. The soil is a source of water and mineral substances for plant life, and through it for the entire living world. Soil is the habitat for many animals and microorganisms. Soil quality depends on the way of its management.

In this regard, land in BiH as well as in the entire region of South East Europe, represents an extremely vulnerable and sensitive resource which must be treated with particular care. However, though we are aware of the changes in time and space, land degradation has not been seriously investigated at the level of BiH or entire region, so it is very difficult to assess objectively the situation at the national level. The socio-economic situation and the effects of displacement of the population within the country are the main causes of land degradation.

The absence of a system for sustainable land management and systemic monitoring of land quality have resulted in its destruction and disappearance. The analysis shows that the share of cultivated land in relation to the total arable land reduces at the annual level; the area of abandoned land is constantly increasing and thus the area of non-agricultural land or land of changed use. The loss of forest resources is also evident.

Inadequate management and use of pastures contribute to the reduction of biodiversity and the destruction of the landscapes of rural areas. Production practices are not adjusted to the natural characteristics of the land in BiH.

Source: E. Hukić, 2014

Figure 10. Pastures and natural meadows in the area of Morine near Nevesinje

Unregulated land, small and fragmented holdings reduce the productivity of agricultural production. Uncontrolled use of mineral fertilizers and other chemicals reduces soil fertility, disrupt soil structure and cause increased erosion. Change in pH level of the soil, i.e. its reduction due to the removal of Ca through yield and leaching, has particularly negative effects. Unadjusted machinery and tillage techniques also contribute to erosion and other types of soil damage. Unplanned, uncontrolled and excessive exploitation of mineral resources leads to land degradation as well. A particular problem is the permanent loss of both agricultural and forest land due to urbanization. Because of the above mentioned and within the scope of looking into the issues of climate change and its impact on soil ecosystem it is necessary to do the following:

- Establish criteria for determining the areas vulnerable to degradation processes;
- Develop a national list of indicators of land degradation;
- Establish a system of sustainable land management and systemic monitoring of land quality.

3.5. Land management designed to adapt to climate change

Agricultural activities have an impact on changes in the environment. Management of soil organic matter deserves particular attention for its role in soil functions. As it increases the capacity to retain water and heat, circulate nutrients, improves the structure and protects the soil from erosion, the management of organic matter can increase the productivity of the soil and quality of the environment.

It is necessary to use the soil as a place to store carbon as well as good agricultural practices to mitigate the negative impact of human activities on the carbon cycle. Understanding of processes and factors that influence the quantity and forms of organic carbon is a prerequisite of good management of soil organic matter.

To achieve larger stocks of carbon in the soil, agricultural practice must:

- Increase the input of carbon in the soil in the form of plant residues (increase biomass production),
- Decrease the level of decomposition (mineralization) of the soil organic matter by applying conservation practices.

The main processes of storing carbon in soil include:

- Humization through the introduction of organic residues in the soil;
- Creation of favorable conditions for humization and establishment of organo-mineral complex of the soil;
- In-depth introduction and storage of organic matter in the subarable layer of soil;
- Improvement of soil by liming;
- Growing of plants with deep root systems.

The aim of these measures is to protect agricultural soil from chemical and biological degradation and maintain it in a condition that makes it favorable habitat for the production of healthy food.

3.6. Biodiversity

Biodiversity or biological diversity is the variety of all living creatures on the planet Earth or the totality of genes (genetic diversity), species (species diversity) and ecosystems (ecosystem diversity) (CBD, Rio de Janeiro, 1992). Biodiversity plays a key role in the food chain as it influences the world food production, ensures sustainable soil productivity and provides the genetic resources for all crops, domestic animals and marine species harvested for food.

The life of people on Earth is largely dependent on the state of biodiversity, though we are not always aware of that dependence.

Climate change and the rapid loss of biodiversity lead to major changes in the food chain we are depending on, in which case the sources of water change, the medicinal plants and other resources on which pharmaceutical industry relies, either decline or disappear and the like.

Climate change is already having an impact on biodiversity and is projected to become even a more significant threat in the coming decades. Ecosystems are already showing negative effects at the current levels of climate change, which are rather modest compared to projected changes in the future. Threatened with extinction is about 50% of the plants, 20% tropical rain forests will be destroyed in 30 years, 50% of the wetlands will be dried out, about 37% of the land will be destroyed, about 36,000 species disappear every day, one in four mammal species is threatened with extinction. These data are alarming and worrying at the global level (Source: http://www.bionet-skola./w/Biodiverzitet).

Some species can benefit from climate change, however, rapidly changing nature suggests that it is detrimental to thw majority of species, especially because most of them will not be able to adapt, i.e. will disappear. All species that are capable of adapting will migrate to the north or to higher altitudes, thus adapting to the given conditions, but species already living at high altitudes or latitudes will not be able to find a new place to live. On the other hands, the dynamics of penetration of invasive non-native species will accelerate, and those more aggressive ones may push out the autochthonous ones from their natural habitats. Species that fail to quickly genetically adapt will disappear.

Susceptibility to plant diseases and pests will increase, which will also lead to further vulnerability of ecosystems or habitats.

In BiH, significant changes are expected in the families inhabiting mountainous areas, especially migration of some woody species in the direction along the Dinarides towards the north-west, with the possibility of local depletion of flora. It can be expected that the number of herbaceous species of narrow ecological valence in the highest mountainous areas will go down as they will not be able to adapt their areal quickly enough. One of the major effects of global warming on ecosystems will certainly be the movement of water supplies and distribution of agricultural pests and diseases. The IPCC in its scenario predicts that the Mediterranean countries that are already largely dependent on irrigation will have 15 to 25% less humid soils in summertime (I P C C , A R 4 , 2007). Moreover, an important segment of the region are the karst areas that are unique phenomena, which indicate the specific patterns of development of the Earth's crust, the hydrological network and biological and environmental diversity. Disturbing one of them causes effects on the remainder of the system (W a t s o n et al., 1997). Anyway, karst geo-ecosystems are very fragile areas undergoing progressive degradation caused by human activities in many parts of our planet (P a r i s e et al., 2009). Managing karst terrains is very difficult, especially when faced with enormous urbanization and progress of agricultural technology. Karst fields are ecologically the most interesting phenomena within the karst areas, characteristic for the existence of a network of underground watercourses and sinking of surface rivers and their reappearance in other places. Another specific feature is the emergence of temporary watercourses that exist only in a certain part of the year and then disappear.

These areas are the habitat for numerous plant and animal species, many of which are endemic and typical only for these areas, while some have a very narrow area of distribution, i.e. they can be found only in some parts of these karst fields.

Source: S. Vojniković, 2015

Figure 11. The Bijambare area - Nišićka Plateau, the plant association (phytocenosis) that is disappearing (*Sphagno - Piceetum*) with species that are disappearing: spruce (*Picea excelsa*) and peat moss (*Sphagnum sp.*). Both the association and species belong to the Boreal Province. This area and species are endangered under the influence of climate change.

Agricultural biodiversity is the diversity of genetic resources of cultivated plants, animals and microorganisms used in agriculture. The result is an interaction between genetic resources, the environment and agricultural practice. Cultivated in agricultural ecosystems worldwide and in all climate zones there are 12 varieties of wheat, 23 varieties of vegetables and 35 types of fruit. It is only 70 species on approximately 1,440 million hectares of arable land in the world, in contrast to the diversity of plants that can be found on a hectare of rainforest, which amounts to over 100 species of woody plants alone. Only 6 genotypes of maize account for over 70% of the area under this crop in the world (T h r u p p , 1998).

Some of the losses expected to occur in the future include potato wild relatives in South America; 16-22% of wild relatives of peanut, potato and bean will be threatened with extinction by 2050. A potential area of distribution will be reduced for 97% of species, and most of them will lose more than 50% of their area of distribution. In accordance with this, the Convention on Biological Diversity (CBD) has developed a special program of work relating to agricultural biodiversity aimed at ensuring preservation, sustainable use and sharing of benefits resulting from the use of agricultural biodiversity which is successfully stopping the loss of biodiversity due to human activity.

At the moment, it is impossible to predict accurately the success of adapting to life in new habitats resulting from climate change. The ideal scenario of the survival of species thanks to migratory movement is realistically possible only in some cases due to isolated ecological niches, natural and artificial barriers. Anthropogenic effects on space, primarily fragmentation of habitats and disruption of migration routes, increase the risk of reducing the area of distribution of species or their extinction. Species exposed to climate change may try to migrate following their life optimum, adapt to new conditions or become extinct (locally or wider). With the shift of climatozonal vegetation belts, it is realistic to expect disappearance of inadaptable or poorly adaptable species.

How to deal with climate change in the area of biodiversity:

1. By developing knowledge and monitoring of trends of biodiversity and risk assessment (better understanding of the significance, distribution and vulnerability of biodiversity, creation of information systems on genetic resources and modeling of future distribution of genetic resources with different scenarios of climate change in order to develop the national strategies);

2. By strengthening adaptive capacity through biodiversity management within management systems (include farmers in planning strategies for the conservation of diversity, establish a long-term monitoring of the functional

agricultural diversity and use appropriate technologies to improve the management and preservation of biodiversity);

3. By developing plans and legislation on genetic resources and climate change (programs and strategies for sustainable use of genetic resources, support the local development of adapted genotypes on farms and strengthen the international cooperation).

3.7. The causes of plant diseases, pests and weeds

The causes of plant diseases, pests and weeds as part of life on Earth that is most directly related to agricultural production, represent a very important segment equally affected by current and future climate change.

It is already certain that drier and warmer climate has an impact on reduced spread of phytopathogenic fungi benefitting from frequent precipitation and high relative humidity, in the sense that it will facilitate the control of certain plant diseases. However, drier climate will require changes in agricultural technologies such as the intensification of irrigation, which may increase the incidence of some other phytopathogenic bacteria. Treatment of these bacteria may increase the production cost which has a direct impact on energy efficiency and greenhouse gas emissions.

In addition, mild winters could contribute to the spread of harmful insects in both horizontal and vertical terms (e.g. intensive expansion of *Capondis tenebrionsis* from the southern to the northern areas), and even the emergence of new species (which is already certain), which would also require control measures and increase the cost of production. Warmer climates could lead to the spread of invasive thermophilic weeds such as *Amorpha fruticosa (*false indigo bush*), Ambrosia artemisiifolia (*common ragweed*), Helianthus tuberosus* (Jerusalem artichoke*)* etc., thus creating additional problems in the agricultural areas which, again, increase the cost of their control. In the past 30 years, change in temperature has led to the extension of the vegetation season of ragweed in Germany for 8-10 days, the increase of its area of distribution further to the north and to higher altitudes, while the increased concentration of CO_2 in the atmosphere favors the formation of male flowers, which causes the higher production of pollen, and ragweed pollen is one of the strongest allergens that cause allergy symptoms in a significant portion of the human population.

Many weeds, pests and plant pathogens thrive at higher temperatures and in humid climates with increased levels of CO_2. More than 11 billion dollars are spent annually on weed control in the USA alone. Weeds and pests are likely to expand to the north. This will cause new problems to farmers as they do not expect them in those areas. Plants weakened by droughts will be easier “targets” for plant pathogens and insects. All this will lead to an increased application of pesticides, which could have a negative impact on human health.

Adverse effect can be expected from the aspect of increased spatial distribution and intensity of existing pests, diseases and weeds, due to increased temperature and humidity. It is difficult to assess the extent of the effects, but it is likely that they will be extremely regionalized. Additionally, the fossil records indicate that whenever climate changes occur, insects move much faster than any other living organisms in biocenosis (herbaceous plants, shrubs and woody species). An example of an insect that has been put on the black list of invasive species in Europe is the Asian hornet (*Vespa velutina*), which first appeared in Europe in 2005 and has been multiplying and spreading dramatically fast ever since.

Figure 12. Asian hornet (*Vespa velutina*)[5]

As they are extremely aggressive, they can kill and eat a whole nest of bees in a minute**,** leaving only bee heads and body parts behind. Most often they nest under the ground and on buildings, and get raged only by the passage by their nest. They are also aggressive towards other insects as well as towards people. Their poison can cause allergic reactions, failure of many oft he body's organs and death.

An example of the strong correlation between climate change and increase of pests is the escalation of the population of rodents in South Africa in 1994 after heavy rains in 1993 that were preceded by drought. As a result, maize yields in Zimbabwe, Malawi and Mozambique were disastrous low (1.6, 0.9 and 0.5 t/ha).

As a result of climate change, there is a decrease in the number of predators impying an increase in pests too. The role of predators is also important. Healthy ecosystems with preserved predator/prey relation provide natural protection against pathogens, insects and other organisms involved in the food chain.

[5] Source: http://www.planetepassion.eu/wildlife-in-france/asian-hornet_vespa-velutina-nigrithorax_frelon%20asiatique_france.html

Farmers will be faced with the challenge of solving ever increasing problems with pests or emergence of new pests.

Apart from plant diseases and pests, weeds are also a cause of problems in agriculture as they grow faster than cultivated plants and consume larger quantities of water which, in drought conditions intensifies scarcity of water in the soil. In weedy crops, soil contains up to 25% less moisture than the one that is not weedy, while topsoil in the summer months shows significant differences in the content of momentary humidity in weedy and non-weedy areas of arable land. Weedy land contains less accessible water, it dries out faster, and its crops suffer more from drought effects. On the other hand, chemical weed control in dry conditions is quite problematic due to the reduced efficiency of herbicides, which is particularly true in herbicides applied after emergence (*post emergence*). Because of this, the so-called soil-applied herbicides are better for dry conditions as they are incorporated before sowing. For the reason of better uptake, translocated herbicides must be applied in combination with a wetting agent, and the treatment should be carried out in the late afternoon. Decomposition of herbicides is slower in dry conditions prolonging their persistence. This should be taken into account in order to avoid damage from residual effects of persistent herbicides on the crops.

3.8. The impact of climate change on domestic animals and animal production

Possible effects of climate change on food production are not limited just to plant production. Climate change has far-reaching effects on the production of milk, meat and other animal products, primarily through the impact on the production of animal feed, health and reproduction of domestic animals. In extreme cases, drought or lack of water can lead to a complete loss of necessary resources in livestock production. Climate change which includes an increase in temperature as well as change in spatial (geographic) and temporal pattern of precipitation, results not only in an increased spread of various diseases but in the emergence and spread of new, exotic animal diseases. This is primarily related to transmissible or vector-borne diseases-viral, bacterial and parasitic. Vectors or carriers of transmissible infectious diseases are organisms transmitting pathogens and parasites from one animal to another (insects, ticks, nematodes, etc.). Because of the spreading of the vector population into colder areas and higher altitudes, new diseases appear in places where they were almost unknown. During the last decade, some significant changes were recorded in the emergence and distribution of certain vector-borne diseases such as: *Lyme disease, leishmaniasis, trypanosomiasis, dengue fever,* etc. Some tick-borne diseases have spread to an altitude higher by 500 m or in northern areas, e.g. the spread of bluetongue in northern Europe (Thornton et al., 2008). Bluetongue attacks both domestic and wild ruminants.

Mass migrations of animals in search of new habitats are conducive to the spread of diseases. Foot and mouth disease and peste des petits ruminants are spread in this way (IUCN, 2010). On the other hand, areas with plenty of rainfall are conducive to the spread of anthrax. In addition to these, many other animal diseases are spread to new areas.

If the predictions come true, the effects of global warming in the next century are not optimistic for the animals, especially those that have already lost their habitat. As faced with new natural enemies many animal species will go extinct, according to scientists' predictions.

Direct effects of climate change on animals are also reflected in heat stress which is detrimental to the animal production and the quality of animal products.

Heat stress

Heat stress occurs at high environmental temperatures, relative air humidity and radiation energy animals are exposed to. It is usually a combination of two or more factors resulting in the inability of animals to release body heat, i.e. the inability to cool down.

The range of air temperature at which the animals feel comfortable is called thermoneutral zone. Within this zone, the energy loss in animals is minimal and constant, which means that the energy the animals receive from feed is used to the maximum extent for the production of animal products (meat, milk or eggs). In unfavorable weather conditions, where the environmental temperature is too high or low, most of the food energy is spent on thermoregulation of the body. This practically means that animals are left with less energy for the production which inevitably begins to fall. Thermoneutral zone is different in different animal species. The highest and lowest critical temperatures limiting a thermoneutral zone are also dependent on the age of animals (Table 2.) and other factors, among which relative humidity and air flow are the most important. With an increase of air humidity, the thermoneutral zone reduces where the lower critical point of temperature goes up and the upper goes down.

Table 2. The lower upper and critical temperature for various species and categories of domestic animals (Fass, 2010; Fraser and Broom, 2001)

Critical Temperature	**Dairy cows**	**Calves (I week)**	**Day-old chicks**	**Broilers**	**Laying hens**	**Piglets (3-15 kg)**	**Pigs (70-100 kg)**
Upper, °C	20* (24)	35	35	26	27-29	32	25
Lower, °C	0*	8-10	32	16	16	26	10

*The average for the European breeds

At the ambient temperature that exceeds the upper critical level, the loss of body heat through radiation, evaporation, conduction or convection in order to cool the body is not effective. Body temperature rises and the signs of heat stress become visible on the animal. The initial signs include rapid breathing, increased sweating, reduced food consumption and reduced production. In the most critical phase, the animals show clear signs of heat stress (open mouth, tongue sticking out). Death of the animal can occur in extreme cases.

Rapid breathing of animals enhances the CO_2 emission from the body which is directly reflected in the change of the balance of electrolytes in the body fluids and the occurrence of alkalosis. Change in the balance of electrolytes reflects negatively on protein metabolism resulting in lower production of milk, meat and eggs. Highly productive animals are more sensitive to the increase in ambient temperature in comparison with the medium or low productive ones. The reason is that high production of meat, milk and eggs results in high production of metabolic heat so the upper critical temperature for such animals is lower (Renaudeau et al., 2010).

Heat stress causes deterioration of the immune system of animals (reduced production of antibodies). Highly productive animals are more susceptible to various diseases due to weakened immunity.

The effect of heat stress on animal production and quality of animal products

Cattle

In dairy cattle, the ambient temperature, humidity and air flow have a significant effect on fertility, reproduction and milk production. The optimum temperature for dairy cows ranges between 5 and 15°C, while the upper critical temperature is

25°C (tolerance to high temperatures also depends on the genetic potential of the cow and climate zone, hence in some cases, this critical level is moved to 37°C). When the temperature exceeds 25°C, cows begin to show the signs of heat stress. Intensity of stress (mild, moderate and severe stress) depends on several factors among which ambient temperature and air humidity are the most important. Temperature-humidity index (THI) (Table 3) is a useful indicator of temperature-climatic conditions.

Table 3. Temperature Humidity Index (THI)

TEMPERATURE	Relative humidity											
	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%
38°C	84	85	86	87	88	90	91	92	93	94	95	97
37°C	83	84	85	86	87	88	89	90	91	93	94	95
36°C	81	82	83	85	86	87	88	89	90	91	92	93
34°C	80	81	82	83	84	85	86	87	88	89	90	91
33°C	79	80	81	82	83	84	85	85	86	87	88	89
32°C	78	79	79	80	81	82	83	84	85	86	86	87
31°C	76	77	78	79	80	81	81	82	83	84	85	86
30°C	75	76	77	78	78	79	80	81	81	82	83	84
29°C	74	75	75	76	77	78	78	79	80	80	81	82
28°C	73	73	74	75	75	76	77	77	78	79	79	80
27°C	72	72	73	73	74	75	75	76	76	77	78	78
26°C	70	71	71	72	73	73	74	74	75	75	76	76
24°C	69	70	70	71	71	72	72	73	73	74	74	75

0000< 74%: Normal	75-78: Caution	79-83: Danger	84: Extreme danger
FAVORABLE CONDITIONS	MILD STRESS	STRESS OF MODERATE INTENSITY	SEVERE STRESS

Generally, in increased environmental temperatures as well as increased air humidity cows reduce the consumption of food and production of milk (1.5-2 liter/cow/day, in some cases even 50%) - Table 4. Heat stress causes a variety of physiological, metabolic and production disruptions. The negative impact of heat stress on fertility and reproduction is manifested through the silent heat cycle, ovulation disorder, reduced insemination index, increased early embryonic mortality, etc.

The increase in temperature also causes hormonal disorders in cows. The concentration of thyroxin decreases while the concentration of triiodothyronine in blood plasma increases. When cows are exposed to a temperature of 40°C the secretion of aldosterone, adrenaline and noradrenaline and glucocorticosteroids abruptly increases.

Refusal of food predisposes an animal for certain metabolic disorders, including ketosis as the most common one. In addition to the decline in milk production, ketosis can cause death of animal.

The exposure of cows to higher temperatures causes a decrease of fat and proteins in milk. The chemical composition of milk fat is changing in the direction of reducing the content of C_6-C_{14} fatty acids.

The loss of water from the body causes a change in water balance and osmotic pressure in cells. The blood pH changes leading to the occurrence of alkalosis.

Heat stress affects cattle for fattening in the same way. The problems are more pronounced in animals that are permanently outdoors. Because of the poor quality of animal feed, the final weight of animal is smaller and meat quality is lower.

