MODULE 4: CROP PRODUCTION SYSTEMS

*Climate-smart crop production contributes to food security, climate change adaptation and mitigation by addressing different current and projected climate change impacts (e.g. variability, unpredictability)*

3.0 Introduction

Crop production, encompassing the series of processes involved in the growing of crops – from land preparation through planting to the produce reaching the farm gate, is not operated in isolation but rather constitutes an integral part of a farming system, which in turn is a constituent of the broader agro-ecosystem and landscape. A priori, crop production is aimed at providing food security, contribute to sustainable diets, raw materials for industries and generally, to improve and sustain livelihoods. The linkages between crop production to the wider overarching agricultural production systems and its value in socio-economic contexts are therefore obvious and these aspects are largely covered in other modules. Against the backdrop of social, economic, institutional and other enabling environments, this chapter will focus on the technical aspects of crop production within the context of evolving climate change and variations. In particular, this chapter will address the concept of the sustainability of crop production systems and explore how crop production can adapt to, and contribute to the mitigation of, the effects of climate change.

3.1 Climate change impacts

The successes and failures of crops have always been subject to prevailing environmental factors and hence the mechanisms for managing the stresses imposed by these factors have remained subjects of extensive studies in varied disciplines. It is noteworthy that currently, crop production is increasingly vulnerable to risks associated with largely new and evolving climatic changes. Variations in environmental conditions that are posing significant challenges to farmers, over and beyond those that are experienced “normally”. The frequency, variability and intensity of these events are increasing. The planet is facing more extreme weather events, such as heavy precipitation events, coastal high water, geographic shifts in storm and drought patterns, and warmer temperatures (IPCC, 2012). For example their impact on the current tillage-based agriculture with no soil cover, low soil carbon and severe plough pan, a dominant approach to production intensification.
These continually evolving climatic changes are projected to have significant negative impacts on agricultural productivity. Specifically for potential crop production, climate change is expected to cause substantial reductions in southern Africa (up to 30% by 2030 for maize production) and South Asia (up to 10% for staples such as rice; declines in millet and maize production could exceed 10%) (FAO/PAR, 2011). In mid- to high-latitudes, crop productivity may increase slightly with increase in local mean temperature of up to 1–3°C, depending on the crop, while at lower latitudes crop productivity will decrease even with a relatively minor temperature change (IPCC, 2007). Localized extreme events and sudden pest and disease outbreaks are already resulting in greater unpredictability of production from season to season and year to year and require rapid and adaptable management responses (FAO/PAR, 2011).

Agricultural production remains the main source of income for most rural communities (about 86 percent of rural people, about 2.5 billion, depend on agriculture for their livelihood [The World Bank, 2008]). Therefore, the improved adaptation of the agricultural sector to the adverse effects of climate change will be imperative to protect and improve the livelihoods of the poor and to ensure food security (FAO, 2012). In practical terms, climate change adaptation requires more than simply maintaining the current levels of performance of the agricultural sector; it requires developing a set of robust and yet flexible responses that allows for the improved performance of the sector even under the changing conditions that climate change engenders. Indeed, the severally well documented dire scenarios projected for agriculture under climate change regimens need not materialize as the integration of sound ecosystem-based practices into farming systems demonstrably can enhance their adaptive capacities and hence resilience.

Measures must be devised for reducing the negative impacts of agriculture on the ecosystem as processes related to agricultural production. Agriculture accounts for 13.5% of global greenhouse gas (GHG) emissions or about 1.8 Gt C/yr (6.6 Gt CO₂/yr), mainly in the form of methane (CH₄) and, more pertinent to crop production, nitrous oxide (N₂O) from fertilized soils, enteric fermentation, biomass burning, flooded rice production (paddy), as well as manure and fertilizer production (IPCC, 2007; IPCC in brief for the Director General at COP16 in Cancun, Mexico, 2010). The increased levels of primary production and microbial respirations in fertilized soils, enteric fermentation, the burning of biomass, rice farming, and the productions of manure and fertilizer are some of the agriculture-related processes that contribute to elevated GHG emissions. In addition, overall land use and land use change accounts for about 31 percent of the total human induced GHG emissions into the atmosphere (Scherr and Sthapit, 2009).