Source: S. Čengić-Džomba, 2014

Figure 13. Grazing in an open field

Table 4. Food consumption, milk production and water consumption in relation to the ambient temperature (Source: Croatian Livestock Center)

Temperature	Expected changes		
	Dry matter intake, kg	Milk production, kg	Water consumption, liters
20°C	18.19	26.99	68.14
25°C	17.69	24.99	73.82
30°C	16.92	22.99	79.12
35°C	16.69	18.00	119.99
40°C	10.21	12.02	105.99

Poultry

In the first days of life the chicks require a warm climate (32-38°C). The optimum temperature for poultry rapidly declines by weeks and after feathering it amounts to 18-22°C (for growth and egg production). The increase of ambient temperature above 30°C leads to a decrease in food consumption and the consequent decline in production followed by an increase in the percentage of poultry deaths. During the heat stress, broilers reduce food consumption by up to 50% and laying hens by 20-50% (Gonzalez-Esquerra and Leeson, 2005). In addition to reduced food intake, digestibility of nutrients also declines due to reduced activity of some digestive enzymes (trypsin, chymotrypsin, amylase). Insufficient consumption of nutrients reduces the production of eggs from 80-90% to 50-60%. Eggs are on average 10 grams lighter and have a lower shell strength which increases the number of broken eggs.

Because of the acid-base balance disorders, excretion of K and N in the faeces and urine increases, whereas the concentration of Cl in the blood increases thus disturbing the balance of water in the body. Consequently water requirements increase.

The production of free radicals in the body is accelerated causing an adverse effect on hatchability of eggs and quality of meat.

The effects of heat stress also include: increased protein degradation which increases the proportion of body fat; increased mobilization of vitamins and minerals from the tissues; the meat is tender and pale in color; nutritional value of eggs and meat is lower.

Pigs

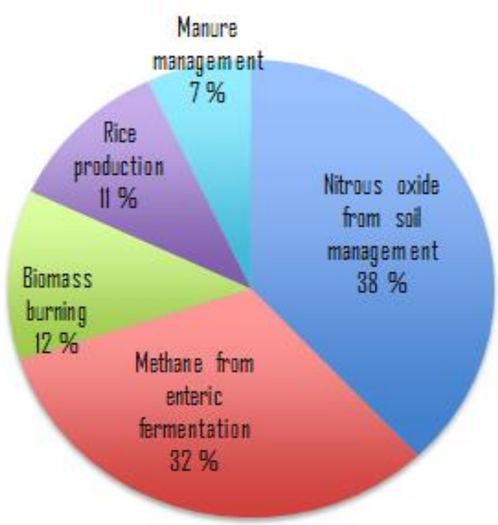
Heat stress is directly reflected on food consumption in all categories of pigs. Reduced food consumption results in lower production. During the growing and fattening stages, pigs deposit fewer proteins in the body which reflects negatively on the quality of meat (proportion of fat tissue is higher). The upper critical temperature is 25-26°C. The exposure of lactating sows to ambient temperature of 29°C causes the food consumption to reduce by 50%. The consequences are low weight gain in piglets, poor physical condition, increased sensitivity and mortality. Heat stress has negative effects on the reproduction too. Embryonic mortality is also increased so the number of piglets per sow is smaller.

WHY IS IT NECESSARY TO START WITH THE ADAPTATION AS SOON AS POSSIBLE? 4

Measures available to mitigate and adapt to climate change in agriculture (from global to local level)

Mitigation of emission and adaptation to climate change in agriculture

Agriculture as one of the most sensitive climate sectors can affect positively and negatively on the course of climate change. Agricultural activities contribute to emission both indirectly and directly, such as in the process of land conversion for croplands and pasture, and through inappropriate agricultural practices, which altogether contributes nearly one-third of total GHG emission. As can be seen in Chart 2, of total emissions from agriculture N_2O emissions from land make 38%, 32% is enteric fermentation of methane (CH_4) from livestock production, while the rest is biomass burning, rice production and manure management.



Source: IPCC, 2007; Smith et al., 2007

Chart 2. *Emissions in the agriculture sector*

Furthermore, agricultural intensification through higher N fertilization, in the lack of adequate cultivable land due to different reasons, such as land conversion, marginalization due to degradation, is expected to increase higher N_2O emissions from agricultural land.

The mitigation options in agriculture, such as soil carbon sequestration through reduced tillage, are said to have a considerable potential for reducing GHG emissions with very low costs or in many cases even with a net profit, yet they are not readily being implemented because of a range of barriers and constraints in adopting these mitigation options. Some common policy-relevant barriers are permanence, additionally, uncertainty and leakage in addition to other issues related to transaction, measurement and monitoring costs. The barrier extends to lack of resources, information and education, interference with other regulations, property rights and financial constraints from a farm level perspective.

Mitigation alone is not enough to address the climate change impact, because farmers may have to compromise the production level while adopting mitigation, which they cannot afford to do so. Secondly, it is also important to adapt to changing climatic variability to continue the farming practices as the impact of climate change has had on agriculture is not well understood. Such agricultural impacts particularly affect low-income rural populations that depend on traditional agricultural systems. Most of the climate change impacts on agriculture can arguably be mitigated through adaptation measures and improved agricultural practices, hence adaptation in agriculture is central to limit potential damages under climate change and even to turn the negative effects of climate change into gains. Farm level studies have shown that large reductions in adverse impacts from climate change are possible when adaptation is fully implemented. Given diverse agricultural practices and activities and types of impacts in terms of magnitude, temporal dimension (short and long-term) and intra-annual, both autonomous and planned adaptation are necessary. Autonomous adaptation, e.g. shift in planting time, can be short-term adjustments without requiring other sectors in their development and adaption, where as planned adaptation are conscious policy options, response or strategies, often multisectoral, aimed at altering the adaptive capacity of agricultural systems of facilitating specific adaptations, e.g. deliberate crop selection. Many adaptation options as measures or practices have been suggested in the literature, which encompass a wide range of forms (technical, financial, managerial), scales (global, regional, local) and participants (farmers, governments, private sectors). Major classes of adaptation include seasonal changes and sowing dates; different variety or species; new crop varieties; water supply and irrigation systems; other inputs, such as fertilizer, tillage methods, field operations, and modify/change cropping systems.

There are several mitigation and adaptation technologies and practices that do exist or have been developed in different parts of the world. These are compiled as best bet practices (Clements et al. 2011; Liniger et al, 2011), which are recommended for adapting to specific ecological and social conditions in different parts of the world. Some of those adaptation measures may need investment while the others primarily require improving awareness and building capacity to deal with new practices.

Lobell et al. (2008) modeled twelve vulnerable regions of the world to identify adaptation priorities and found that rice crop in Southeast Asia, wheat in South Asia, and maize in Southern Africa are most important crops that need adaptation investments. The need for such investments in local adaptive measures, such as developing resistant varieties and changes in crop management, could be substantial. With regard to farmers' awareness about climate change and adaptation needs is concerned, there is no total lack of awareness. For example, there is a different level of perception about adaptation between the farmers of different regions in Kenya. Farmers have been adopting diversification in the high zone, and water conservation, irrigation, shading creation for valuable crop in the low zone to deal with changing climate condition.

Experiences show that a sound work program on agriculture is not yet sufficiently included in wider climate agreements until COP 16 in Cancun in spite of agriculture's role in climate change mitigation and adaptation and most importantly in food security. Nonetheless, adaptation in agriculture is challenging as it encompasses a wide range of forms, scales, and participants with multifaceted interactions. There is a speedy need of agricultural adaptation for the reason that, if implemented appropriately and an integrated manner, it can help achieve multiple objectives of reducing GHG emissions, increase carbon sequestration, conserve natural resources and ensuring sufficient quantities of foodby maintaining/enhancing agricultural production. It has been only very recently in COP 17 in Durban, where some progress can be seen to recognize the role of agriculture in climate negotiation by making crops and pasture eligible under Clean Development Mechanism (CDM).

MEASURES OF MITIGATION AND ADAPTATION TO CLIMATE CHANGE IN THE AGRICULTURAL SECTOR

5

5.1. The time and method of tillage

Agriculture is affected by the negative effects of climate change more than any other economic activity. In order to adapt to new circumstances the FAO experts specifically advocate for the application of conservation tillage methods. This technology is based on the combined application of three principles: direct seeding (without classical ploughing), continuous mulching (using residues of the previous harvest) and crop rotation. Reduced tillage is a system which requires leaving 15-30% crop residue on the soil surface, whereas conservation tillage system which includes direct sowing implies that more than 30% of the soil surface is covered by crop residue (Nozdrovický, 2008). This tillage system has a great potential for any farm size, though its adoption is most beneficial for small farms, and those faced with the lack of the work force.

Table 5. Advantages and disadvantages of conservation systems

Advantages	Disadvantages
– Reduced costs on the farm, savings in time, human labor and machinery – Increased soil fertility and retention of moisture leading to long-term increase in yield, reduction of variation in yield and higher security of food production – Soil conservation measures and protection from erosion lead to reduced leaching of soil down the slope – Reduced toxic contamination of surface and ground waters – Filling of aquifers due to better infiltration – Reduced air pollution resulting from the machinery used in tillage practice – Reduced CO_2 emission to the atmosphere (carbon sequestration) – Conservation of biodiversity	– Acquisition of specialized machinery for seeding and planting – Short-term problems with pests due to changes in crop cultivation – Acquisition of new management skills – High risk for farmers due to the technological uncertainties – Development of appropriate technical packages and training

The different forms of conservation or reduced tillage have a different impact on the accumulation of organic matter in the soil. In principle, any shallow and simplified tillage practice which involves a smaller number of operations or none at all, contributes to the accumulation of organic matter in the soil, especially in its top layer.

According to K o v a č e v i ć (2004) conservation systems in crop production are based on the specific changes in the technology of cultivation, primarily conditioned by the character of tillage. A significant reduction in the number and intensity of tillage operations or their absence while leaving the total mass of crop residue on the soil surface, represents the principle of the functioning of these tillage systems in their essence.

Table 6. Classification of conservation tillage systems which can be used in organic farming (Kovačević and Oljača, 2005)

Form of conservation tillage	Concept, strategy/tool
Protective tillage	- tillage using a chisel plow - peeling/trimming - tillage using combined tools - cultivators/multi-tillers - multi-tillers - robust harrows - rotary cultivators
Partial tillage	- strip-till - zone-tillage - scarification in/between the rows
Ridging	- mound tillage - bed tillage
Direct seeding	- system of double/triple coulters - system of Chisel coulters - system of coulter blade - system of coulter rotation - system of hoe coulter - duck leg - inverted 'T' sowing boot

5.2. Time and method of seeding

The application of a set of appropriate agricultural practices can mitigate but not entirely eliminate the negative effects of drought. Some of the most important practices include crop rotation, tillage, fertilization, mulching, and the choice of crop variety, time and density of seeding, weed control and forest protective strips.

For every crop grown in a given habitat, there is an optimal seeding time that is adjusted in accordance with regional and local conditions. Time of seeding modifies the pace of development, especially the length of the vegetative phase and the period of grain formation and grain filling having a significant impact on the yield of cultivated crops. The rule that crops need to be seeded as early as possible within their optimal seeding timeframe is applicable to any habitat. Seeding should be started with late and ended with early maturing genotypes. Seeding within the optimal timeframe is especially important in arid conditions as it provides a better growth and development of the crop as well as a better utilization of pre-vegetation reserves of moisture from the soil. Intensive varieties and hybrids are grown at high planting density compared to the extensive genotypes. In dry conditions, the cultivation of maize using high planting density leads to a decrease in yield of 30-50%, and in sandy soils with poor water retention capacity it can be totally damaged. The situation is similar with other row crops, whereas sunflower suffers less from the effects of drought in dry years. Amounts of precipitation in the vegetation period can satisfy the water requirement of plants at a frequency of 10-30%, therefore, while planning the planting density of cultivated crops it is necessary to know the pre-vegetation soil moisture reservesup to a depth of two meters. Crops with deeper roots can use this water in the vegetation period and based on this information it is possible to plan the optimal planting density for certain varieties and hybrids. But, a drastic decrease in yield is inevitablein extremely dry years. Since the frequency of dry years in our country is higher than the average and wet ones, the number of plants in small grains and row crops should be 10-20% smaller than the recommended (M o l n a r et al., 2001).

In dry conditions, it is very important to know the depth to which some pre-crops dry out the soil humidity to the permanent wilting point. Crops of short growing season such as winter fodder mixtures, peas or small grains, can dry out the soil to a depth of 100-120 cm, maize of 180 cm, and sugar beet and alfalfa over 200 cm.

The difference in the content of plant available water may exceed 130 mm, which corresponds to the amount of irrigation water in moderately dry years. Such differences in pre-vegetation water reserves only occur in soils with favorable water regime. In light sandy soils with small water retention capacity, the impact of the pre-crops on the content of water in the spring is insignificant as the water quickly sinks into deeper layers. In dry years more suitable are the crop rotations with a higher participation of small grains and other early pre-crops. This also supports a more favorable pre-crop value of crops that are sooner removed from the field.

To be best prepared to the projected climate change, farmers can, among other things, change the usual practices of rotating crops in order to achieve maximumuse of the available soil moisture; harmonize the seeding days with temperature and precipitation patterns; use crop varieties that are better adapted to new weather conditions. Hedges or less forested belts reduce the loss of moisture from the soil, contribute to the increase in relative air humidity and at the same time serve as a protection against wind which significantly accelerates the soil dry out. At the sectoral level, providing accurate and updated information on climate risks to farmers as well as support through extension services and training is the key measure for adaptation.

Some phenological changes as a result of the changes in the mean annual weather conditions are already visible in Europe. For example, in the south of France, it was observed that peaches and apricots start blossoming one to three weeks earlier. In Germany, maize and sugar beet are sown ten and in southern France 20 days earlier than usual. Such changes in the agricultural calendar suggest that farmers independently adapt to new weather conditions. As the changes in weather patterns intensify, farmers will have to introduce completely new crop varieties and specific methods of cultivation.

5.3. Organic farming

Organic farming is a production system which improves the health of soil, ecosystems and people. It relies on natural ecological processes, biodiversity and cycles that are adapted to local conditions, rather than the use of inputs that do not come from the farm. The aim of organic farming is to obtain controlled products of high quality while protecting natural resources (land, water and biodiversity), health and quality of life.

Compared to conventional production systems, organic farming is considered to have less negative effects on climate change and the environment. At the same time, this type of sustainable agricultural production is betted adapted to climate change, so that even in unfavorable environmental conditions (e.g. lack of moisture in the soil) it is possible to achieve higher yields compared to conventional production.

Organic farming uses agricultural practices that are aimed at strengthening the agroecosystems through the optimization of circulation of nutrients and energy in agroecosystems, growing of local and traditional varieties of plants and breeding of indigenous breeds of livestock.

The significance of organic farming in terms of mitigation of and adaptation to climate change is reflected in:

- Increased soil quality, especially organic matter;
- Capture and storage of carbon dioxide (CO_2) from the atmosphere in soil (C sequestration);
- Improved physical, chemical and biological properties of soil;
- Prevention of erosion and conservation of soil moisture;
- Reduced cost of N fertilizers and prevention of nutrient leaching;
- Reduced greenhouse gas emissions from the soil;
- Lower consumption of fossil fuels due to less intensive tillage, use of local sources of N (growing legumes, use of manure),
- Preservation of the environment and human and animal health.

The increase in quality of soil, especially organic matter. Compared to conventional production, organic farming has a higher capacity for increasing the soil quality as it involves crop rotations that include growing annual and perennial legumes and interim crops and mostly organic fertilizers with a reduced level of tillage (smaller number of operations and shallower depth of tillage).

Capture and storage of CO_2 from the atmosphere in the soil (C sequestration). One way of reducing the concentration of CO_2 in the atmosphere is its binding in the process of photosynthesis, and after the death of plant, accumulation of C organic compounds in the soil. The increase of reserves of organic C in the soil occurs when losses of C due to respiration are smaller than its accumulation through the photosynthetic activity of plants. The increase of organic matter in soil is an important strategy for biological sequestration of carbon.

Agricultural practices that increase reserves of organic C in the soil include the application of conservation and reduced tillage, mulching, increase of organic matter content in degraded soils and increase of soil fertility.


Source: M. Manojlović, 2014

Figures 14 and 15. Straw mulching in organic farming

Improvement of physical, chemical and biological properties of soil. Many studies have shown that organic farming has a positive effect on the quality and biological activity of soil. A higher content of soil organic matter and reduced tillage improve water-physical properties of the soil so that they are characterized by stable structure, good aeration, infiltration and retention of water as well as high content of available nutrients. The biological activity of the soil is increased as the microorganisms and small soil organisms require mainly organic sources of nutrients and energy, hence the rule that the soils richer in the organic matter contain a larger number of microorganisms.

Prevention of erosion and preservation of soil moisture. A higher content of organic matter in soil, keeping land covered by cover crops and organic materials (mulch) throughout the year and reduced tillage reduce the risk of erosion and enhance the moisture retention in the soil which allows for higher yields in years with insufficient precipitation compared to conventional production.

Reduced cost of N fertilizers as the result of using organic fertilizers produced on the farm such as manure and compost, as well as of growing and ploughing down and incorporating leguminous plants that have the capacity to capture atmospheric N and incorporate it in its organic compounds. After the plough-down, gradual mineralization process releases the mineral form of N from organic compounds, which is then used by plants and microorganisms. Sustainable supply of nitrogen (N) through growing legumes and applying organic fertilizers from the farm contributes to a reduced consumption of natural resources used for the production and transport of nitrogen fertilizers (fossil fuels). In addition, the gradual release of mineral N from soil organic matter and organic fertilizers result in lower emissions of nitrogen oxides (NOx) and reduce the risk of nitrate leaching from the soil at the end of the growing season, thus keeping the reserves of N stored in the soil for the next vegetation and reduces the need for fertilizers produced outside the farm.

Reduced greenhouse gas emissions from the soil. Emissions of nitrogen oxides (NOx) and methane (CH_4) from arable land or pastures can be reduced by organic farming practices. NOx emissions will be lower if less of mineral and especially nitric N is retained in the soil after the vegetation period. Research shows that the concentration of mineral N at the end of the growing season is lower in organic farming compared to the conventional. Methane is largely produced by livestock, as a metabolic product of enteric food fermentation. In addition, CH_4 and N_2O are also released from manure during storage. CH_4 emissions can be reduced by changing the diet of animals and applying the improved measures for manure management, which include covering, separating liquid and solid phases of manure or collecting released CH_4. Taking out and spreading dry manure on the land plot followed by quick ploughdown into the soil result in a reduced amount of released CH_4.

Lower consumption of fossil fuels due to reduced tillage and use of local sources of N (the cultivation of leguminous plants and use of manure) contributes to lower CO_2 emissions into the atmosphere.

Table 7. Potential of organic farming to mitigate climate change

Source of greenhouse gases	Share in the overall human emissions	Impact of organic farming	Remarks
Direct emissions from agriculture	10-12%		
N_2O from soils	4.20%	Reduction	Higher nitrogen-use efficiency
CH_4 from enteric fermentation of cattle	3.50%	Opposite effect	Change in the diet and selection of livestock of higher quality
Biomass burning	1.30%	Reduction	Burning prohibited
Management of organic fertilizers	0.80%	Equal	Reduced CH_4 emissions but no effect on N_2O emissions
Direct emissions from forest clearing	12%	Reduction	Restricted clearing in ecosystems
Indirect emissions			
Mineral fertilizers	1%	Totally avoided	Prohibited use of N minteral fertilizers
Food chain		(Reduction)	Energy saving, but still inefficient system
C sequestration			
Arable lands		Enhanced	Increased soil organic matter
Grasslands		Enhanced	Increased soil organic matter

Source: Scialabba and Müller-Kindenlauf, 2010

Lower greenhouse gas emissions and increased accumulation of carbon dioxide, combined with additional positive effects of the cultivation of species and varieties adapted to local conditions and lower negative impact on the environment, make organic farming the option with numerous advantages and significant potential for mitigating and adapting to climate change.

5.4. Crops and varieties resistant to drought

The effects of climate change can be mitigated by choosing crops and varieties resistant to drought. However, it is not easy to say which crops and varieties are drought-resistant. There are several groups and types of such crops and varieties.

Plant species that are native to the southern circles of latitude generally have a higher tolerance to higher temperatures. For example, warmer climate plants that can be grown here include: sweet potato, soybean, sesame, sorghum, tobacco, cassava, etc.

Some of our contemporary domestic varieties are tolerant to high temperatures and drought as they contain genes that were taken from the varieties of the southern regions through the breeding process. These genes often have the role to enable synthesis of "*heat-shock*" proteins (HSP90, HSP70, HSP60, HSP20 and ubiquitous) used by the plant to defend itself from the destruction of proteins at high temperatures (Vierling, 1991). Sometimes it is the genes that determine the specific morphological properties of the plant in terms of increased resistance to drought (Ashraf, 2010). Such properties include, for example, thick cuticle, formation of tendrils in lieu of leaves, shedding of old and emergence of new leaves.

It is well known that maize varieties with deeper root systems, upright leaves, larger tassels and deeply embedded kernels have a higher tolerance to stress and drought. Recommendations regarding new varieties that have genes of resistance to drought are provided by scientific institutes involved in plant breeding and agricultural extension services.

The varieties that have a short growing season are often resistant to drought as they produce yield before the beginning of the hottest part of the summer (July-August). For example, early varieties of wheat such as Simonida and Dragana can mature 15 to 30 days prior to the late maturing ones. Early maize hybrids are those belonging to FAO maturity groups of 100 to 400 (e.g. ZP196, ZP260, ZP360, ZP434). In all types of crops there are early and late maturing varieties. Another option for avoiding drought is to use crops that reach technological maturity early. Examples of such crops are early potato, lettuce, onions and other.

Some local (autochthonous) or old varieties and populations of plants have developed special forms of adaptation to local production conditions, which include the prevalent pathogens and climate variation, i.e. the emergence of high temperature and drought. These varieties are often not available on the market but are maintained "*on farm*" and through the exchange of seeds among farmers. For instance, there are old and autochthonous varieties of onions, legumes (green beans, beans, wide beans), cabbage family vegetables, cucurbits (pumpkin, melon and watermelon) and fruiting vegetables (pepper, tomato). Most of these varieties can be found in the Bank of Plant Genes.

In general, if you grow a variety resistant to drought, it does not necessarily mean that the yield will be as high as the one of some non-resistant variety in the conditions of intensive agricultural production (irrigation). However, varieties resistant to drought perform much better than many popular ones in the conditions where there is no irrigation and provide a stable yield under variable external conditions, especially dry air and soil.

5.5. Importance and role of intercrops

Cover crops take a special place in the sowing structure with new trends in agricultural production, such as sustainable agriculture and especially organic agriculture. In those plant production systems, the main goal of cover crops is not only the yield, but also the protection of agroecological systems. That includes reducing, or completely omitted application of fertilizers and pesticides. Namely, in sustainable agriculture priority is given to the soil fertilization and not to cultivated crop, with a special emphasis on biological factors, primarily legume plants. The system of free management, industrial farming and growing crops in monoculture, as well as the awakening of environmental consciousness of consumers (rising public awareness regarding environment protection), intensify the criteria in producing quality food while preserving natural resources and protecting the environment. In those farming systems, intercrops have an extremely important role in crop rotation and sowing structure as an inevitable link in the production of healthy food. Farmers used intercrops in the new strategy that is based on the conservation of natural resources and gaining the yield and profit at the same time. Intercrops are sole crops or their mixtures grown between two main crops. However, in some situations they can be grown as main (cash) crop. Primarily they are sown as winter crops, then as subsequent crop or after grain cereals, including many species from families of legumes, grains and brassicas.

In addition to pure crops and their mixtures, intercrops can be sown in intercropping systems when they are sown between the rows of the main crop.

Source: B. Ćupina, 2014

Figure 16. Trial with intercrops

Intercrops importance. Introducing intercrops in plant production can be useful from ecological and economical point of view.

Summarizing many authors' results regarding plant production, importance of growing intercrops can be based on:

- reducing fertilizer costs,
- preservation of soil moisture and preventing nutrient leaching,
- repair (correction) physical, chemical and biological soil properties,
- erosion prevention,
- reducing the use of pesticides, especially herbicides (suppression of diseases, pests, nematodes and weeds),
- preservation of water quality,
- preserving environment and health in general.

These advantages are significantly dependent of agroecological conditions, but at least two or three benefits are always realized.

Reducing fertilization costs is achieved by using primarily legume forage crops as winter intercrops and their positive impact on the next crop-main or subsequent. It is known that legumes have the ability of biological nitrification, so the plants grown after legumes can use 30-60% of nitrogen provided by nitrification.

Source: B. Ćupina, 2014

Figure 17. Intercrops plowing

Prevention of nutrient leaching. Intercrops affect the efficient circulation of elements, by removal of nutrients, which otherwise could be lost by rinsing, causing pollution of groundwater, local streams and ponds. The best intercrops for preventing nitrogen leaching are plants that rapidly form a hairy root system after harvesting the main crop. Here especially stands out rye having a high resistance to low temperature and as a winter crop can be grown during the winter. Other cereals, like wheat, barley, oat, then English rye grass from grasses, use half of the nitrogen in comparison to rye, while legume forage crops have less importance in nitrogen conservation. In order to solve problems of nutrient leaching efficiently intercrops should be sown on time, so the plants will develop their root system sooner.

Repair of physical, chemical and biological soil properties. By growing intercrops, physical, chemical and biological soil properties are improved in different ways. Soil protection from erosion is perhaps the most obvious positive impact of intercrops. Increase of soil organic matter content requires a longer period for observing. Intercrops affect indirectly health condition of soil. They convert some nutrients in an accessible form for plants, they increase biological properties, decrease compaction of some soil layers and help draining wetlands (soil with higher moisture).

As organic green manure, intercrops positively influence on soil structure, increase infiltration, field soil water capacity, capacity for cation exchange and retention of plant nutrients. After plowing, intercrop residues act on soil structure, and they reduce evapotranspiration that decreases stress during a drought period.

Timely plowing of winter intercrops in the spring has positive influence on soil moisture in dry and wet years. Hairy root system of intercrops from the family *Poaceae* improves soil structure by linking soil aggregates.

Figure 18. Soil is biologically active under intercrops

Erosion prevention. As fast-growing crops, intercrops rapidly make plant stands, and their aboveground mass protect the soil from rain and the impact of raindrops, reducing the appearance of crust.

Suppression of diseases, pests, nematodes and weeds. Application of pesticides reduces by cultivating intercrops, then reduces production costs, protects the agroecosystem and finally increases consumer confidence. Crop protection starts with making a healthy environment and biologically active soil. Studies of various authors indicate that diseases and pests emerge to a lesser extent in good and biologically active soils compared to the infertile soils with poor physical, chemical and biological properties.

Intercrops are fast-growing crops with a dense standthus suppressing weeds by a strong competition for water, nutrients and light. Intercrops have a positive impact on water quality by preventing the leaching of nitrogen and other nutrients, by erosion reduction and by reducing or avoiding the use of pesticides and fertilizers.

Source: B. Ćupina, 2014

Figure 19. Intercrops mowing

Selection and properties of the most important intercrops. In order to select properly an appropriate intercrop or mixture for specific pedo-climatic conditions the situation should be carefully analyzed and determine which of the mentioned primary benefits of intercrops is preferred. Effects of the intercrops use depend primarily on the correct choice of a plant species.

In order to achieve complex effect, forage intercrops should have developed a root system with a possibility of utilization-mobilization of nutrients from less soluble compounds and deeper soil layers, and to have fast growth, high and quality yield and short life. Additionally, intercrop seed should have a low price, because a higher seed amount is used to provide a dense crop and to enable better withstand competition with weeds. It is necessary to determine the right time and place of intercrop sowing in the present farming system. Intercrops should be properly incorporated into existing crop rotation. Table 8 provides an overview of the most important and the most represented forage intercrops, as well as their basic properties and role within sustainable agriculture.

Table 8. Properties and role of the most represented intercrops

Species *	Nitrogen fixation (kg/ha)	Dry matter yield (t/ha)	Soil structure repair	Erosion prevention	Weed suppression	Harvest value	
						*F	**G
Rye	-	4-10	5	5	5	2	2
Sorghum and Sudan grass	-	8-12	4	5	4	5	1
Brassicas	-	4-10	3	2	4	5	2
Phacelia	-	2-4	2	2	2	2	1
Vetches	90-200	2.5-5	4	4	4	2	2
Field pea	90-150	4-5	3	4	3	5	4
Red clover	70-150	2-6	4	3	4	5	3
White clover	80-120	2.5	3	4	4	4	3

* Evaluation of suitability of intercrops: 1-bad, 2-poor, 3-medium, 4-very good, 5-excellent
* Forage, **Grain

5.6. Fertilizers and fertilization

The application of fertilizers

Fertilizers, both mineral and organic, have a huge impact on the yield of grown crops as well as on the quality of soil, water and air. In terms of climate change, the importance of timely and appropriate application of fertilizers is even greater. On the one hand, fertilizers (nitrogen mineral and manure) are responsible for the emission of nitrogen oxides from the soil and methane from manure. On the other hand, with proper selection of type of fertilizer, form and amount of nutrients, timing and method of application, plants will be better adapted to the distribution of precipitation and changed humidity and temperature conditions resulting from climate change.

The application of fertilizers needs to be consistent with local conditions, tailored to the production system, the type and quality of the soil, the available nutrient content, plant species and varieties. Given that nitrogen (N) has the greatest impact on the yield of plants but also huge negative impacts on the emission of “greenhouse” gases as a result of release of nitrogen oxides from the soil and nitrate leaching, the effective use of N is an important aspect of the application of fertilizers in order to mitigate climate change and adapt production to these changes (Chart 3). The quality of the soil, i.e. the content of organic matter and C in the soil, also plays a crucial role in the selection of the types and doses of fertilizers. Due to the improved adsorption properties of soil, N losses from soils with high organic matter content are lower compared to sandy soils, and the increase of organic matter content in the soil is an important strategy of adaptation to climate change.

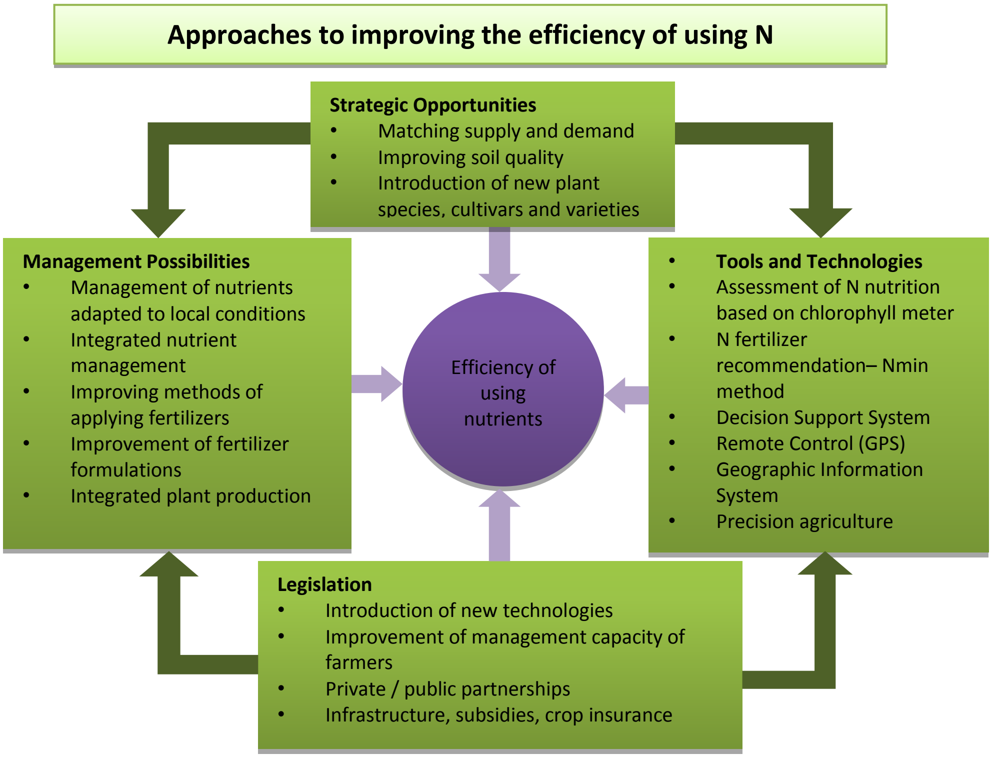


Chart 3. Approaches to improving the efficiency of using nitrogen (N)

Fertilization practices/techniques to mitigate and adapt to climate change:

– Application of organic fertilizers (manure, green manure) and ploughdown of crop residues will enable increase/maintenance of the soil organic matter content and soil water capacity and reduce the risk of soil erosion and compaction and thus denitrification and nitrogen oxides emission.
– Fertilization with manure should be adjusted to local conditions-different properties of soil and climate and weather conditions. The collection, storage and treatment of manure are crucial for its quality. Better control of manure management systems aimed at reducing emissions of methane into the atmosphere.
– Recycling of organic waste and the application of compost and mulch will enable return/accumulation of organic matter in the soil and reduced evapotranspiration.

- Inclusion of legumes in crop rotation will reduce the need for N fertilizers whose production consume natural gas and emit CO_2 and nitrogen oxides.
- Perennial legumes should not be fertilized with N-fertilizers. Moreover, N-fertilizers should not be applied to a crop that is to be planted on the plot where perennial legumes were grown in the first year of growing. After annual legumes, crops are to be fertilized with N-fertilizers in accordance with the N_{min} method.
- Increasing the efficiency of the use of N by selecting a crop rotation which includes winter non-legume intercrops.
- Adjusting the fertilization systems and doses of fertilizers to the needs of crops and genotype will ensure greater efficiency of the application of fertilizers and higher yields and root mass and harvest residues. In the long run, this will lead to an increase of soil organic matter.
- Recommendations for the fertilization based on crop needs, soil fertility control and analysis of plant material should be adapted to the weather conditions.
- Recommendations for the fertilization with N-fertilizers based on the N_{min} method need to be adapted to the weather conditions.

5.7. Energy crops, biomass

The term biomass implies all agricultural crops, woody and other plants, agricultural (eg. manure) and forest residues, which can be used as raw material in the production of renewable energy (electricity, cooling and heating) or transport fuels as well as for the production of bioproducts such as fibers, bioplastics and biochemicals. Biomass may also include industrial by-products and organic fractions of processed solid municipal waste. Biomass has become one of the most widely used renewable energy sources in the last two decades, just behind the hydroelectric power plants in the production of electricity, and it accounts for about 15% of total energy consumption in the world and for as much as 35% in developing countries, mainly for cooking and heating.

There are numerous plants that have the ability of converting solar energy in biomass with high efficiency, such as herbaceous crops, fast-growing woody crops, fodder crops (alfalfa, clover), sugar crops (sugar cane, sugar beet, sweet and fiber sorghum), cereals (maize, barley, wheat) and oil seed crops (soybeans, rapeseed, palm, sunflower, cotton).

Plant biomass provides cleaner products of combustion compared to fossil fuels as the crop growing cycle consumes CO_2 in the process of photosynthesis, making thus the cycle of producing energy from biofuels almost CO_2 neutral. This is why it is expected that biomass will become one of the key energy resources in combating global warming and depletion of fossil fuel reserves.

The role of agriculture in providing the biomass is twofold.

Firstly, it involves large amounts of biomass residues resulting from agricultural activities. Most of the crop residues are left on the field for reducing erosion and returning organic matter to the soil, however, a part of these residues could be used for energy production without adverse effects on soil. Other residues, especially manure and residues from processing agricultural products can also be profitably used for energy production thus reducing the costs of waste disposal and pollution. Although the use of crop residues for energy production causes air pollution, it would otherwise be disposed of in a landfill or incinerated.

Secondly, it involves the cultivation of energy crops. These crops are grown only for energy production and can be produced in large quantities, just as crops for food. Though maize is currently the most widely used energy crop, it is likely that woody and grass energy plant species will become more popular in the future. The reason for this lies in the fact that these perennial crops require less activity in terms of cultivation, have lower costs compared to annual agricultural crops, so they are less expensive and more sustainable to produce.

Thre are two important groups of energy crops: woody species and perennial species of the grass family. The grass family species are the most promising herbaceous energy crops. They are high-yield, fast-growing crops that may be reaped 20 years on one location, achieving a high biomass yield with high cellulose content. They include *Miscanthus gigantus, Panicum virgatum, Andropogon gerardi* and *Phalaris arundinacea*. The second group are perennial fast-growing woody species. They can grow up to 40 meters high in less than eight years and can be used 10 to 20 years. The best choice for cold, humid areas, are poplar and willow, and it is maple for warmer areas.

Advantages of perennial energy crops include:

- Deep roots of these crops improve soil structure and increase organic matter content; there are less physical damages caused by machinery due to less frequent tillage;
- They need considerably less fertilizers and pesticides than annual species. Reduced use of chemicals protects the soil and surface waters from toxins and excessive growth of aquatic plants. Additionally, deeply rooted energy crops can serve as filters to protect waterways from chemical discharges from other areas and prevent sedimentation caused by erosion;

– They can create a number of different habitats by attracting various species such as birds, small mammals, pollinators and other useful insects, and increase their abundance. They also improve habitat for fish by increasing the quality of water in nearby streams and ponds. Given that they have a relatively long harvest period, its timing is easily adjusted to avoiding the period of nesting and mating.

Source: M. Đikić, 2014

Figure 20. *Miscanthus gigantus*in Butmir Sarajevo, June 2014

Source: H. Čustović, 2015

Figure 21. *Miscanthus gigantus* in Butmir Sarajevo, September 2015

There is a significant area of agricultural land that is marginal for agricultural crop production but could be used for the production of energy crops. Researches worldwide indicate that mullock heaps of the abandoned mining sites can be used for this purpose. In our country, there are approximately 14,000 ha of such areas.

It is possible to convert biomass into energy by incineration where the heat can be directly used for heating buildings and drying crops as well as in dairy industry and industrial processes. It can also be used to generate electricity; it can be converted into liquids or gases to produce electricity or fuel for transport.

Table 9. The use of biomass and methods for the production of energy

Energy conversion method	Type of energy produced	Feedstock
Combustion, gasification and pyrolysis	Thermal and electrical	Wood pulp, straw and other forestry and agricultural products
Anaerobic digestion	Biogas (a mixture of methane and CO_2) that can be burned to produce electrical or thermal energy or used as fuel for vehicles or injected into the gas network for heating buildings.	Manure, food waste, non-woody crops and bio-degradable materials from landfills and sewage
Fermentation	Liquid fuels for vehicles	Wheat and sugar beet for the production of bioethanol (similar to gasoline) or rapeseed for biodiesel

In addition, it should be noted that the use of biomass for energy production has a twofold effect on reducing the level of greenhouse gas emissions: firstly, the energy of crops' biomass is "carbon neutral" just like other types of renewable sources such as aeolic and solar energy. Secondly, the cultivation of energy crops creates a "carbon sink" because the binding of carbon increases the organic matter content in the soil.

The use of biomass for energy purposes is important as it provides:

- Clean alternative energy for power plants;
- Feedstock for the production of ethanol (cellulose or sugar) and biodiesel;
- Additional income for farmers and rural economic development;
- Greater energy independence (imported oil and gas);
- Productive use of environmentally damaged land.

5.8. Grassland

Our natural grasslands are subjected to extensive type of management. To improve forage production on grasslands it is necessary to implement measures increasing the yield and quality of forage. With regard to the method of implementation, all measures can be grouped in two basic categories-technical and agrotechnical measures.

Agrotechnical measures on natural grassland

The main role in maintaining the production of animal feed on grassland is played by agrotechnical measures. Agrotechnical measures enable for grasslands to be cared for, improved and properly used. Implementation of these measures allows the exploitation of the grassland production capacity and significantly improves the quality of forage. The most important agrotechnical measures include: fertilization, tillage, sowing, weed control and biological reclamation of natural grassland.

Fertilization of natural grassland

Fertilization of grassland is a necessary measure for achieving higher yields on meadows and pastures. Continuous use of the grassland without bringing plant nutrients in the soil, inevitably leads to depletion of soil and degradation of grassland into less quality and lower yield grasslands.

"There is no better way that is so easy and that uses simple means, which would allow us to increase yield on grassland with a maximum certainty than mineral fertilizers. Without any special effort, but with the improvement of mineral nutrition, it is easy to achieve for the meadow plants to fully develop and thus enable the production of large quantities of valuable forage. This is the basis for better nutrition of livestock, for increasing its productivity as well as a prerequisite for increasing the number of livestock" (Gericke, 1960).

The most important nutrients for grassland as well as for other cultivated plants are nitrogen, phosphorus and potassium. Nitrogen is the driver of yield on grassland. The problem of nitrogen fertilization has been intensively studied around the world and there are numerous recommendations for nitrogen fertilization.

Table 10. Amount of major nutritive substances in the soils of hilly and mountainous areas in the Balkans

Type of grassland	Total N	P_2O_5 mg/100 g of soil	K_2O mg/100 g soil
Hilly	0.28-0.49	0.57-1.8	17.0-20.7
Mountainous	0.36-0.62	0.60-1.0	19.2-25.0

Table 11. Required amount of NPK fertilizer for achieving hay yield

Applied nutrients (kg/ha)	For hay yield of 6 t/ha	For hay yield of 10 t/ha
Nitrogen (N)	108-120	180-200
Phosphorus (P_2O_5)	48-60	70-100
Potassium (K_2O)	105-132	180-220

Fertilizers applied on grassland must be balanced as the application of individual nutrients can cause damage to grassland. Single application of nitrogen intensifies the development of grasses and suppresses legumes.

Effects of fertilization on yield of forage on natural grasslands

A number of recent results in the world as well as in our country indicate that the application of fertilizers on natural grasslands increases forage yields by 5 to 10 times on average.