It is clear therefore that the overall efficiency of the agricultural sector, its resilience, adaptive capacity and its potentials for contributing to the mitigation of the effects of climate change and variations can be enhanced by improving these constituent components. Indeed, by improving the efficiency of agricultural production, emissions
can be reduced and sequestration capacity enhanced. Conversely, climate change will have a significant impact on crop production (Table 1), but alternative adaptation approaches and practices can address this by helping to reduce the net GHG emissions while maintaining or improving yields (FAO, 2011; Pretty et al., 2011).

Table 1: Examples of projected climate change impacts on crop production

<table>
<thead>
<tr>
<th>Phenomenon and direction of trends in weather and climate events</th>
<th>Potential impacts on crop production</th>
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<tr>
<td>Cold periods becoming warmer and shorter (warmer and more frequent hot days and nights over most land areas) (virtually certain)</td>
<td>Increased yields in colder environments; decreased yields in warmer environments; increased outbreaks of new insect pests and pathogens</td>
</tr>
<tr>
<td>Heavy precipitation events increasing in frequency over most areas (very likely)</td>
<td>Damage to crops; soil erosion; inability to cultivate land due to waterlogging of soils</td>
</tr>
<tr>
<td>Drought-affected area increases (likely)</td>
<td>Land degradation and soil erosion; lower yields from crop damage and failure; loss of arable land</td>
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<tr>
<td>Intense tropical cyclone activity increases (likely)</td>
<td>Damage to crops</td>
</tr>
<tr>
<td>Extremely high sea levels increase in incidence (excludes tsunamis) (likely)</td>
<td>Salinization of irrigation water, estuaries and freshwater systems; loss of arable land</td>
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Source: adapted from IPCC, 2007, in FAO, 2008a

Crop production has always been impacted by environmental stresses, and has looked for ways to manage these. Climate change adaptation requires more than simply maintaining the current level of performance from the agricultural sector, but rather developing a set of responses that allow the sector to improve performance under the changing conditions climate change implies. Because agricultural production remains the main source of income for most rural communities, adaptation of the agricultural sector to the adverse effects of climate change will be imperative to protect and improve the livelihoods of the poor and to ensure food security (FAO, 2012). Examples of ways are local adaptation to the stress through plant breeding, pest management strategies, and seed delivery systems, to name a few. Today, however, crop production is increasingly vulnerable to risks associated with climate change. This is because climate change is causing variations in environmental conditions that are posing significant challenges to farmers, over and beyond those that are experienced “normally”.

Some examples of changes in climatic conditions that influence crop systems include rain quantity and distribution (and consequent water availability), extreme events such as floods and droughts, high temperatures\(^1\) and shifting

\(^1\) The Earth’s average surface temperature has risen by 0.76 °C since 1850 (European Commission, 2011).
seasons. The rate of climate change will possibly exceed the natural rate of adaptation of natural systems including crops, and this creates high concern for food availability (Allara et al., 2012). In essence, what this means is that crops that were usually planted in one area may not be able to grow there any longer. But that is not all – it is not just the crop itself that may be impacted, it is also the ecosystem services that ensure crop growth (e.g. pollination, soil biodiversity), and for these reasons it is necessary to address crop production at the farming systems level. However, with the proper technical, institutional, socio-economic and policy infrastructure in place, there is a huge potential for crop management practices adapt to, and contribute to, the mitigation of climate change.

3.2. Sustainable crop production intensification

Sustainable crop production intensification (SCPI) aims to enhance crop production per unit area, taking into consideration all significant aspects that affect the productivity and sustainability, including the potential and/or real social, political, economic and environmental impacts (FAO, 2010a), therefore involves the addressing of the constraints to crop production from a farming systems level. It is also a paradigm for crop production whereby natural resources are managed and enhanced. The sustainability of crop production systems therefore presupposes that the risks and vulnerabilities that arise from climate change are also addressed. SCPI is underscored by a holistic ecosystem approach that draws on nature’s contribution to crop growth – soil organic matter, water flow regulation, pollination and natural predation of pests – and applies appropriate external inputs at the right time, in the right amount. Social, economic and policy dimensions are also factored into the devising of SCPI strategies. In essence, sustainable crop production systems are those that capitalize on natural biological processes by managing biodiversity and ecosystem services, optimize efficiencies in crop production and provide options to farmers for ensuring long-term crop production.