Table 12. Effects of fertilization on hay yields of natural grasslands

Lowland grasslands	Hay yield t/ha	1 kg NPK increases hay yield for (kg)
Arrhenatheretum elatioris-Novigrad-Šoštarić-Pisačić		
Without fertilization	7.68	-
N_{50} P_{50} K_{50}	10.45	26.20
N_{100} P_{100} K_{100}	12.26	22.00
Alopecuretum pratensis-Stepojevac-Mijatović		
Without fertilization	4.18	-
N_{45} P_{45} K_{45}	7.04	21.10
N_{110} P_{55} K_{55}	9.26	23.90
N_{140} P_{90} K_{90}	10.82	20.70
Hilly grasslands		
Agrostidetum vulgarae-Majdan-Mijatović et al.		
Without fertilization	3.80	-
N_{50} P_{50} K_{50}	5.32	15.40
N_{100} P_{50} K_{50}	6.22	16.00
N_{150} P_{100} K_{100}	7.58	15.70
Festuceto-Agrostidetum vulgarae-Bukor-Ocokoljić et al.		
Without fertilization	1.31	-
N_{60} P_{60} K_{60}	5.12	21.10
N_{100} P_{60} K_{60}	5.67	19.80
N_{100} P_{100} K_{100}	7.50	20.60
Mountainous grasslands		

Lowland grasslands	Hay yield t/ha	1 kg NPK increases hay yield for (kg)
Danthonietum calycinae-Suvobor-Mijatović et al.		
Without fertilization	2.81	-
N_{100} P_{50} K_{50}	7.05	20.20
N_{150} P_{100} K_{100}	7.29	13.00
N_{200} P_{150} K_{150}	8.76	12.00
Agrostidetum vulgarae-Prokletije, 1400 mn.v.-Pajković		
Without fertilization	1.76	-
N_{50} P_{50} K_{50}	3.74	13.20
N_{100} P_{50} K_{50}	4.86	15.40
Festucetum Halleri-Šara, 1600 m n. v.-Mijatović		
Without fertilization	1.32	-
N_{50} P_{50} K_{50}	3.79	16.50
N_{100} P_{50} K_{50}	4.97	18.20
N_{100} P_{100} K_{100}	4.93	12.10
Nardetum strictae-Golija, 1680 mn. v.-Porpević and Mijatović		
Without fertilization	1.18	-
N_{50} P_{50} K_{50}	3.21	13.50
N_{100} P_{100} K_{100}	3.81	7.70

Effects of fertilization on the quality of forage of natural grasslands

Fertilization of grasslands, in addition to significantly increasing forage yield, also increases its quality. This improvement of quality is achieved in a direct and indirect way. Direct improvement of quality is reflected in the increase of favorable nutrients in plants (proteins, minerals, vitamins, carotene), while indirect one is reflected in changed floristic composition, dominancy of plants of greater nutritive value and suppression of lower quality plants.

Application of mineral fertilizers on grasslands

The application of mineral fertilizers is very important for grasslands with regard to their advantages in comparison with organic ones. Primarily, they contain high level of nutrients, their transport is cheaper and the ratio of nutrients can be adapted to the requirements in the field, as discussed in previous chapters. The application of mineral fertilizers on grasslands results in high and stable forage yields. Therefore, without the application of mineral fertilizers, there is no high and stable production on grasslands.

Many studies indicate that the most favorable ratio of NPK in our conditions is 1-2:1:1 or 2:1.5:1, for the soils deficient in phosphorus often found in our mountainous areas (V u č k o v i ć , 1999).

Numerous studies on the effects of fertilizers on grassland forage yield have been conducted in our country.

Table 13. Approximate fertilization of natural grasslands

Doses of fertilizer	Quantities of active nutrients (kg/ha)		
	N	P_2O_5	K_2O
Lower doses	60-80	40-50	40-50
Medium doses	100-120	70-80	70-80
Higher doses	140-160	90-100	90-100

Lower doses of fertilizer are applied to less productive grasslands (mountainous and poorer hilly), medium doses of fertilizers are used for hilly, better mountainous and poorer lowland grasslands, while higher doses are used for lowland and high quality hilly grasslands.

The time of application of fertilizers largely depends on the botanical composition of grassland, environmental conditions, methods of use and the properties of fertilizers.

Nitrogen fertilizers have high solubility releasing nutrients faster and are easier to leach. Therefore, it is recommended dispensing them in the soil in the springtime and during the vegetation period, two or three times.

When it comes to phosphorus and potassium fertilizers, it should be noted that they release nutrients slower compared to nitrogen, and migration across the profile is weak. This is the reason why these fertilizers can be applied in the late autumn and early spring, as they use the autumn, winter and spring precipitation to dissolve.

Mineral fertilizers can be spread in many ways: manually and by planes in less accessible areas and using agricultural machinery (spreaders attached to the tractor).

Any interruption in the fertilization of grasslands causes their deterioration, thinning, reduction of forage yield and quality. Interruption of the fertilization of previously fertilized grasslands inevitably leads to degradation of vegetation cover and a decline in its productive value that may go even below the level of permanently unfertilized areas. Absence of fertilizer in just one year reduces the yield to the level of natural grassland that was never fertilized.

Table 14. Effects of the absence of fertilization on the natural grassland type *Agrostidetum vulgarae*

Fertilization	**Hay yield (t/ha)**	**Representation of certain plant groups in hay yield (%)**			
		Good grasses	**Palatable legumes**	**Palatable herbages**	**Poor quality plants**
Without fertilization	2.56	41.7	10.5	10.2	37.6
Regular fertilization	7.07	67.5	12.7	5.2	14.6
1 year interruption	3.10	47.7	10.5	6.2	33.6
2 year interruption of	2.25	34.5	12.0	7.0	46.5
3 year interruption of	1.83	30.6	13.0	6.5	49.9

5.9. Water resources and irrigation

Water resources. 97% of the earth's water is salt water and only 3% is fresh water. More than two-thirds of this water is frozen in glaciers and polar caps. The remaining unfrozen part of fresh water is found primarily as ground water while just a small part is present above the ground or in the air. Water supply is mainly based on the use of ground waters and springs (80-90%), rivers (10-20%) and only about 1% from natural lakes and artificial accumulations.

Irrigation. Irrigation is a controlled, artificial application of water for agricultural purposes. It is a measure in plant production where, through special man-made systems, water is added to the soil in order to meet the plant water requirements when there is not enough precipitation water. When irrigating, it is necessary to use water efficiently, that is to apply only the required amounts for the given crop and in doses which can be infiltrated into soil to a certain depth.

Infiltration of water in the plant's root zone should occur without any runoff. The amount of water per one irrigation treatment and frequency of irrigation depends on: a) the type of soil, b) mechanical composition (texture) of the soil and its structure, c) plant density and water requirement, and d) microclimate. Sandy soils and sandy clay absorb water quickly so they need to be irrigated more frequently using smaller quantities of water in order to prevent water losses, outside the plant's root zone. On the other hand, clayey soils absorb water slowly and if irrigation water is added too quickly runoff occurs. In such soils, water has to be added intermittently, giving the soil time to absorb added water before adding the next quantity, which is a method known and “cyclic” or “pulse” irrigation. There are many irrigation methods that are usually grouped into: a) surface, in which water is brought on the land surface, and b) subsurface, which brings water to the root zone of plants below the land surface by capillarity. In surface type of irrigation water can be brought to the land surface either by gravity or under pressure. Surface irrigation where water is supplied by gravity is performed in one of the following methods: furrow (infiltration into furrows), infiltration into bowls, spillover and immersing. The surface irrigation, where water is supplied under pressure, usually involves sprinkling and localized irrigation through drip and micro-sprinklers. If the water is introduced below the land surface, we speak about subsurface irrigation that can be provided by open channels and under pressure.

Source. H. Čustović, 2011

Figure 22. The modern method of drip irrigation in the area of Popovo polje

Each of the above-mentioned techniques and methods of irrigation has certain advantages and disadvantages, and the choice of appropriate method depends on:

- Size, shape and slope of the land plot;
- Type and mechanical and physical properties of the soil;
- Type, quality and availability of water supply for irrigation system;
- Type of crops that are grown;
- Initial expenses and availability of funds; and
- Farmer's priorities and their previous experience with irrigation.

Within the framework of climate change, adaptation to drought is one of the most important tasks. Therefore, the way of managing the water resources is of particular importance. In arid areas, and not only there, there is a great need for collecting precipitation water (*water harvest*) through micro and macro reservoirs, supply channels or waterways, water supply networks, cisterns, tanks, etc., for irrigation purposes.

Reservoirs (artificial lakes) are formed by damming the river flows in valleys. Reservoirs are used for storage (accumulation) of water at a time when it is abundant and can be used at the time of water shortage (as a source of irrigation water in dry seasons when there is not enough water for the needs of cultivated plants) as well as for other purposes. When building a reservoir it is very important to take into account the design of dams and locks and provide appropriate facilities and equipment (spillways, outlets, hydro-mechanical equipment) that allow: the creation of reservoir and retention of water, intake of water for irrigation and other various purposes, diverting the water flow (if necessary) and distributing and managing the water.

Artificially dug channels to supply water for irrigation (waterways) are the best-known way of using water in small agricultural areas where water is scarce. This allows farmers to have access to irrigation water, thereby creating better conditions for agricultural production. There are several terms commonly used for these channels: gullies, gutters, drains, canals. Such channels are a social, village property. Through these channels or waterways, it is possible to bring water from one area to another and thus provide a source for distributing water in various ways.

Tank or cistern is a water storage tank in waterless areas. In some places, they are called "*bistijerna*" or "*gustijerna*". Former construction technology was complex. First, they dug holes in the ground and then walled them in hard stone. The mortar was made from red soil. Such mortar was used for brickwork and subsequently for plastering the inner surface. The pit was also closed on the top side leaving an opening called a window in the middle. Rainwater was collected from the catchment area called "*splova*". To take water from the pit, they used the bucket tied to a rope. With the emergence of new building materials, construction of pits has become faster and easier. In Herzegovina and Montenegro, building pits to collect water for irrigation (as well as for other purposes) would be a practical and good solution for small farms and also for water supplies for people and livestock. The concept of water harvesting through micro and macro reservoirs as well as pits or cisterns should be popularized and put into the context of rural development and its sustainability.

Source: M. Marković, 2014

Figure 23. Tank

5.10. Anti-hail nets

Hail is a harmful natural occurrence, especially for agriculture. Hailstones are formed in clouds that are called cumulonimbi in professional terminology. Hail causes mechanical injuries to plants, damaging the leaf mass, damaging or destroying the reproductive organs, which has a direct impact on the reduction or even total destruction of the yield. Furthermore, such damaged plants are more susceptible to plant diseases and physical defects.

Central and southern Europe are particularly affected by this occurrence, and the trend of current climatic events indicates that even more intense thunderstorms with hail can be expected (Dejanović, 2012). Since this phenomenon is associated with temperature, it is likely that the increase in temperature will lead to an increase in the number of days with hail.

Anti-hail protection is being implemented in 19 European countries, using different methods: anti-hail rockets filled with silver iodide based reagent; anti-hail protection by planes for cloud seeding where a reagent based on silver iodide is deployed in clouds; anti-hail protection by terrestrial generators as the primary means for cloud seeding with the reagent based on silver iodide and by anti-hail cannons. The level of effectiveness in suppressing the occurrence of hail in Europe ranges between 20 and 95%, and the highest level of efficiency was achieved by using anti-hail rockets (Dejanović, 2012).

Hail is one of the major risk factors in growing fruit. The increasing cost of fruit growing means that farmers require an efficient and active system of protection against potential crop damage caused by hail. The most reliable and most cost-effective solution for new plantations is to protect them with anti-hail nets.

Direct and indirect benefits arising from the use of anti-hail net in comparison with the method of passive protection (insurance policy) are as follows:

- Security of harvesting fruit without damages or major wounds.
- Protection of the trunk and branches (the vital elements for optimal growth) and young plants (after the planting).
- Windbreak and sand barriers (reduction of broken branches and shoots, uniform flowering, removal of the friction caused by sand).
- Anti-hail net acts as a barrier against soil evapotranspiration. The level of reduction in evapotranspiration is proportional to the density of the net. In the summer months, this effect is positive as it reduces the water requirement, while in the rainy season it is negative because it reduces air circulation and increases the humidity.

During the dry and sunny periods, the net becomes electrostatically charged and attracts dust particles. The dust which remains on the net reduces excessive light intensity in the summer period. With the first autumn rains, dust comes the net off thus returning it into original condition. The correct balance between the screen and light intensity promotes a balanced process of photosynthesis that allows plants to absorb nutrients and develop plant tissues.

5.11. Accumulation of organic carbon in the soil (C sequestration)

Intensive agricultural production in many cases leads to the loss of organic matter and soil erosion, thereby releasing CO_2 which contributes to global warming and climate change. Degraded soils are less productive as well as less resistant to the adverse effects of climate change that is reflected in the frequent occurrence of droughts and periods with excessive rainfall causing flooding. It is believed that agriculture is responsible for one quarter of the global anthropogenic greenhouse gas emissions. However, certain agricultural measures have a positive impact on reducing the concentration of CO_2 in the atmosphere through the process of photosynthesis and accumulation of organic carbon compounds after the death of plants.

The increase in the reserves of organic C in the soil occurs when losses of C due to the decomposition of organic matter are lower than its accumulation. The strategy is to increase the content of soil organic matter through larger production of biomass and the development of the plants' root system as well as to encourage humification and formation of organo-mineral complex which improves and stabilizes the soil structure. By increasing biodiversity (e.g. earthworms and other soil fauna) we improve the soil quality.

Agrotechnical measures and practices used to increase the reserves of organic C in agricultural land include (Table 15):

- Measures of organic farming (see the chapter on organic farming);
- Application of conservation and reduced tillage;
- Crop rotation;
- Mulching and intercropping;
- Application of organic and mineral fertilizers;
- Application of N-fertilizers based on the assessment of available N in the soil;
- Reclamation of degraded soils and an increase of soil fertility;
- Maintenance of permanent pastures;
- Change in land use; and
- Afforestation.

The application of conservation and reduced tillage. Reduced tillage systems leave crop residues on the land surface as mulch which reduces the risk of erosion and increases the concentration of organic C in the top layer of land. The depth of tillage affects the accumulation of organic C. Ploughing at 12 cm depth in relation to 24 cm depth results in an increase by approximately 72 kg of organic C/ha/yr. Plant residues contain about 40% C which, among other things, affects the concentration of organic C in the soil. Research shows that about 18% C incorporated in soil become part of the soil organic carbon pool.

Crop rotation on the land parcel has a positive effect on the accumulation of organic C due to differences in the systems of soil tillage and fertilization for different crops. The crops that are grown in rotation provide higher yields and leave more residues compared to those in monoculture, thus increasing the content of organic C. The content of C also depends on the type and characteristics of the plant species. A higher content of organic C was recorded on the plots under legumes or their mixture with grasses in comparison with plots under grains and row crops.

Mulching and intercropping. Covering soil with plant residues and growing intercrops in rotation with row crops has a positive effect on the accumulation of organic C in the soil.

Table 15. The potential for capturing organic carbon in agricultural and forest ecosystems in moderately cold climate (Lal, 2004)

Activity	Quantity of captured carbon (kg $ha^{-1}yr^{-1}$)
I Agriculture and forestry	
1. Arable land (conservation tillage, crop rotation, intercrops, soil fertility, water management)	200-600
2. Pastures (improvement of varieties, controlled grazing)	200-400
3. Forests	100-200
II Change of land use	
1. Reclamation of degraded land	200-800
2. Reclamation of strip mining sites	200-500
3. Restoration of wetlands (marshes, boglands, ponds and reed lands)	500-1000
III Urban land	
1. Forest plantations	200-500
2. Facilities for recreation	400-600

Application of mineral and organic fertilizers causes an increase in yield and biomass production and thus returning larger amounts of organic matter into the soil which results in an increase in the content of organic C in the soil. The absence of fertilization or fertilization with only mineral fertilizers leads to a decrease in reserves of organic C in the soil. Results of a research conducted on Moore's trial, the oldest maize monocrop trial in the United States, have shown that the application of N-fertilizers in the amounts exceeding the loss of N through yield, leads to a decline in the content of organic C in the soil, regardless of the positive impact of N-fertilizer on the larger amount of harvest residues incorporated in the soil. Results of field trials of own researches of the Institute of Field and Vegetable Crops of Novi Sad in Rimski Šančevi, showed that the application of mineral fertilizers in maize monocropping during the period of 32 years did not increase the reserves of organic C in the soil layer of 0-30 cm depth compared to the control without fertilization.

However, the application of mineral fertilizers combined with harvest residues (F+HR[6]) or farmyard manures (F+FYM[7]), compared to the control without fertilization, during the period of 35 years, had an impact on a significant increase in the reserves of organic C in the soil. Reserves were increased by 6.81 Mg ha^{-1} in F+HR treatment and by 15.2 in F+FYM treatment, which corresponds

[6] F – mineral fertilizer, HR – harvest residues
[7] FYM – farmyard manure

to the accumulation of 195 kg ha^{-1} yr^{-1} (F+HR) and 435 kg ha^{-1} yr^{-1} (F+FYM). The largest amount of organic C was accumulated in F+FYM treatment in two-field crop rotation of maize/spring barley (M a n o j l o v i ć et al., 2008).

The application of N-fertilizers based on the assessment of available N in the soil. N-fertilizers, if added to fertile soils in the amounts that exceed those being lost through fruit/grain, accelerate the decomposition of harvest residues and organic matter. To prevent further degradation, reduce CO_2 emissions and prevent water pollution by nitrates, the application of N-fertilizers should be based on an assessment of available nitrogen in the soil (N_{min} method).

Reclamation of degraded land. Most of the degraded land has lost a significant portion of C from the initial reserves of organic C. Soil erosion by water and wind is the most common type of degradation process at the global level and the adoption of conservation tillage practices can reduce the erosion-induced losses of C. The change of crop rotation, intercropping, application of farmyard manure and organic soil improvers have a positive impact on the accumulation of organic C and soil organic matter as well as on the improvement of the soil quality, which results in an increased yield of cultivated plants. The application of lime to acid soils also has a positive impact on the accumulation of C.

Maintenance of permanent pastures includes proper application of fertilizers, controlled grazing, overseeding of legumes and grass mixtures tailored to the ecosystems, irrigation. According to C o n a n t et al. (2001), the improvement of pasture can store between 0.11 and 3.04 Mg C/ha/yr. with an average of 0.54 Mg C/ha/yr.

Change of land use from degraded land to pasture or forest has a positive impact on the accumulation of organic C. The level of accumulation depends on the climate, temperature, plant species and fertilization.

Afforestation and formation of shelterbelts have positive effects on the accumulation of organic C due to the prevention of erosion, loss of organic matter and improvement of microclimatic conditions.

5.12. Measures to protect animals from high temperatures

In general, the animals are more resistant to climate change in relation to crops because of their mobility and the ability to find new resources. The extent to which livestock production can adapt to climate change primarily depends on the socio-economic and environmental conditions of the local community and the available resources.

Solutions to reduce adverse effects of climate change on livestock should be sought through synchronized processes: (i) the adaptation of animals and livestock management systems to climate change; and (ii) the reduction of climate change causes in general, to include those generated by various operations in the systems of keeping and exploiting animals.

None of these processes is likely to achieve good results by itself so it is necessary to focus on both mitigation and adaptation through the support of local communities in order to be able to respond to their effects.

There are several different but ultimately integrated strategies for the livestock sector adaptation to climate change:

1. *Adapting the system of livestock production*. Changes in production practices could include: (i) diversification, intensification and/or integration of production systems through the use of pastures, crop production and livestock production; (ii) change in land use and the application of irrigation; (iii) change in the timing of operations; (v) conservation of ecosystem; (vi) modification of the trade of animals (vii) introduction of the so called combined system through the stable feeding system and the exploitation of pastures, and (viii) change in the structure of meals to compensate for insufficient consumption of nutrients and reduced production of heat.

2. *Selection of genotypes*. Many local breeds are already adapted to severe climatic conditions. On the negative side, such breeds are mainly widespread in developing countries that are generally characterized by a lack of technology and breeding programs that would speed up the adaptation. It is important to note that the strategy of adaptation is not based just on animal tolerance to heat but also on increasing the animals' ability to live, grow and reproduce in adverse conditions (inadequate nutrition and exposure to pathogens) (Hoffmann, 2008). Some measures of this strategic approach include: (i) the identification and conservation of local breeds that are already adapted to the local climate stresses and food sources, and (ii) improvement of the genetic material of local breeds by their crossing with breeds that are more tolerant to temperature change and diseases.

3. *Market.* Develop the market of agricultural products (animal feed, animals, products) while favoring inter-regional trade, credit scheme and the like.

4. *Changing institutional policy*. This measure implies inter alia the introduction of financial support and trial insurance system with the introduction and development of forecasting and alarming systems so that measures to protect animals and livestock production in general could be timely undertaken.
5. *Research and development of technologies.* The objective is to achieve a better understanding of the impact of climate change on livestock, develop new breeds and genetic lines, protect the health of animals and improve soil and water management. The effects of this strategic approach are of a long-term nature.
6. *Building knowledge of farmers* especially of the animal owners to respond properly to climate change. Training in advanced technologies and production practices and food preservation will help improve the volume and quality of forage and consequently, reduce malnutrition and mortality of animals.

A special approach should be designed for the poor areas where it is impossible to apply new technologies. It involves: (i) provision of shelter and making water available to animals in order to reduce heat stress, (ii) reduction of the number of animals-a smaller number of more productive animals leads to a higher production efficiency and lower GHG emissions, and (iii) improvement of the management of water resources through the introduction of simple irrigation techniques, and combined with the infrastructure for rainwater harvesting.

5.13. The reduction of methane emissions through animal nutrition

Due to the specific digestive processes which, to a large extent, include microbial decomposition of food in the rumen, the largest producers of methane from animal production are ruminants. More specifically, the rumen fermentation of carbohydrates produces methane as a byproduct. Globally, ruminants account for 1/5 of totally released methane, and in rural areas for nearly ½. A cow can produce up to 200 l methane/day, whereas sheep produce up to 30 l/day (G H G M P , 2005).

Animals lose approximately 10% of energy due to daily methanogenesis which has a negative impact on productivity and thus the sustainability of production. Methanogenesis is impossible to stop completely as it is an integral part of the ruminal fermentation. For a better understanding of methane production in the rumen, it is necessary to understand the role of certain nutrients and various microorganisms in the ruminal fermentation. The main precursors for the synthesis of methane in the rumen are the acetate, CO_2 and H_2. These metabolites are formed in the process of decomposition of carbohydrates, especially cellulose. In contrast, fermentation processes resulting in the formation of propionic acid reduce the production of methane.

Recommended solutions for reducing methane emissions include:

- Increasing the number of non-ruminants while reducing the number of ruminants;
- Genetic manipulation of methanogenic bacteria;
- Intensification of production;
- Rearing breeds that produce less methane;
- Animal nutrition with appropriate fodder (meals);
- The use of various additives (organic acids, probiotics, ...);
- Adding fat in the diet of ruminants.

Given the complexity of some of the above listed solutions (technical, economic, social) the implementation of various dietary methods to reduce methanogenesis seems to be the most acceptable. Although methane production in ruminants depends on several factors, it appears that animal nutrition is the most important one.

Voluminous forage

Changing the structure of ruminants' meals has a direct impact on reducing methane production in the rumen.

A high proportion of concentrated forage in a meal reduces the population of protozoa in the rumen, lowers the pH of the rumen, changes the ratio of propionic and acetic acids (larger amounts of propionic acid are synthesized), all of which result in a lower production of methane per kilogram of feed consumed. For this effect to be manifested, share of concentrate in the meal should be higher than 50%. In grazing type of cattle nutrition, adding concentrate in large quantities is not economically justified. Therefore, other strategies are used to reduce methane production.

Source: S. Čengić-Džomba, 2014

Figure 24. Cow farm in Livno

The diet of ruminants that is based on mostly voluminous fodder causes ruminal fermentation to produce larger amounts of acetic acid increasing the production of methane. This practically means that the quality of feed has a significant impact on the production of methane. To reduce the production of methane it is necessary to feed animals on voluminous fodder having a lower share of fibers and a higher share of the soluble carbohydrates. When it comes to grazing cattle, they should be let graze only in the period when the plants are in their early stage of development (Lovet et al., 2004).

The inclusion of legumes in the diet increases the consumption of dry matter and reduces energy loss of feed due to the production of methane. Such effect of legumes is attributed, on the one hand, to a smaller share of structural carbohydrates and, on the other hand, to tannins having a toxic effect on certain microorganisms of the rumen, especially protozoa, the bacteria involved in the decomposition of the fibers and on methanogenic microorganisms (Waghorn, 2008). Tannins also reduce the risk of bloating. The lack of tannin in meals reduces fiber digestibility. Tannins are phenolic compounds found in many legumes including red clover (*Trifolium pratense*), birdsfoot trefoil (*Lotus corniculatus*) and flowers of white clover (*Trifolium repens*).

Pelletizing, fine grinding or ensilaging voluminous fodder of poor quality has a positive effect on reducing methane production in ruminants.

Saponins reduce the number and activity of rumen protozoa and increase the activity of bacteria and food utilization. The main commercial sources of saponins are *Yucca schidigera* (Yucca or Adam's needle) and *Quillaja saponaria* (Soapbark), plants that thrive in the rocky desert areas.

Besides the positive effects tannins and saponins have on reducing the production of methane, they have also some anti-nutritive effects, so additional research is needed regarding the dosage and use. Routine use is as well limited by the price of these compounds on the market.

Change of the cation/anion ratio of voluminous meals reduces the production of methane in the rumen, while other aspects of ruminal fermentation remain unchanged.

Concentrated forage

Unlike voluminous, concentrated forage due to a higher share of soluble carbohydrates, direct ruminal fermentation towards creating higher concentrations of propionic acid and less free hydrogen thus decreasing the production of methane in the rumen.

Concentrated feed lowers the pH of the rumen and reduces the number of methanogenic microorganisms due to their low tolerance to low pH levels of substrate. The increase of the content of starch in meals above 45% significantly reduces the production of methane without any negative effects on animal performance. Even better results in reducing methane production are achieved by using concentrated meals containing higher amounts of easily soluble sugars (T a m m i n g s et al., 2007).

Cereals are more efficient than the byproducts in reducing methanogenesis given the lower proportion of fibers in cereals. The increase in digestibility and available energy of meals reduces methane production in the rumen.

When feeding ruminants with meals containing higher amounts of concentrated forage one should keep in mind the provision of the minimum amount of fibers required by animal physiology as well as the potential risk of acidosis.

Feeding method (system) also has an impact on the emission of methane. The production of methane is lower in the system of mixed rations (TMR) relative to separate voluminous or concentrated forage feeding (S e j i a n et al., 2011).

Adding fats, enzymes, prebiotics and probiotics to animal feed

Adding fats and oils to the diet of ruminants also reduces the emissions of ruminal methane due to: (i) a toxic effect on the methanogenic bacteria, (ii) reduced number of protozoa in the rumen, and (iii) the effect of biohydrogenation. When adding fats and oils it is necessary to keep in mind that higher concentrations may adversely affect the digestion of fibers, milk composition and the production results in general (GHADS, 2005).

Adding enzymes-cellulase and hemicellulase to the diet of ruminants has a positive effect on the digestion of fibers. Change of the acetate/propionate ratio reduces the production of methane.

Adding prebiotic galacto-oligosaccharide (GOS) to the diet of dairy cows reduces the production of methane by 11% (Charalampopoulos and Rastall, 2009).

Adding probiotics to stimulate the development of ruminal microbial population reducing methane emissions is still being tested. This refers primarily to adding acetogenin and yeast to the meals of ruminants. Although *in vitro* studies on yeast have established a methane emissions' reduction (Newbold and Rode, 2006), it is necessary to confirm these results by *in vivo* experiments.

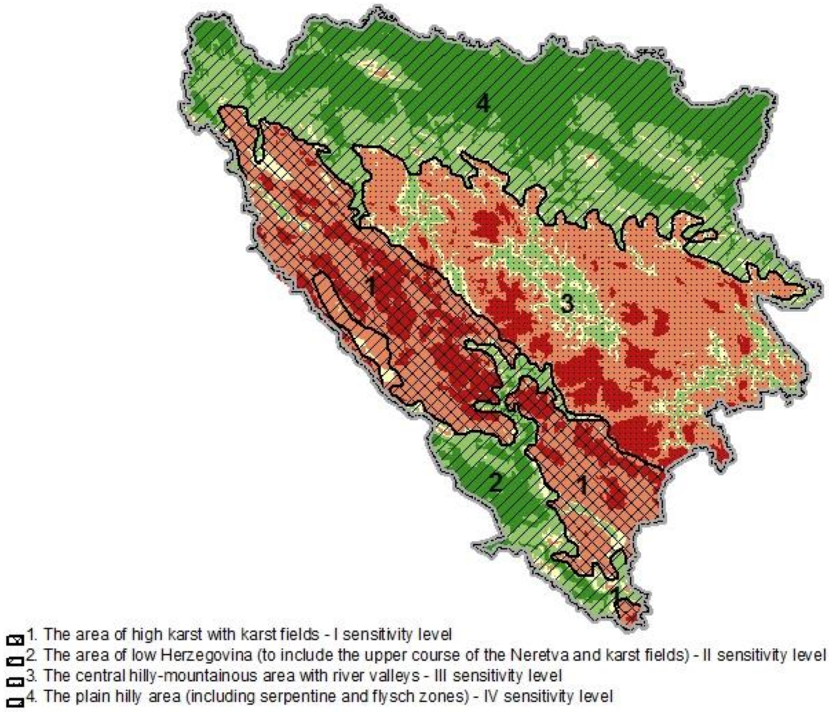
ASSESSING THE IMPACT OF CLIMATE CHANGE IN BOSNIA AND HERZEGOVINA - CHOICE OF MITIGATION AND ADAPTATION MEASURES

6

6.1. Bioclimatic (agroecological) regions

In BiH there are four major agroecological regions[8]:

- The area of high karst with karst fields;
- The area of low Herzegovina (to include the upper course of the Neretva and karst fields);
- The central hilly-mountainous area with river valleys;
- The plain hilly area (including serpentine and flysch zones).



Source: H. Čustović, PAM Institute, Faculty of Agricultural and Food Science University of Sarajevo

Figure 25. The main agroecological regions of BiH

[8] NAP BiH, 2014

The area of high karst with karst fields

This is a mountainous region above 800 above sea level, which encompasses a significant number of high mountains extending in the Dinaric direction (NW-SE) and with pronounced relief forms and inclinations. Basic features of the Dinarids relief include deep river valleys and canyons, vast karst fields and mountain ranges whose altitude goes from 1,000 to the highest peak of Maglić at 2,386 m (Čičić, 2002). Going from the northwest, in the zone of outer Dinarids, there are the mountains Plješevica, Dinara, Grmeč, Maglić, Čabulja, Prenj, Čvrsnica, Velež, Viduša, then Kamešnica, Vran and Ljubišnja which have slightly lower altitudinal distribution than previous, indented and with rounded tops. Among these mountains are river canyons of the Una, Sana, Vrbas, Pliva and Neretva as well as numerous karst fields such as Bosansko Petrovačko, Glamočko, Livanjsko, Duvanjsko-Šuičko, Kupreško, Gatačko, Nevesinjsko and many plateaus. Karst fields are enclosed karst valleys like green oasis in the karstic grey. Sloped terrain of the surrounding mountains is covered mostly by very shallow soils with pasture vegetation, shrubbery and degraded forests, which is exposed to strong erosion and denudation processes. Activities in the higher areas have a direct effect on the state of soil in karst fields and ground waters.

Karst fields are very sensitive and vulnerable ecosystems, on the one hand, due to the fact that they accumulate all substances arriving from shallow soils of the surrounding catchment area, and due to constant flooding throughout the year on the other hand. Particular attention should be paid to the problem of erosion and,in that way, ensure the sustainable management of these soils through the implementation of good agricultural practices, rational use of forest resources, properly organized grazing and improvement of the state of pastures, as well as taking the necessary preventive measures and practices to prevent fire. Additionally, it is necessary to plan the expansion of protected areas with different levels of protection, depending on the degree of sensitivity to degradation as a result of climate change and human activities.

The area of low Herzegovina (including the upper course of the Neretva and karst fields)

In terms of geomorphology, the area is known as low, Mediterranean Herzegovina, and it encompasses the upper course of the Neretva river, the hinterland reaching Posušje, Stolac, Bileća and Livanjsko field[9] which is the world largest karst field and is located at the transition zone towards the high karst. The entire area is crisscrossed by hillocks, hills and other relief forms at an altitude ranging between 500 and 700

[9] Ramsar site since 2008

m.a.s.l. It accounts for about 10% of the total area of BiH and is surrounded by mountains such as Trtla, Viduša, Ivan, etc., and karst fields on the upper terraces such as Mostarsko blato, Bekijsko polje, Kočerinsko, Dabarsko and many other smaller fields and plateaus. In the canyon of the Neretva River, represented are the sediment alluvial and colluvial-diluvial deposits in the Bijelo and Bišće fields, Hutovo Blato, as well as some smaller fields in the delta of the Neretva to Metković. In the very south of Bosnia and Herzegovina, in the valley of the Trebišnjica River there are Trebinjsko and Popovo fields. This area, just like the above mentioned one, is characterized by pronounced karstic erosion along with other karst phenomena. Fields are semi-enclosed or enclosed, and their hydrological regime is regulated by the capacity of sinking zones to receive surplus rainfall in the fall and winter period. Droughts are a frequent occurrence related to the growing season when the water is most needed by plants, which reflects negatively on agricultural production. On the other hand, there is the problem of flooding and long-term waterlogging from fall to spring, which further aggravates the situation. Agriculture is relatively intensive, especially along the rivers Trebišnjica and Neretva, where irrigation causes sporadic occurrence of secondary salinization. Fields are sensitive ecological systems, open to external influences, which is why hydrology of the area is of great importance. Namely, karst is characterized by a loose river network which is mainly concentrated in the karst fields, with a large number of sinkholes and low flows.

Given the potential dynamic pressures, changes and processes, it is necessary to make an inventory of the state of the soil and their state (contents of all relevant substances, plant nutrients, heavy metals, polycyclic aromatic hydrocarbons, residues of pesticides, radionuclides, etc.), based on which compulsory measures to control erosion processes and degradation will be developed as well as measures for the application of good tillage practices, land consolidation, sustainable forest management and fire protection. As part of the adaptation to climate change, these measures can provide a significant contribution and help reduce the adverse effects on all ecosystems of this area.

The central hilly-mountainous area with river valleys

This area is the northern boundary of the karst, inner Dinarids, with the mountains of Romanija and Javor, and mountains of the Paleozoic era such as Vranica, Bitonja, Bjelašnica, Jahorina, Treskavica, Visočica, Lelija, Zelengora and northern slopes of Maglić.

Towards the southern edge of the Pannonian plain, cascade the mountains of Borja, Ozren, Konjuh, Javornik, Devetak, etc. The largest river valleys are those of the Sana, Vrbas, Bosna, Drina springs, and the largest basins are those of

Sarajevo, Zenica, Jajce, Donji Vakuf, Foča and Goražde which are also the transversal valleys. It should be noted that this area is rich in lakes, especially on Mt. Zelengora which has seven karst glacial lakes, Mt. Treskavica four and Mt. Vranica one glacial lake. Common name of these lakes is “gorske oči” (“mountain eyes”) and they are of particular value as a natural phenomenon.

Source: E. Hukić, 2014

Figure 26. Zelengora mountain

In terms of geology and geomorphology, this is a very complex region. The lower parts are characterized by numerous watercourses along which (as well as at the foot of the hills enclosing these valleys) fertile fluvial, fluvial-colluvial and colluvial soils are found as well as smonitza (vertisols) on clayey substrates. On the terraces above the river valleys, depending on geological substrates and relief, there are soiltypes of slope pseudogley on loamy clay. On calcareous substrates there are loose, erosion prone soils such as regosols, rendzina, lithosols, black soil and brown soil on limestone. Predominant soils found on silicates are loessivized acid brown soils, and eutric and forest soilson igneous rocks. This area is also characterized by rich mineral deposits whose exploitation and building of infrastructure caused a significant damage to land and disruption of space in general. There are favorable conditions for the development of animal husbandry and fruit production, but the use of the land must be based on sustainable bases and implementation of erosion control measures in accordance with best practices.

In addition, it is necessary to begin with the remediation of areas damaged by mining and rehabilitation of abandoned industrial facilities and plants. Due to the flooding of lowland parts of the terrain, the issue of potential pollution of watercourses is also very striking. This area is also very sensitive to various degradation processes, particularly to climate change and water regime change, be it drought periods or floods that are becoming increasingly common. Snow cover is becoming thinner and thinner and is typical only for the altitude above 1,500 m.

The plain hilly area with serpentine and flysch zones

This area extends from the southern edge of the Pannonian Plain covering the Sava plain, Punja and Lijevče fields to the mouth of the Drina river, the peripheral terrace of the Sava river which extends to the south and connects with the younger chained highlands in the southern edge of the Pannonian basin (Kozara, Vučjak, Trebavac, Majevica). Horst mountains like Prosara and Motajica are extending along the Sava River.

Among these mountains there are wide river valleys and large areas of relatively flat land such as: i) Prijedor and Sana basin and terrains from Bosanski Novi to Bosanska Dubica, and Bosanska Krajina area within the Una basin; ii) Lijevče field-Nožičko-Srbačka plain; iii) Bosanski Brod-Derventa-Prnjavor; iv) Brčanska Posavina-Semberija. The younger tectonic formations include Sprečko and Omarsko fields as well as several smaller fields of jagged relief. Serpentine zone is characteristic for Ozren, Konjuh and other smaller mountains, and flysch for Majevica, Trebovac, Vučijak and Kozara. In the river valleys of varying width, especially the valley of the Sava river and some major tributaries (Una, Vrbas, Bosna, Drina), there is almost flat Holocene terrace built of multi-layered sediments (gravel, sand and clayey materials) with very heterogeneous properties. The most fertile fluvial soils and various hydromorphic gley soils are found here. Predominant are Pleistocene terraces built from precipitated loess and non-carbonate-acid Pleistocene clays on which mostly stagnogley appears on which precipitation waters stagnate. This is the most significant area in BiH when it comes to the cultivation of field crops, vegetables, industrial crops and fruits. Particularly developed is the fruit growing on automorphic soils of the gently rolling and hilly terrain, but there also good conditions for the development of viticulture, animal husbandry and vegetable growing. Priority should be given to agricultural production and measures to protect land that include mandatory monitoring should be focused on this priority. Since this area ends in the alluvial plane and terrace along the Sava river bank, it is most affected by pollutants and potential contamination. In other parts of the elevated relief and terraces it is necessary to implement protective measures against erosion, proper tillage methods, increase the buffering capacity of acid soils and protect against loss of fertile and productive soil. The areas abandoned due to wartime activities where arable land is mostly under the succession of dominant weeds and forest plantsare also significant. Given that this is the most important agricultural area in the country, climate change has the most direct effect on food production and safety of food consumed by the population of BiH. Climate change is most visible in the north-east, especially the area of Bijeljina where long dry periods with high daily temperatures, consequently, occur, while in May 2013 there was a massive flooding. The application of measures of good agricultural practices and measures to mitigate and adapt to climate change is going to be one of the important tasks in the future period.

6.2. Analysis of climatic characteristics

In BiH there are three main types of climate: (1) continental and moderate continental, (2) mountain and mountain-ravine, and (3) Mediterranean and modified Mediterranean climate (INC, 2009). Continental climate is present in the north, Mediterranean in the south and there is an area of high mountains, plateaus and gorges along the line that separates these two regions where dominates, depending on altitude, the mountain climate.

Source: Federal Hydrometeorological Institute, 2014

Figure 27. The climate of Bosnia and Herzegovina

Continental and moderate continental climate are represented in the area of northern BiH and in the main river valleys of the Una, Sana, Vrbas, Bosna and Drina from Višegrad**.** Semberija is under the influence of the Pannonian (steppe) climate due to the proximity of the Pannonian Plain. The main features of this type of climate are warm summers and cold winters. Summer temperatures can rise over 40°C, and the absolute maximum of 43°C was measured in 2007 in Bijeljina and Višegrad. The average air temperature in the warmest part of the year (July) ranges between 20 and 23°C, while the average temperature in the coldest period of the year (January) is about 0°C. The absolute minimums can reach up to -30°C. The average annual temperature is above 10°C. In the areas with moderate continental type of climate, most of the precipitation occurs in the warm part of the year reaching the maximum level in June. Annual precipitation amounts range from 750 l/m^2 in the north, along the Sava River, to 2,000 l/m^2 in the central and southeastern mountain regions of Bosnia and Herzegovina.

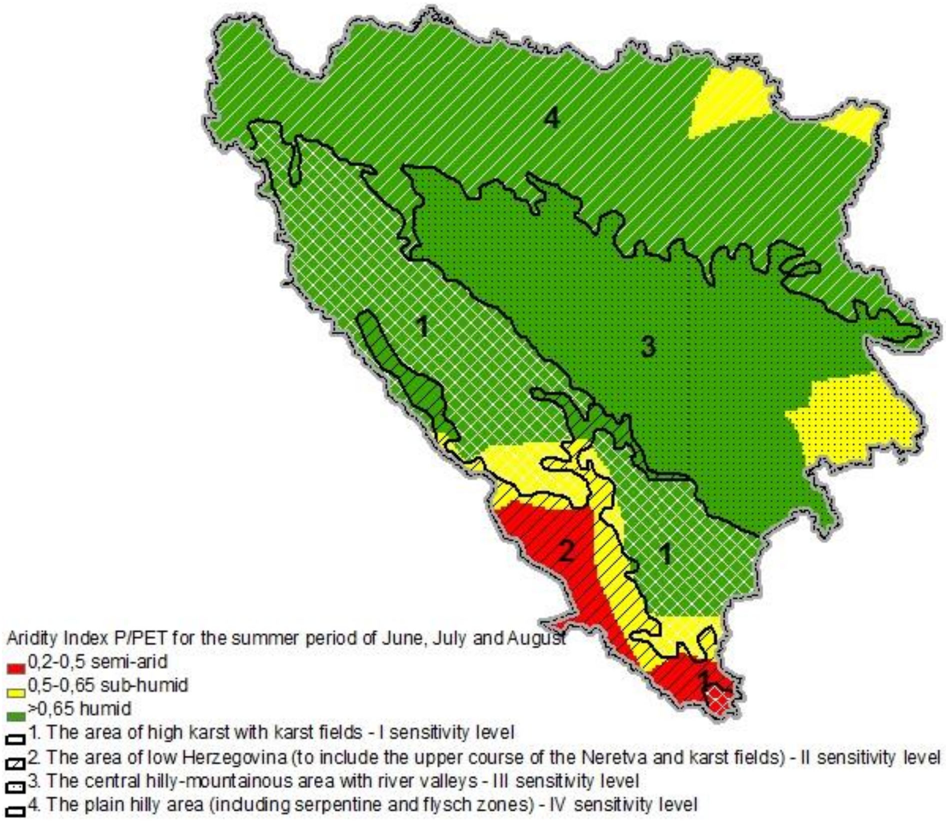
Moderate continental climate is partly represented at altitudes up to 1,000 m in the mountainous-ravine area of central Bosnia and Herzegovina. With the increase in altitude, the climate gradually changes to sub-mountainous (pre-Alpine), and over 1,400 m.a.s.l., to mountainous climate, which is predominant in the mountainous central part of the country. The characteristics of mountainous climate are brisk and short summers, cold and snowy winters with abundant snowfall. Average January temperatures range from -3.5 to -6.8°C, and July from 14.8 to 16.9°C. The absolute minimum temperatures range between -24 and -34°C, and the absolute maximum between 30 and 36°C. Transitional seasons (spring and fall) are less pronounced. The amount of precipitation is about 1,200 l/m^2, with a lot of snowfall and snow cover that remains for a long period of time. Sub-Alpine climate is a bit milder with moderately warm summers and cold winters. The amount of precipitation in these areas is a little lower and amounts to 1,000 l/m^2.

In the mountainous regions, mostly in ravines, thermal inversions are rather frequent. Temperature amplitudes range from 20 to 21°C. Autumns are warmer than springs. Precipitation is evenly distributed.

Mediterranean (Adriatic, subtropical) climate is represented in the southwest, i.e. in Herzegovina. Low Herzegovina encompasses the lower course of the Neretva River with the surrounding karst fields and has a Mediterranean and modified Mediterranean climate, while high Herzegovina is in the transition between the Mediterranean and Alpine climate, depending on the altitude (moderate mountainous-Mediterranean and mountainous climate). The climate of low Herzegovina is under a direct influence of the Adriatic Sea, thus the winters are mild with an average January temperature of 3 to 6°C. Summers are very hot with the mean July temperatures averaging from 22 to 25°C. Extreme temperatures in winter, depending on altitude, range from -8°C in lower to -15°C in higher regions. In summer, the maximum temperatures rise up to 40 to 45°C. The main feature of this entire region is precipitation. The annual precipitation amounts to approximately 2,000 l/m² but it can go up to 3,000 l/m² as recorded in Grab, the rainiest place in BiH with an average of 3,000 l/m² of precipitation annually. Snow is a rare occurrence in the lower parts of Herzegovina. However, in February 2012 an extremely heavy snowfall was recorded.

Moderate mountainous-Mediterranean climate is found in the area of high Herzegovina. The influence of the Mediterranean as well as mountains is still visible here. Air temperature decreases with an increase in altitude and distance from the sea. As we go further from the sea and deeper into the continent, temperature drop ranging from 0.6 to 0.8°C occurs in every 10 km. Winters are harsher here with the mean January temperature ranging from -3 to 0°C. The absolute minimum reaches -15 to -20°C. Summers are a bit milder than in low Herzegovina, but extreme temperatures reaching even 40°C can also occur. Precipitation is also abundant and amount to about 1,800 l/m². These areas have snowfall in winter, which is often heavy and followed by the formation of a high snow cover. The bora is rather frequent occurrence, especially in winter. It can be extremely strongin the passes. Because of diverse relief there are different climates as well as combinations of several types of climate depending on the altitude. In terms of potentially hazardous meteorological occurrences, they also vary by region. The hazardous meteorological occurrences can be classified as heavy rainfall, drought, strong winds, heavy snow, extremely high temperatures, extremely low temperatures and local disasters that include hail and ice. All these occurrences are possible in all regions. In the south of Herzegovina, there is no need for caution against extremely low temperatures. However, snow must be included (especially after the winter of 2012). As for the mountainous areas, only extremely high temperatures are not to be taken into consideration. In the last decade BiH, like most countries in the region, has been faced with the effects of climate change that are reflected, among other things, through the ever more frequent occurrence of extreme weather conditions, particularly floods and droughts. As shown in the Aridity Index map of average values for the summer period (June, July and August) in the period 1961-1991, there are no arid zones in BiH. Semi-arid zones, in our conditions, represent the areas that are most vulnerable to drought and water deficiency. They are typical of the utmost south of the country, i.e. of the area of the southern sub-Mediterranean part of Bosnia and Herzegovina. Towards the inland (continent), this zone continues into sub-humid zone which is also found in the east of the country in the area of Goražde and Višegrad (Podrinje) as well as in the northeast in the area of Posavina and

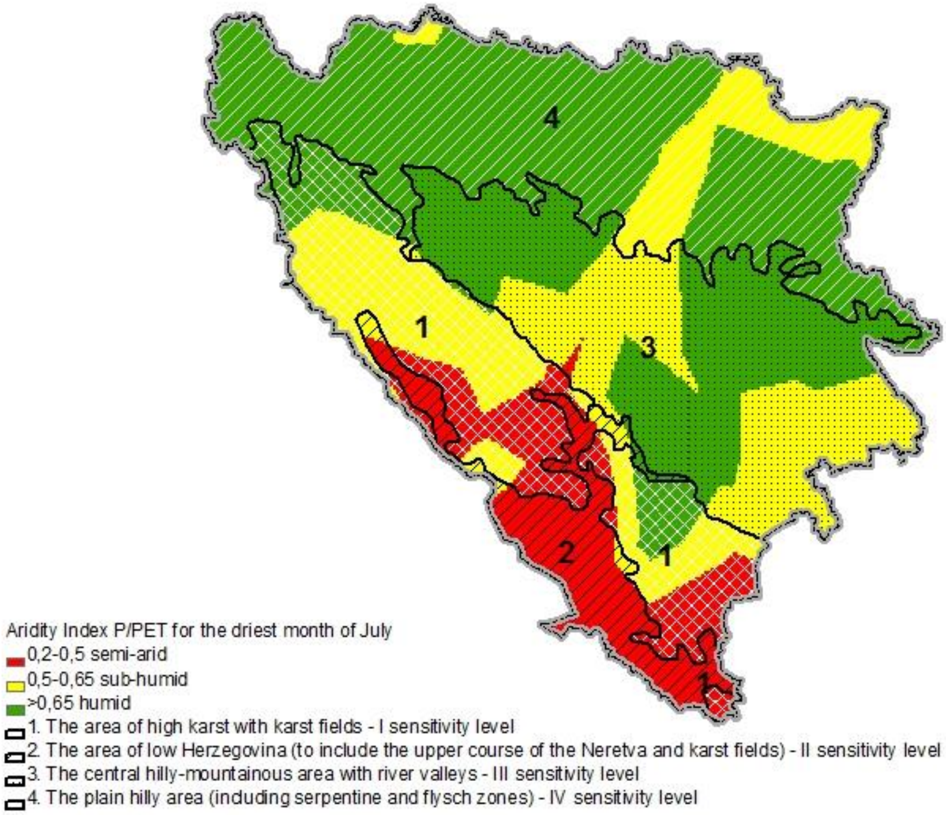
Semberija. These areas are very important for agricultural production in BiH which makes this situation and distribution of aridity relating to climate change and occurrence of dry intervals during the vegetation period particularly significant. According to this indicator, the remaining part of BiH is a humid zone.



Source: H. Čustović, PAM Institute, Faculty of Agricultural and Food Science University of Sarajevo

Figure 28. Aridity Index P/PET for the summer period of June, July and August

In BiH, July is on average the month with least precipitation. As was the case with the summer period, there are no arid zones here either (Figure 29). Semi-arid zones include the area of sub-Mediterranean part of BiH, extending to the north from Gacko, via Ljubinje, Mostar, Jablanica to Prozor and Livno. Semi-arid zone covers a much larger area than it was the case with the spatial distribution of the summer period Aridity Index. This zone extends in the central part of the country, from Goražde via northern Herzegovina to Zenica, Bugojno and all the way to Drvar in the east. Additionally, this zone includes areas in the vicinity of Posušje, Bosanska Dubica, and Posavina and Semberija in the north. Humid zone is mainly located in the northeast (Podrinje) in the vicinity of Srebrenica, in the central part of Bosnia and Herzegovina, i.e. in the area of high mountains near Sarajevo, and in the north and northwest of the country (Krajina).



Source: H. Čustović, PAM Institute, Faculty of Agricultural and Food Science University of Sarajevo

Figure 29. Aridity Index P/PET for the driest month of July

Aridity Index for the summer period in northern and central Bosnia is slightly higher than in Herzegovina, ranging from semi-humid to humid. The driest summers are recorded in the area of Goražde and Gradačac. The driest month in southwestern Herzegovina is July, particularly in the area of Livno, and in northern Bosnia-in the area of Gradačac, it is August. It should be noted that the mean values for a longer period of time are used in the development of the Aridity Index. Therefore, the occurrence of extremes and large fluctuations can not be seen by this method.The biggest threat to a stable agriculture and secure supply of the population with food is posed by extreme droughts or extreme amount of rainfall of high intensity.

A comparison of the two sets of information for the periods of 1961-1991 and 2000-2012, indicates to an increase in the Aridity Index value or precipitation deficit, which is particularly evident during the growing season. The increase in the Aridity Index is present at all shown meteorological stations, i.e. sites; it was determined at the vegetation, seasonal and monthly levels. During the growing season, this increase averaged between 0.08 and 0.2, and is between 0.02 and 0.25 during the summer.

The largest increase in the Aridity Index during the growing season was established for the area of Mostar (the difference between the periods was 0.2), while the area of Bihać has an increasingly warmer summer period (difference of 0.25). From April to August there is an increase in the Aridity Index. The most noticeable change occurs in the first part of the growing season, i.e. in April and May. In September, at all locations, there is a noticeable increase in the index valued, i.e. precipitation deficit reduction. In conclusion, let us say that the projected change in precipitation and its distribution (spatial and seasonal), combined with an increase in temperature and evaporation that results in an increased precipitation deficit, is likely to continue to cause extreme events (drought) leading to a lack of water availability during the summer when most needed by the plants. The area of Herzegovina particularly stands out in this regard (most serious in limestone and karst area), where these changes are most pronounced. Consequently, in the future we will have reduced yields due to reduced rainfall, increased evaporation and reduced stocks of water in the soil.

Bosnia and Herzegovina is faced not only with the problem of droughts, which is almost a regular occurrence, but also with the problem of flooding, which is of extreme character. In mid-May 2014, there were disastrous floods as a result of precipitation that exceeded the highest level recorded in the past 120 years. In the period of just 48 hours (13-14 May 2014) some areas of BiH received more than 150 l/m². The Bosna, Drina, Sana, Sava, Vrbas and many other rivers overtopped their banks and flooded Brčko, Maglaj, Doboj, Derventa, Tuzla, Prijedor, Travnik, Janja, Bijeljina, Zenica, Živinice, Vareš, Zavidovići, Ključ, Banja Luka, Čelinac and many other towns and villages.

Source: www.bh-index.com

Figure 30. Floods of catastrophic proportions in Maglaj-Bosna River, 2014.

6.3. State of the agricultural sector

Agriculture has always been an important sector for the overall economy of Bosnia and Herzegovina. The share of agriculture in gross national income of BiH has been reduced from 9.24% (2000) to 6.97% (2013). The total value of agriculture, hunting, forestry and fishery in 2000 amounted to 1,095,408 million KM or 1,833,770 million KM in 2013. According to the 2013 Labour Force Survey, 155,000 people were employed in agricultural activities.

Of the total arable land in 2013, about half or 517.000 ha is being used. In the structure of sown arable areas, predominant crops are grain (59%), fodder (25%), vegetables (15%), whereas the production of industrial crops is rather symbolic and accounts for just 8,000 ha or 2% in the structure of arable areas. In the production of cereals, maize and wheat are most represented. Predominant crops in the structure of production of forage crops are fodder corn, clover, alfalfa and grass-clover mixtures. When it comes to vegetables, the predominant crop is the potato which is grown on an area of 35,451 ha with an average production of 371,140 t. The area under other vegetable crops amounts to 39,549 ha. Soy and tobacco are predominant crops in the structure of production of industrial crops.

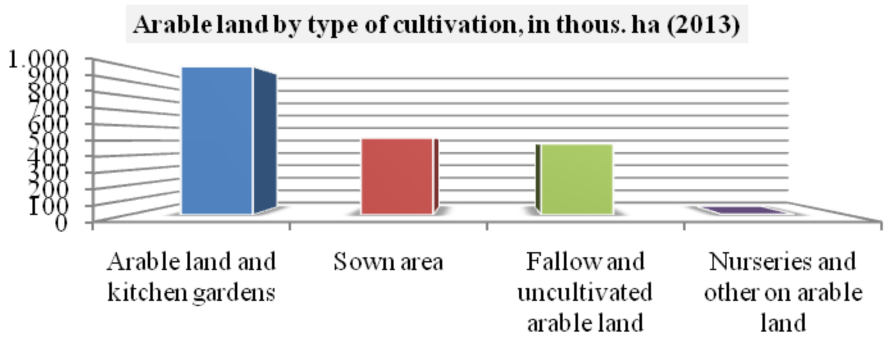


Chart 4. *Arable land by type of cultivation in BiH*

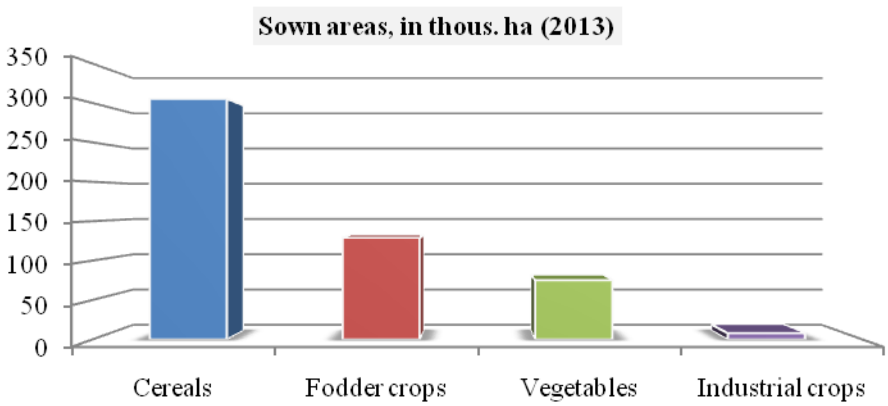


Chart 5. *Sown areas in BiH*

According to statistical data for 2013, the total number of trees of various fruits amounted to 23.8 million, of which the most represented were plum (12.1 million), apple (6.2 million) and pear (2.5 million). Total production amounted to 377,538 t. Average yields are still rather modest and far below the European average, due to the absence of a clear specialization in plant production.

Thanks to a high share of grassland in the overall agricultural areas, animal husbandry is one of the most important branches of BiH agriculture. However, extensive livestock farming remains prevalent. A small part of the production is organized on modern, well equipped farms. Observed by the number of livestock, the most represented are poultry (24.7 million), sheep (1.02 million), pigs (0.5 million) and bovine (0.4 million).

Data on the actual number of farms in BiH do not exist. According to BiH MoFTER (2012), there were 114,740 of registered farms and clients, of which 48,509 in the Federation of BiH, 63,795 in RS and 2,436 in the Brčko District of BiH. Yet, it is estimated that BiH has a total of 515,000 farms. Within this number, over 50% of these production units or 250,000 are assumed to be less than 2 ha in size, while over 80% or 400,000 are less than 5 ha. Just over 20,000 households or 4% of the total number are bigger than 10 hectares. What is certain is that the farms in Bosnia and Herzegovina remain small (averaging 3.3 hectares) and fragmented, divided on average into 7-9 smaller plotscausing low productivity and modest overall efficiency.

Source: H. Čustović, 2011

Figure 31. Fragmentation of land holdings in Ljubinje

In addition to small and fragmented land holdings, the modest overall agricultural production is also affected by poor technical equipment of farms, obsolete production technologies, low use of inputs, almost symbolic use of irrigation systems and the presence of still predominant extensive and natural production methods (Bajramović et al., 2007).

In addition, the existing drainage systems are not maintained while land areas involved in land consolidation are out of social control (Čustović and Bajramović, 2005). Climate change is also a factor that in recent years has had a significant impact on the overall agricultural production (Čustović et al., 2013). This was particularly evident in 2014, when catastrophic floods destroyed nearly the entire agriculture in the flooded part of BiH.

6.4. Analysis of agricultural practices in crop production[10]

The majority of farmers sow both spring and winter crops. Most of them apply autumn deep plowing, while for spring crops they usually plow in the spring. All respondents use manure, and most of them plow it down in the soil in the autumn. They also use mineral fertilizers, mainly in the spring, combined with sowing or as top-dressing. Half of the respondents use their own seeds, especially for vegetable crops, but they buy seed potato every second or third year in agricultural pharmacies. The majority buys maize, vegetable, barley and other crops seed in agricultural pharmacies. All of them are trying to sow within the optimal timeframes if the weather permits. They use pesticides, mostly herbicides, but also insecticides and fungicides. Very few apply mulching in the open fields when it comes to arable crops (only 16%). Mulch material (foil) is most used in the greenhouse production of vegetables and in berry fruit production.

6.5. Livestock farming methods

BiH has a high potential for the development of animal husbandry. The lowland areas are suitable for farmyard cattle farming. The mountain areas provide a possibility for pasture cattle farming as well as animal feed production, while the sub-Mediterranean area is suitable for sheep and goat farming. However, the current situation in this branch of agriculture is quite bad. The reasons for this situation are manifold:

1. One of them is the land fragmentation which prevents farmers from producing adequate amounts of animal feed and, consequently, dictates the number of animals on farms. This results in the majority of livestock production being based on small households and mini-farms (1-5 heads) which prevents the rapid development of animal husbandry in BiH.
2. Number of livestock is unsatisfactory and according to official data, it is even on the decline in some species of domestic animals.
3. Current production of animal feed does not meet the requirements of animals in terms of both quantity and quality. Due to poor crop management, the yield of forage crops is low. Mowing of fodder crops is not performed at optimal stage of plant development when they are easily digestible for animals. Preservation of animal feed is traditionally

[10] The analysis is based on the results of a survey conducted in the summer of 2014 by the University of Sarajevo, Faculty of Agricultural and Food Sciences. A total of 52 farmers were surveyed in the area of Una-Sana, Tuzla and Sarajevo Cantons and the Brčko District of BiH.

done by dryingin most cases, while the use of other methods (e.g. silage, heylage making) is rare or present only in major producers.

4. Lack of a sufficient number of extension services and little or no education of farmers as well as limited financial resources available to farmers are the reason for inadequate nutrition of domestic animals. In most cases the animals are fed on unbalanced meals not consistent with their actual needs, which negatively affect the production results that are significantly lower than the European average. With such nourishment, the genetic potential of animals is only partially exploited.

5. Inadequate accommodation for animals.

6. Farmyard manure is mainly stored in a primitive way which adversely affects not only the climate through methane emissions but the environment in general.

This depiction of the current state of animal husbandry in BiH will become even more complex with the forthcoming climate change. Data on the emissions of greenhouse gases originating from livestock in BiH are provided in Table 16.

Table 16. Main sources and the greenhouse gas emissions from the livestock sector in BiH (2005-2010)

	Gases	2005	2006	2007	2008	2009	2010
		Greenhouse gas emissions (Gg CO_2 equivalent)					
Digestive fermentation	CH_4	1,069	1,098	1,075	1,056	1,062	1,118
Manure management	CH_4	140	143	135	131	134	138
	N_2O	228	235	234	231	235	239

Source: BiH Agency for Statistics (2012)

Animals are sensitive to climate change, particularly the increase in ambient temperature. When planning the breeding of certain species of domestic animals it is necessary to take into account change of temperature zones. Given that some of the above-mentioned characteristics of BiH livestock are directly related to climate, the upcoming climate change will require the implementation of significant changes and adaptations in the sector.

This primarily refers to:

- Production of animal feed-through the adoption of new techniques of growing fodder crops,
- Quality of animal feed-provide that animals are fed on highly nutritional fodder with a low level of fiber,

- Digestibility of feed materials-mechanical or chemical treatment of voluminous forage of lower quality in order to increase digestibility,
- Application of additives-introduce the practice of applying different additives to the feed for ruminants in order to reduce the production of methane,
- Facilities for animals-adjust the existing facilities for keeping livestock to the animal requirements depending on climate and microclimate that are specific for certain species and categories of domestic animals (introduction of animal cooling systems (ventilation, misting), the construction of appropriate shelters in the open),
- Disposal of manure in a manner that will ensure the least environmental pollution-preferably in closed concrete tanks to obtain the biogas and better quality manure (based on data on livestock in 2010 and 2011, a potential biogas production in BiH amounts to 800,000 to 850,000 m^3/day),
- Breeding and selection work-place a focus on the breeding of highly productive cattle resistant to high temperatures.

6.6. Handling of manure and mineral fertilizers *(Best Agricultural Practices)*

Agriculture is an important source of two major greenhouse gases: nitrous oxide (N_20) and methane (CH_4). Nitrous oxide (N_20) is released into the atmosphere, mainly as a result of different ways of managing agricultural land, from the application of fertilizers to the irrigation and soil tillage methods. Management of agricultural land is responsible for more than half of the emissions of N_20 from the agricultural sector. Between 70 and 80% N_20 emissions come from the production and use of nitrogen fertilizers. Future growth in food production thus has to be achieved without a matching increase in the use of fertilizers. Consumption of nitrogen in the EU-25 should be by 27% lower compared to 1986, when the highest annual consumption was recorded.

The release of CH_4 is mostly a result of fermentation in the digestion process of ruminants, provided that emissions of N_2O and CH_4 are also a result of the storage of manure, especially in the conditions of reduced presence of oxygen, as well as its application on agricultural land. Management of manure accounts for about 13% of total greenhouse gas emissions from the agricultural sector in the United States.

In BiH there are more than 500,000 agricultural farms of smaller or larger capacity. Given the still underdeveloped way of administration and management of farms, all of them individually pose a potential problem in terms of the amount of produced and inadequately stored manure.

Source: H. Čustović, 2005.

Figure 32. An example of bad practice with manure handling

Table 17. Production of manure and nitrogen in BiH (2011)

Type of livestock	Number of heads (000)	Fresh manure per head in t/year	Total production of manure in t/year	The amount of N in kg/t of manure	Total N produced from manure in t/year
Bovine	455	8.7	3,954,000	4.5	17,793
Sheep	1,021	0.53	540,360	10.0	5,404
Pigs	577	1.18	681,480	5.0	3,407
Horses	19	4.8	91,200	5.5	502
Goats	65	0.7	45,500	10.0	455
Poultry	18,703	0.006	112,218	15.0	1,683
Total			**5,424,758**		**29,244**

The use of mineral and organic fertilizers in BiH is still below the average of many European countries, and also below the level permitted by the Nitrates Directive of 170 kg N/ha of agricultural land. Neverthelss, this does not mean that problems do not exist when it comes to choice, method of application and handling of mineral fertilizers and manure.

To increase the yield, farmers add nitrogen to plants in the form of mineral or organic fertilizers, and depending on the type of crops, daily intake of nitrogen amounts to 5 kg N ha^{-1} or 20-70% of the applied, while the remainder stays in the soil after harvest (Ritter et al., 2000).

How to improve the current condition and at the same time adhere to the rules of good agricultural practice? Legislation relating to the application of measures of good agricultural practice does not exist in our conditions. However, these measures are promoted and training providedthrough the implementation of certain projects. Some of the measures recommended for liquid manure include: digestion of manure to produce biogas, adding straw to manure and production of organic fertilizer, manure storage in lagoons and separation of sludge as a fertilizer, permanent chemical treatment of manure with a subsequent production of humus by composting.

Construction of facilities for the storage, proper loading, transport and distribution of organic fertilizer are crucial to a successfully management plan.

The application of measures of good agricultural practice aimed at preventing the formation of diffuse pollution source is necessary if we are to protect the water, land and nature. In our conditions, this is possible to achieve by introducing GAP measures through integrated and organic farming.

Growing oats and rye intercrops in alternation with maize and soy reduces the loss of nitrates by more than 70% (Longsdon et al., 2002, cit. Oljača and Dolijanović, 2013).

Interpolated crops cover land between the two major crops. Their significance is reflected in the better use of the vegetation period, the immobilization of nutrients and their utilization, which at the same time means reducing the risk of nutrient leaching. Oljača and Dolijanović (2013) state that the cultivation of row crops in succession of legumes reduce the trend of the use of pesticides and mineral fertilizers by 20-25%, while the yield can be increased by 50%.

Different parts of the EU legislation contribute to reducing the effects of climate change, for example the Nitrates Directive. The Directive has two main purposes: to reduce the pollution of watercourses by nitrates from agriculture and to prevent their further pollution. The Directive is complied with by all the EU Member States individually and it includes: (i) continuous monitoring of water quality in relation to agriculture; (ii) the identification of nitrate vulnerable zones;

(iii) the establishment of (voluntary) codes of good agricultural practice and (mandatory) measures that are to be implemented within the Action Programs for nitrate vulnerable zones. For these zones the Directive has also determined the maximum amount of nitrogen from manure, which can be distributed on an area of one hectare: 170 kg N/ha per year.

The Code of Good Agricultural Practice includes agricultural activities such as: the most favorable periods for fertilization, the use of fertilizers in the proximity of watercourses and on slopes, proper storage of manure and methods of its dispersal as well as the rotation of crops in time and space.

Sector is already applying certain measures of farm management that can potentially reduce emissions of harmful gases below the current level. These practices vary in their cost-effectiveness and practical use, and they include: the optimization of the use of artificial fertilizers, reduced use (or restoration) of organic land such as peatland which contains a large amount of carbon; and better control of the manure management systems with the aim of reducing methane emissions into the atmosphere-e.g. through the use of solid covers for lagoons, composting or anaerobic treatment systems (for methane capturing and processing into biogas). Further development of renewable energy obtained from agricultural biomass could contribute to reducing CO_2 emissions from power plants and transport, while providing benefits to the agricultural sector. However, there are limits to how much can be accomplished in reducing greenhouse gas emissions from farms, primarily due to the very small number of technical solutions available to farmers at an affordable price.

Organic farming, given that in general it does not use mineral fertilizers and uses smaller quantities of organic fertilizers compared to conventional agriculture, contributes to reducing emissions. Organic farming also uses less energy (both per unit area and unit product) compared to conventional agriculture.

Table 18. Possible ways of reducing greenhouse gas emissions from agriculture

Type	Way of reducing emissions	Examples
Land management and crop production	Adjusting the method of land management and crop production.	- Fertilization of crops with a precise amount of nitrogen, since less efficient application of nitrogen can lead to an increase in N_2O emissions - Discharge of water from the wet fields and meadows during the growing season reduces CH_4 emissions
Livestock farming	Adjusting the animal nutrition and other management methods to reduce the amount of CH_4 resulting from digestive fermentation.	Improved quality of grazing increases the productivity of animals, which can reduce the amount of emitted CH_4 per head.
Manure management	- Controlling the way of manure decomposition to reduce CH_4 and N_2O emissions - Capturing CH_4 from manure during its decomposition and using it to produce energy from renewable sources.	- Handling solid manure or its disposal on grassland rather than storage in a liquid form in lagoons is likely to reduce CH_4 emissions, but it can also increase N_2O emissions. - Storage of manure in anaerobic conditions in order to maximize the production of CH_4, followed by capturing CH_4 which is used as an energy substitute for fossil fuels.

WHAT STEPS SHOULD BE TAKEN AT THE LOCAL LEVEL IN THE IMPLEMENTATION OF MITIGATION AND ADAPTATION MEASURES? 7

7.1. Legislative framework

The United Nations Framework Convention on Climate Change (UNFCCC) entered into force in 1994. The main objective of the Convention is to ensure the stabilization of the greenhouse gas emissions (CO_2, N_2O, CH_4, HFCs, PFCs and SF_6) in the atmosphere at a level which will prevent dangerous anthropogenic interference with the climate system. The Convention has been ratified by 186 countries and the EU as an economic community (The first national report of Bosnia and Herzegovina in accordance with the UNFCCC, 2009). When it comes to the commitments of the Parties to the Convention under the UNFCCC they include:

1. Developed countries-Annex I of the Convention: they are responsible for regulating greenhouse gas emissions on the territory of their country,
2. Developed countries-Annex II of the Convention: they are responsible for covering the cost of adaptation to climate change for the economies of developing countries,
3. Developing countries: they are responsible for reporting on their state-level greenhouse gas emissions as well as the vulnerability of their natural resources and economy to climate change.

Non-Annex I Parties should investigate the impact of climate change on their territory and vulnerability to climate change as well as identify adaptation measures to climate change and request appropriate assistance from developed countries through appropriate mechanisms. These countries, of course, must be able to establish a comprehensive system for addressing climate change, for which they should again receive support from developed countries. Types of measures that are available to them include actions in all economic sectors affected by climate change and actions to reduce global greenhouse gas emissions. The capacity to address climate change has to be a national capacity with sufficient funding for both mitigation and adaptation actions.

Bosnia and Herzegovina became a member of the Convention in 2000. The Kyoto Protocol was ratified by BIH in 2007. In order to fulfill its obligations, BiH has established a state-level Climate Change Committee consisting of 32 members as well as the Subcommittee on Climate Change (UNDP, 2011). BiH adopted the Climate Change Adaptation and Low Emission Development Strategy for Bosnia and Herzegovina in 2013. BiH has no Law on Environmental Protection, while the entities and Brčko District of BiH have laws on environmental protection as the fundamental laws and other laws and regulations governing the area of environmental protection deriving thereof.

High priority in BiH is the preparation of specific strategies, programs and action plans with a special focus on, among other things, the legislative framework and the establishment and strengthening of the institutional framework (Marković, 2012).

In addition to this Convention, BiH has ratified the UN Convention to Combat Desertification in Those Countries Experiencing Serious Droughts and/or Desertification as well as the UN Convention on Biological Diversity, the Convention on Environmental Impact Assessment in a Transboundary Context, the Convention on Conservation of European Species and Natural Habitats, etc.

United Nations Framework Convention on Climate Change is in conjunction with the aforementioned conventions, especially the UN Convention to Combat Desertification in Those Countries Experiencing Serious Droughts and/or Desertification and the UN Convention on Biological Diversity.

It is essential for BiH and other Western Balkan countries that they establish appropriate policies and measures as well as to make sure that the existing policies are in line. Institution and capacity building in these countries is of crucial importance.

7.2. Increasing public awareness of significance and role of agriculture in global changes

Most of the ecological problems are regional or global issue, thus work on environmental protection and raising the awareness of global warming must involve joint action. In West Balkan Countries (WBC) there still not enough awareness about global changes and their consequences, so the united activities are of particular importance. Therefore, the European Union aims to WBC cooperate on environmental protection, especially about climate changes presenting a global problem and cannot be analyzed separately. Significant part of ecological problems of this region derives from people habits and lifestyle. Thus, their attitudes, habits and above all the level of ecological awareness are one of the key factors of solving ecological problems in this region.

West Balkan Countries, i.e. states for which one of the objectives is EU accession, will have to make a series of institutional changes, but also several changes in sociological and cultural patterns that will necessarily lead to the changes in a way of life of their citizens. One such area is the protection of environment directly linked to the global changes and represents one of the key points for entry into the EU. In addition to the adoption of environmental principles at the institutional level, it is necessary to raise environmental awareness not only for EU accession but also to enable sustainable development of the entire region. More research regarding environmental awareness is missing in this part of Europe for the time being.

The importance of environmental awareness for the successful implementation of legislation has been proved by the Europe experience. Thus, it is necessary to learn from the mistakes and to harmonize the process of implementation of EU legislation in WBC by rising environmental awareness of citizens and their involvement in decision-making processes relating to environmental protection. To this end, it is necessary to inform citizens about environmental problems, to promote ecological values, but above all to encourage their local activities and participation in ecological and all other fields of social life.

Agricultural production, especiallyplant one, is strongly dependent on weather conditions and farmers always had to cope with weather changes. Based on numerous studies, climate changes will lead to permanent changes of temperature and precipitation, so their impact on agriculture and food production will differ from one region to another. Higher temperatures will prolong growing season in some areas, while in other longer droughts will increase yield losses. In WBC, these variations will be caused primarily by different relief with different pedo-climate properties. Farmers will have to adapt to new climate conditions. Some of the adaptation measures to climate changes in agriculture that should be pointed out are:

Development of environmentally friendly (acceptable) agricultural production. Agricultural production depends on natural ecosystems and its processes. Unfavourable climate impacts can be mitigated with different measures at the local level. This primarily refers to planting and maintaining high vegetation near agricultural areas, planting windbreaks, conservation of wetland habits and more.

Crop rotation where legumes have a special roleis of particular importance. Nitrogen fertilization is partially or totally omitted by growing legumes and thus gas emission taking place as a result of oil combustion needed for fertilization production.

Improving farmers' knowledge- sharing knowledge. For efficient adaptation to climate changes, it is necessary to apply advanced solutions that meet specific local conditions. Farmers will need to acquire new knowledge and to receive constantly new scientific and technological ideas in order to adjust their production with environmental changes. Universities and institutes play an important role therein. Namely, universities are opening educational and research programs, courses and modules that are important for environment protection and global changes.

Increasing energy efficiency in agricultural production. It is certain that the costs for energy needs for agricultural production (transportation, soil cultivation, greenhouse heating, irrigation, storage and processing of products) will increase significantly due to global changes. This is why it is important to rationalize consumption and to increase efficiency of energy use. When it comes to crop production, there is a possibility of using some plant species and their residues for biomass and energy production. In doing so, it should be taken into consideration to avoid imbalances or overrepresentation of certain species and disturbing ecological systemsin order to preserve biodiversity.

Development of irrigation systems. Irrigation will certainly be one of the key mechanisms for adaptation to climate changes, since it is expected that temperature will rise in many regions, and it will be uneven precipitation distribution and lack of rainfall during a growing season. However, drainage and in this regard the construction, and especially maintenance of existing networks of channels and recipients should be taken into account in some years with a large amount of precipitation. Maintaining and building dikes in the lowlands along the waterways protects agricultural production and human population from floods. The construction of water recipients and water micro-reservoirs in Dinaric Mountains improves biodiversity and enables sustainable survival of the population in these marginalized and abandoned areas.

The selection of new species and varieties – those well adapted to extreme conditions in terms of temperature and precipitation and are more resistant to changes.

Changing soil tillage modes – is of particular importance because it affects moisture conservation and circulation and emission of gases. By changing way of soil tillage decomposition of organic matter (mineralization) is slower as well as the release of elements and gases.

Changes in methods of application and types of fertilizers– it is primarily about the planned and rational fertilization, where the plant is fertilized based on the analysis and state of soil fertility. Increased doses of fertilizers, in addition to adversely affect the environment and the circulation of matter, are requiring additional costs.

Changes in sowing time of plant species – affect on avoiding critical periods during the growing season, and thus the yield and quality.

Application of protection measures (anti-hail nets, defrost nets) – implies higher investment, but certainly safer and high-quality production resulting in a better marketing of products.

7.3. Increasing public awareness of organic agriculture

The Western Balkans Region has a great potential for agricultural production. Different soil and climate factors provide a possibility for growing numerous plant species, which is of particular importance to maintain and to increase biodiversity. In addition, this part of Europe still has preserved most of their arable land from pollution caused by intensive agricultural production. This especially applies to natural grasslandsoccupying a significant part of agricultural land. Thus, the Western Balkans Region fits into the basic principles of sustainable agriculture and enables introduction and development of organic production. The national plan of all these countries includes organic agriculture as a great potential for achieving good results having a significant importance for the community. Each production, including organic one, has three basic postulates, namely: (i) to achieve yield and quality yield while preserving the environment, where organic farming is definitely in the first place, (ii) such production must be economically approved, and what is very important for the community, (iii) must be socially acceptable. Therefore, measures to inform the population about the benefits of organic agriculture are necessary.

The population of this part of Europe is not fully familiar with the term “organic agriculture”. This kind of farming is mostly identified with traditional production, where human work is intensive, where farmers use seeds from their own production and where use of fertilizers and pesticides is reduced. Increased awareness about organic agriculture-plant and livestock-is found in urban areas where the availability of information is higher. An important factor in dissemination of information and knowledge in the last few years are media. They collect information and work on their own education about this topic in order to represent correct data. It is important to inform and educate consumers continuously, as well as potential producers about organic farming, what is specific for organic products, where they can be found or bought. So far, producers have tried to reach a larger number of future consumers by sending printed advertisement material. However, this requires certain funds and additionally burdens producers. Thus, it is important to get every support of government institutions and non-governmental organizations, which are very active in this field.

As mentioned, organic agriculture requires a significantly larger workforce, funds for the investment, and is taking place on smaller areas, thus the price of those products is higher compared to products from conventional production. This is often a limiting factor for higher consumption, because the population of the Western Balkans Region is characterized by a low purchasing power. However, that is not a reason not to work on community education of both potential producers and consumers.

The population should get indication about main advantages of organic food as follows:

- Quality and food safety,
- Organic products have higher biological value,
- Food is free of pesticides and heavy metal residues,
- Reduced nitrate content,
- GMOs and their products are prohibited in organic agriculture etc.

Having in mind the natural potential of the region and BiH in particular, it is necessary to utilize and realize higher production in all respects. However, in order to achieve that state activity and further activity of numerous organizations working on spreading an “idea” about organic farming is required. Special attention should be dedicated to rural areas, especially in hilly and mountainous areas having enormous potential for livestock production. By placing emphasis on rural areas it is possible to employ and return the population in these regions. Namely, this is a common problem of the entire region, particularly in recent years when younger part of the population is leaving rural areas and migrating to the cities. In order to prevent this and to intensify organic agriculture and rural development the support of the entire community is necessary. Local communities with specific incentives and bonuses can give their support for that kind of production. In addition, work on providing market for these products should be synchronized. Therefore, it is important to inform the public about the characteristics of organic production and products, their advantages, how to identify organic products, what guarantees are given to consumers, where they can buy them, etc. The best effects will be achieved by measures providing basic information along with presenting the producers and the products.

Source: B.Ćupina, 2014

Figure 33. Problem of rural areas

Raising public awareness of characteristics and benefits of organic production and organic products requires continuously education of consumers by campaigns, publications, events and media reports. It is also necessary to have promotional campaigns for priority group of consumers and for specific products.

Organic agriculture should be introduced in educational programmes of primary and secondary schools (visits to organic farms, organic school gardens, etc.) in order to raise awareness of young people and future generations of farmers. It is important to offer information through projects that will enable young people to see organic agriculture in practice and better understand it. Higher education institutions or faculties of agriculture are extremely important in the educational process as they are introducing the study course Organic Agriculture in undergraduate and master study programs and thus raisingthe education of students and future users of such practice to a higher level. Teachers involved in education have a special role in spreading awareness of organic agriculture through all mentioned activities. Implementation of the plan about organic production development needs a coordination of different ministries. This will be accomplished by setting new tasks in this area linked to the EU integration process and by constant communication with organic producers. It is necessary to strengthen capacities gradually, starting with the appointment of a person who will be dedicated exclusively to the issues and the promotion of organic agriculture. Each part of this chain should be included, from production to processed products.

7.4. Preparation and evaluation of projects/programs

Today, in addition to some other indicators, the decision-making process takes account of the environmental criterion. If an investment operation has an environmental impact, it has to assess the acceptability of the impact in the context of existing alternatives or possible acceptable solution. In circumstances where in addition to the long-term, a short-term sustainabilityexists, decision-makers need to integrally evaluate different aspects (economic, social, environmental, geo-political, etc.). The methods they use include various multi-criteria, cost-benefit and other analyses.

Environmental Impact Assessment (EIA) is a procedure that ensures that all environmental implications, certain decisions (consequences in all their manifestations) are taken into account prior to making final decision (prior to issuing approvals, licenses, prior to the adoption, etc.).

The EIA procedure includes:

- Analysis of the possible/probable impacts of certain decisions (interventions) on the environment, which includes:
    - Identification of potential negative effects on the environment,
    - Their prediction,
    - Description,
    - Evaluation,
    - Proposed alternative measures,
    - Proposed measures to mitigate or avoid adverse implications on the environment,
    - Program of monitoring (control and monitoring) and management during and after the intervention.
- Documenting the analysis (evaluation) of the report (each individual decision preceding the final decision should be documented).
- Public consultation (ideally, consultations should be conducted with stakeholders and expert groups through all stages of the process of making the assessment).

- Taking into account the reports and comments from the analysis while making the final decision about continuing with or withdrawing from the subject proposal.
- Informing the public about the decision.

Strategic Environmental Assessment (SEA) is an impact assessment conducted in the initial planning stage of some investment operation, while several options are still open. It is based on a broader picture which allows for the totality of the impact of certain operations to be perceived in a more natural manner. SEA is used when assessing the impact of plans, programs or policies on the environment. In relation to the Environmental Impact Assessment (EIA), the SEA is more proactive, more flexible, focused on the goal and framework implications rather than on specific effects as they are impossible to determine in the initial stage of the assessment. SEA hierarchically sets the framework within which the EIA is more efficient and effective. For example, the environmental impact assessment is applied specifically to an object (wind farm, highway, landfill, etc.), whereas the strategic environmental assessment is used for planning the development of such facilities in the region, where it is necessary to determine the total maximum capacity and to provide general guidelines or eligibility criteria for each individual operation in that particular implementation.

Indicators on the state of the environment

As we have already pointed out, the overall setting of sustainable development is based on the principle that daily activities are performed in an environmentally acceptable manner. Generally, it is cheaper and more convenient than subsequent interventions. The assessment of agricultural impact on the environment should therefore be viewed in this context, i.e. whether the agricultural activities have negative effects on the agroecosystem and the adjacent ecosystems.

European Environment Agency-EEA is a leading European public institution that was established with the aim of providing the environmental information and data, support to sustainable development and ensuring a measurable improvement of the European environment. Sectoral topics addressed by the EEA include: agriculture, chemicals, energy, transport, land use development and planning as well as international topics. EEA coordinates the work of the European Environment Information and Observation Network (EIONET). EIONET consists of a network of experts and five topic centers (European Topic Centers–ETC) for: air and climate, biodiversity, land use and spatial information, resources and waste and water.

In 2004, the European Environment Agency (EEA) developed a set of indicators of the state of the environment (EEA Coreset of Indicators-CSI) which are organized in accordance with the DPSIR concept. The indicators are related to several environmental topics: land (terrestrial environment), biodiversity, water waste, climate change, air pollution and ozone depletion, and four sectors (agriculture, energy, transport, fishery). The EU member states regularly prepare reports for EEA, mainly on this basis.

DPSIR framework is a standard methodology in EU countries. It uses the indicator approach to describe:

1. **D-Driving Forces-**causes of environmental impact (consumption of agrochemicals, water, energy, production method, size of agricultural population).
2. **P-Pressures-**environmental pressures caused by drivers (pollutant emissions, erosion, change of land use, etc.).
3. **S-State-**state of the environment (soil quality, nitrates and pesticides in the water, land use, species depletion, etc.).
4. **I-Impact-**effects of pressures (GHG emissions, pollution by nitrates, use of water, etc.).
5. **R-Response**-measures and instruments for environmental preservation (agricultural policy, market economy, training and the like).

A new concept of agricultural development promoted in Maastricht (Multifunctional Role of Agriculture and Land) insists on environment-friendly interventions in agriculture. An important role in this concept is played by the indicators of sustainable land management or the so-called agroecological indicators, used to determine the level of sustainability of a procedure applied in agricultural practice.

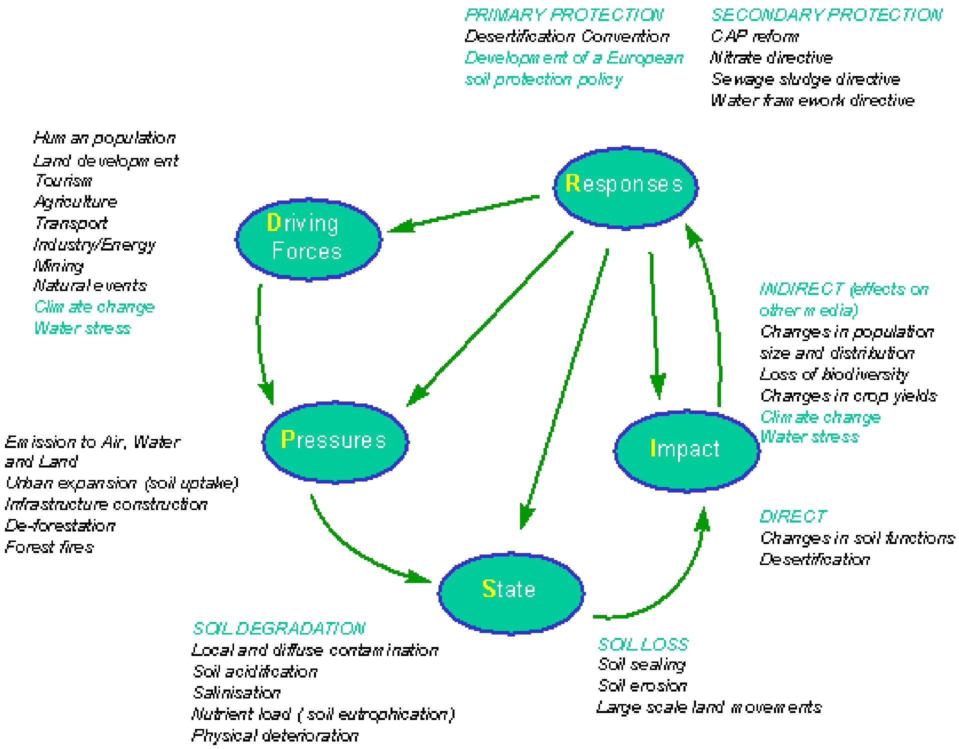


Figure 34. DPSIR model

As part of the IRENA project, a list of 35 indicators divided into groups by the DPSIR model approved by EEA was developed.

Table 19. IRENA set of agricultural-environmental indicators

Group	Subgroup	No.	Name of the indicator	Explanation
Drivers	Use of investment	8	Consumption of fertilizers	Farming method, consumption and use of agro-chemicals, energy, water, etc.
		9	Consumption of plant protection products	
		10	Consumption of irrigation water	
		11	Consumption of energy	
	Land use	12	Change of land use	
		13	Trends in change of agricultural production	
		14	Methods of farm management	
	Trends	15	Intensification/extensification	
		16	Specialization/diversification	
		17	Marginalization	

Group	Subgroup	No.	Name of the indicator	Explanation
Pressures	Pollution	18	Balance of nutrients Discharge of ammonia from agriculture	Accumulation of nutrients in the soil and water; release of ammonia and methane
		19	Emissions of methane and nitrous oxides from agriculture	
		20	Soil pollution by pesticides	
		21	Water pollution	
	Exhaustion	22	Use of water	Inappropriate use of water and soil; destruction of natural and abandoned habitats; the loss of natural diversity
		23	Erosion of agricultural soils	
		24	Changing the cover of agricultural land	
		25	Genetic diversity	
	Protection and improvement of the environment	26	Highly valuable agricultural land	Creation/protection of landscapes, habitats, land covers; destruction of natural and abandoned habitats; the loss of natural diversity
		27	Renewable energy production	
State	Natural diversity	28	Depletion of bird species	Trends in bird populations on farms
	Natural source	29	Soil quality	Soil quality; quantity and quality of water
		30	Nitrates and pesticides in water	
		31	Levels of surface water	
	Landscape	32	State of the landscape	Cultivated, partly natural space in which agricultural production is carried out and which is determined by its biophysical, geophysical and cultural characteristics
Impact	Habitats and diversity	33	Impacts on habitat and diversity	Cumulative effect of agriculture at the national level. It is necessary to determine environmental effects at the local level.
	Natural source	34.1	Agriculture's share in GHG emissions	
		34.2	Agriculture's share in nitrate pollution	
		34.3	Agriculture's share in water use	
	Diversity of landscapes	35	Impact on the diversity of landscape	
Response	Policy	1	Areas under agro-environmental incentives	Agricultural and environmental policy. Changes in technology, skills and attitudes of consumers and producers.
		2	Level of implementation of the code of good agricultural practice	
		3	Level of achieved environmental goals	
		4	Share of agricultural areas in total areas under the protection of nature	

Group	Subgroup	No.	Name of the indicator	Explanation
	Trademarks	5.1	Prices of organic products and share in the market	
		5.2	Revenues of organic farms	
	Techniques and skills	6	Level of training of farmers	
	Attitudes	7	Areas under organic farming	

Until 2009, the indicator framework DPSIR, being an important analytical tool, was not applied in Bosnia and Herzegovina to the required extent. Preparation of indicators for regular reporting to EEA was mainly based on informal sources of individuals. Today, the application of this methodology is at somewhat higher level. For example, in the Federation of BiH there is a list of 80 defined environmental indicators (State of the Environment in FBiH, FBiH Ministry of Environment and Tourism, 2010). One part of the indicators is taken from CSI and the rest were defined to reflect the specific environmental parameters in the Federation BiH. Indicators in the Federation BiH are classified as follows:

- Nature-14 indicators,
- Water-9 indicators,
- Land-16 indicators,
- Energy-9 indicators,
- Air-10 indicators,
- Waste management -22 indicators.

Type of environmental indicators in the Federation of BiH has not yet been fully defined with regard to the list of environmental indicators of the state of nature and the list of environmental indicators of the state of waste management sector.

The environmental indicators of the component *nature* include: natural environment, biodiversity, geological diversity, natural heritage, habitat conversion, conversion of primary ecosystems, conversion of secondary ecosystems, excessive exploitation of resources, pollution, climate change impacts on nature, invasive species, the state of public awareness, identification (rating) of ecosystems with high biodiversity values and description of particularly valuable areas.

8 VALORIZATION OF IMPLEMENTED MEASURES

An assessment of benefits from ecosystems is always desirable. It has been increasingly insisted upon by civil sector, non-governmental organizations as well as financial institutions that finance projects, which are likely to have an impact on the state of the environment, and especially on the state of climate change and human well-being. These assessments are important in terms of making decision on the allocation of public funds for measures of monitoring, conservation, preservation or restoration.

Valorization of an ecosystem is important in order to recognize its general values and encourage public participation and support to environmental initiatives as well as to compare the benefits of different projects and programs. Only the evaluation and valorization of implemented measures make it possible to prioritize conservation and restoration projects as well as to maximize the profit from the environment per unit of money invested. In such analyses, it is recommended to answer five important questions along with a comprehensive list of beneficiaries and stakeholders who are expected to discuss and offer a response to policy makers and recommend guidelines for a solution based on the assessment. These questions are as follows:

- What is the current state and trend of the ecosystem, ecosystem services and its impact on the state and well-being of humans?
- What is a possible future change in the ecosystem and its function and what could be the effects on changes relating to human well-being?
- What can be done to increase the human well-being and conserve the ecosystem? What are the advantages and weaknesses of the possible optional answers which could be considered for the implementation of avoidance of specific events in the future of the ecosystem?
- What are the main uncertainties that could impede making the decision to preserve, conserve or rehabilitate an ecosystem?

– What procedures and methodologies can support the capacity to assess ecosystems, the services provided by investigated ecosystems, impact on human well-being and the weakness of options that are applied in response to an occurrence?

Under the Millennium Ecosystem Assessment, the term ecosystem services implies the type of services that are provided by nature at no cost and for humans to use. Examples of such services are pollination of flowers by insects, natural filtration of rainwater through the soil, the availability of fish in aquatic ecosystems. Ecosystem services can be divided into four categories:

- Services which are freely available; food, water, wood, fiber, genetic resources,
- Services which can be (partly) influenced; regulation of climate, flooding, diseases, water quality, waste removal,
- Cultural services; holidays, aesthetic enjoy, spiritual fulfillment,
- Services supporting the formation of soil, pollination, nutrient cycle, etc.

The life of people would not be possible without these services. Nevertheless, there are continuous attempts to express these services in a monetary value, which indicates the dimension of human dependence on nature. Additionally, this illustrates the relationship between actually invaluable environmental service and material goods obtained partly by destroying the environment. Therefore, one must not overlook the monetary valorization of ecosystem services, since many of them are irreparable.

Formulating monetary value can therefore be viewed as putting the price on damage rather than the price in lieu of natural ecosystem service.

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USEFUL SOURCES OF MEASURES TO MITIGATE AND ADAPT TO CLIMATE CHANGE IN AGRICULTURE

ADAPTATION

Agroforestry (adaptation)		Agroforestry is an integrated approach to the production of trees and of non-tree crops or animals on the same piece of land.
Biotechnology for Climate Change Adaptation of Crops		Breeding for improved performance under environmental stresses involves activities accumulating favourable alleles (different forms of a gene) which contribute to stress tolerance...
Biotechnology for Climate Change Adaptation of Crops		Breeding for improved performance under environmental stresses involves activities accumulating favorable alleles (different forms of a gene) which contribute to stress tolerance. ...
Climate Change Monitoring System		A Climate Change Monitoring System integrates satellite observations, ground-based data and forecast models to monitor and forecast changes in the weather and climate. A historical record of spot...
Community-based Agricultural Extension Agents		‘Agricultural extension’ describes the services that provide rural people with the access to knowledge and information they need to increase productivity and sustainability of their production...
Conservation Tillage		Tillage is the agricultural preparation of the soil by mechanical, draught-animal or human-powered agitation, such as ploughing, digging, overturning, shoveling, hoeing and raking. Small-scale...

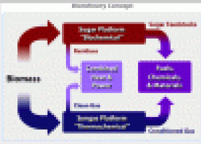
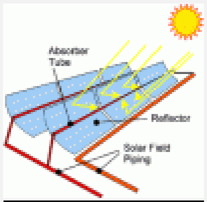
Crop Diversification and New Varieties		The introduction of new cultivated species and improved varieties of crop is a technology aimed at enhancing plant productivity, quality, health and nutritional value and/or building...
Crop Diversification and New Varieties		The introduction of new cultivated species and improved varieties of crop is a technology aimed at enhancing plant productivity, quality, health and nutritional value and/or building crop...
Decentralised Community-run Early Warning Systems		An Early Warning System (EWS) is a set of coordinated procedures through which information on foreseeable hazards is collected and processed to warn of the possible occurrence of a natural...
Drip Irrigation		Drip irrigation is based on the constant application of a specific and focused quantity of water to soil crops. The system uses pipes, valves and small drippers or emitters transporting...
Ecological Pest Management		Ecological Pest Management (EPM) is an approach to increasing the strengths of natural systems to reinforce the natural processes of pest regulation and improve agricultural...
Ecological Pest Management		Ecological Pest Management (EPM) is an approach to increasing the strengths of natural systems to reinforce the natural processes of pest regulation and improve agricultural production. Also known...
Farmer Field Schools		The Farmer Field School is a group-based learning process that has been used by a number of governments, NGOs and international agencies originally to promote integrated pest management (IPM). The...
Floating Agricultural Systems		Floating agriculture is a way of utilizing areas, which are waterlogged for long periods of time in the production of food. The technology is mainly aimed at adapting to more regular or...

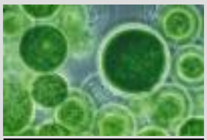
Flood-Proofing		The primary objective of flood-proofing is to reduce or avoid the impacts of coastal flooding upon structures. This may include elevating structures above the floodplain, employing designs...
Fog Harvesting		Fogs have the potential to provide an alternative source of fresh water in dry regions and can be harvested through the use of simple and low-cost collection systems. Captured water can then be...
Forest User Groups		In many countries, forest governance has remained a centralised and top-down process. Policies ignore the role of forests in tribal livelihoods and cultures, violating the overlapping laws...
Index-Based Climate Insurance		Climate insurance against crop loss is common in developed country agriculture where farmers insure against crop loss due to extreme climatic events such as flooding or drought. Typically payments...
Integrated Nutrient Management		Soil is a fundamental requirement for crop production as it provides plants with anchorage, water and nutrients. A certain supply of mineral and organic nutrient sources is present in soils, but...
Livestock Disease Management		Livestock systems in developing countries are characterized by a rapid change, driven by factors such as population growth, increases in the demand for livestock products as incomes rise, and...
Mixed Farming		Mixed farming is an agricultural system in which a farmer conducts different agricultural practice together, such as cash crops and livestock. The aim is to increase income through different...
Rainwater Harvesting		Rainfall can provide some of the cleanest naturally occurring water that is available. There is considerable scope for the collection of rainwater when it falls, before huge losses occur due to...

Seasonal to Interannual Prediction		This technology allows for a forecast of weather conditions for a period of three to six months ahead. Seasonal forecasts are based on existing climate data; in particular, on the sea surface...
Seed and Grain Storage		Seed security is a key to the attainment of household food security among resource poor farmers in developing countries (Wambugu et al, 2009). Good storage helps ensure household and...
Seed and Grain Storage		Seed security is a key to the attainment of household food security among resource poor farmers in developing countries (Wambugu et al, 2009). Good storage helps ensure household and community food...
Selective Breeding Via Controlled Mating		Genetic make-up influences fitness and adaptation and determines an animal’s tolerance to shocks such as temperature extremes, drought, flooding, pests and diseases.
Slow-Forming Terraces		A terrace is a leveled surface used in farming to cultivate sloping, hilly or mountainous terrain. They can be used on relatively flat land in cases where soil and climate conditions are...
Sprinkler Irrigation		Systems of pressurized irrigation, sprinkler or drip, can improve water efficiency and contribute substantially to improved food production.
Water User Groups		A Water User Association (WUA) is an organization for water management made up of a group of small and large-scale water users, such as irrigators, who pool their financial, technical, material,...

MITIGATION

Advanced Bio-Hydrocarbon Fuels		Advanced bio-hydrocarbons are second generation biofuels and are derived from lignocellulosic biomass such as trees, grasses, waste, agricultural or forest residues, or algae. These fuels are not...
Aerobic Biological Treatment (Composting)		Many developed and developing countries practice composting and ...
Agriculture for Biofuel Production		Biomass from the agriculture sector can be used to produce biofuels – solid, liquid and gaseous. Biofuels substitute fossil fuels for energy delivery. If biomass is grown in a sustainable cycle to...
Agroforestry (Mitigation)		Agroforestry, as defined by the World Agroforestry Centre, is “a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the...
Biochar		Biochar is a charcoal-like substance produced from agriculture and forest wastes that contains 70% carbon. It is used as soil enhancer to increase fertility, prevent soil degradation and to...
Bioethanol from Sugar and Starch Based Crops		Liquid biofuels for transport have, to a certain extent, been in use for a very long time. In recent years, however, they are enjoying renewed interest in both developed and developing countries as a...
Biomethane CNG Hybrid Fuel		Transport sector is one of the major oil consuming sectors; it consumes 51% of the final oil consumption (International Energy Agency, 2010). There is a huge need of a sustainable fuel for the...
Biopolymer Production for (Petro-)Chemical Sector		A polymer is a large molecule (macromolecule) composed of repeating structural units typically connected by covalent chemical bonds. Examples of synthetic polymers are plastics, Bakelite and nylon...

Biorefinery		With the surge in bio-based activities around the globe, a new concept called bio-refining starts to emerge. IEA Bioenergy ...
Cellulosic Ethanol		Cellulosic ethanol is an alcohol produced from the feedstock available in a wide variety of plant materials and agricultural residues. Although chemically identical with the first generation...
Concentrating Solar Power		Concentrating solar power (CSP) systems concentrate the energy from the sun for electricity production. This is done by heating a fluid which is then used to raise steam for a conventional...
Conservation Tillage		Conventional tillage is the traditional method of farming in which soil is prepared for planting by completely inverting it with a tractor-pulled plough, followed by subsequent additional tillage...
Cover Crop Technology		Cover crops are fast growing crops such as winter rye and clovers that are planted between periods of regular crop cultivation. By covering the soil surface, they protect the soil from erosion,...
Covering Manure Storage Facilities		Manure coverage is the practice of covering the surface of manure with materials of certain thickness instead of the traditional method of piling up manure to be exposed to air. Manure coverage...
Crop Varieties with Enhanced Carbon Sequestration		This biological approach uses traditional plant breeding and newer biotechnological methods to select and tailor crop varieties with greater carbon sequestration capacity. Improvements in...
Cropland Management		Agricultural ecosystems hold large carbon reserves (IPCC, 2001a), mostly in soil organic matter.Historically, these systems have lost more than 50 Pg Carbon, but some of this ...

Grazing Land Management		Agricultural ecosystems hold large carbon reserves (IPCC, 2001a), mostly in soil organic matter.Historically, these systems have lost more than 50 Pg Carbon, but some of this ...
Household Biogas Digesters		Biogas is a flammable gas produced by organic materials after it has been decomposed and fermented by anaerobic bacteria in tightly sealed environmental digesters under certain temperature,...
Irrigation		CO_2 emissions can be reduced with effective irrigation by increasing yields and crop residues that can enhance carbon sequestration. (Smith et. al., 2008).
Livestock Management		Livestock is important source of methane. The United States Environmental Protection Agency calculated that livestock, especially ruminants such as cattle and sheep, account for...
Livestock Management: Feed Optimization		The principle of nutrition regulation technology to reduce methane emissions is: to optimize the concentrate to forage ratio in the diet by controlling the crude fiber content of the diet or the...
Livestock Management: Genetically Modified Rumen Bacteria		To optimize the synthetic or metabolic pathway of micro-organisms related to methane synthesis by employing modern molecular biotechnology to obtain genetically modified microorganisms. Then the...
Livestock Management: Straw Ammoniation and Silage		Straw ammoniation is a process by which low-value forage such as corn stalks, rice straw, wheat straw, and straw of other crops is ammoniated. Adding liquid ammonia, urea, or ammonium bicarbonate...
Manure Management Practices		Agricultural lands (lands used for agricultural production, consisting of cropland, managed grassland and permanent crops including agroforestry and bio-energy crops) occupy about 40-...

Micro-Algae for Mitigating Carbon Dioxide		Micro-algae is a group of unicellular or simple multicellular fast growing photosynthetic microorganisms that can conserve CO_2 efficiently from different sources, including the atmosphere,...
Nutrient Management: Mycorrhiza		Mycorrhiza assists plants in obtaining soil nutrients. Therefore, any resulting stimulations in plant growth provide additional plant residue, which in turn can lead to increased carbon storage in...
Nutrient Management: Nitrogenous Fertilisers		Efficient use of nitrogenous fertilizers can reduce N_2O emissions from agricultural fields. In addition, by reducing the quantity of synthetic fertilizersrequired, improved management...
Off-Field Crop Residue Management		Crop-residue management is an important mitigation technology using biomass, vermicompost etc. processed under aerobic conditions which is being utilized as a commercial option to reduce...
Organic Agriculture		Organic agriculture is a production system which avoids or largely excludes the use of synthetic fertilizers, pesticides and growth regulators. It can sequester carbon using crop rotations, crop...
Rice Production Technologies		Rice cultivation is responsible for 10% of GHG emissions from agriculture (Figure 1). In developing countries, the share of rice in GHG emissions from agriculture is even higher, e.g. it was 16%...
Rice: Agricultural Biotechnology		The biotechnology approach for methane mitigation technology involves identification of rice cultivars, which emit less methane. It also involves the tailoring of plants which translocate less...
Rice: Alternate Wetting and Drying		The International Rice Research Institute (IRRI) in the Philippines has developed a new mitigation technology for methane known as alternate wetting and drying (AWD) (IRRI, 2009). AWD is a...

Rice: Chemical Fertilizer Amendment		Emissions of GHGs are affected by the amounts and types of fertilizers applied, so judicious choice of fertilizer application rates and fertilizer types can reduce emissions. Rice cultivation is...
Rice: Direct Seeding		Pre-germinated seeds or seedlings are directly planted in soil or broadcast in the flooded field under this technology. Rice cultivation is responsible for 10% of GHG emissions from agriculture. In...
Rice: Electron Acceptors		Addition of electron acceptors, such as ferrihydrite, to paddy fields can stimulate microbial populations that compete with and slow the activity of methanogens, thereby reducing emissions of...
Rice: Fertilizer, Manure and Straw Management		Fertilizer and manure management in rice fields are important methane mitigation technologies. The fertilizer management mitigation option includes changes in: fertilizer types; fertilizer...
Rice: Mid-Season Drainage		Mid-season drainage involves the removal of surface flood water from the rice crop for about seven days towards the end of tillering. The duration of the dry period must be long enough for rice...
Rice: Potassium Fertilizer Application		Fertilization with muriate of potash (MOP) can significantly reduce emissions of methane from flooded soils planted with rice. Rice cultivation is responsible for 10% of GHG emissions from...
Rice: Reduced Tillage		For upland crops, reduced tillage technology for paddy rice involves planting or transplanting directly into the soil with minimal prior tillage in the residues of the preceding crop. Rice...
Solar Dryer		Traditional method of food drying is to spread the foodstuffs to place the foodstuffs in the sun in the open air. This method, called sun drying, is effective for small amounts of food. The area...