Resilience and adaptability of agricultural production systems/agricultural landscapes will become more important properties. To achieve this, crop production systems will need to have greater reliance on ecological processes that produce positive feedbacks on sustainability and production and ensure improved provision of all ecosystem services (FAO/PAR, 2011). Adopting these agricultural practices that already exist and have multiple benefits for food security and environmental health could be improved over the short term. However, barriers to adoption of these practices will need to be addressed through enabling means (e.g. investment, capacity building, financing, information, research, incentives, supportive policies and agreements),
Farming practices that rely on natural biological processes and biodiversity to increase the production of agro-ecosystems are “climate-smart”

Sustainable crop production intensification can be achieved through good farming practices, which are based on improving efficiencies and managing biological processes. SCPI is based on agricultural production systems and management practices that include:

- maintaining healthy soil to enhance soil related ecosystem services and crop nutrition;
- cultivating a wider range of species and varieties in associations, rotations and sequences;
- using well adapted, high-yielding varieties and good quality seeds;
- integrated management of pests, diseases and weeds;
- efficient water management.

3.3 Underlying principles: managing for resilience

Sustainable crop production and climate change adaptation and mitigation are not distinct from each other. Managing agro-ecosystems for producing food and fodder and managing agro-ecosystems to adapt to and mitigate climate change have the same underlying principles, and can work together to achieve the same goal: feeding the population, into the future. Both crop production and climate change adaptation and mitigation require a resilient ecosystem, and this can be ensured through approaches and practices that are based on the sustainable management of biodiversity and ecosystem services.

Climate-smart agriculture in crop production is a sustainable crop production system (Figure 1) that – inherently in its nature – addresses climate change. Sustainable agricultural systems also contribute to the delivery and maintenance of a range of valued public goods, such as clean water, carbon sequestration, flood protection, groundwater recharge, and landscape amenity value. By definition, sustainable agricultural systems are less vulnerable to shocks and stresses. In terms of technologies, therefore, productive and sustainable agricultural systems make the best of both crop varieties and livestock breeds, and their agro-ecological and agronomic management (Beddington et al., 2012). Sustainable crop production systems are, by definition, climate-smart and provide options for adapting to, and mitigating, climate change.
3.3.1 Natural biological processes

The negative effects of climate change on productivity are already being felt by the agriculture sector today. For example, in India the rice production decreased by 23 percent during 2001–2002 (FAOSTAT, 2012) owing to drought. In order to increase future food production, crop production will need to adapt to and mitigate climate change. Hence, so as to contrast the effects of climate change, there is a need for a better understanding of the biological processes involved in farm management practices and of both above and below ground management. In this regard, ecosystem management must incorporate measures of resilience and risk mitigation into agriculture – elements that are increasingly relevant under changing climates – and, for example the maintenance of biodiversity and ecosystem services is critical.

Climate-resilient systems are those that offer a range of productivity, socio-economic and environmental benefits to producers and to society at large, including high and stable production and profitability; adaptation and reduced
vulnerability to climate change; enhanced ecosystem functioning and services; and reductions in agriculture’s GHG emissions and “carbon footprint”.

**Biodiversity and ecosystem services**

Biodiversity is necessary in order to sustain key functions of the ecosystem, its structure and process – and to provide essential ecosystem services. It is an important regulator of agro-ecosystem functions, not only in the strictly biological sense of impact on production but also in satisfying a variety of needs of the farmer and society at large. In particular, it increases resilience of agro-ecosystems and is, as such, a means for risk reduction and adaptation to climate change. Agro-ecosystem managers, including farmers, can build upon, enhance and manage the essential ecosystem services provided by biodiversity in order to work towards sustainable agricultural production.

The conservation and enhancement of biodiversity in cropping systems both above and below ground (e.g. soil biodiversity – see Box 1), and the management of ecosystem services, underpin sustainable farming practices. The composition and diversity of planned biodiversity (e.g. selected crops) influences the nature of the associated diversity – plant, animal, microbial – and hence also of ecosystem services. An ecosystem approach is a means to integrate planned biodiversity that is maintained with the associated diversity (e.g. wild pollinators – see case study). For example, greater on-farm diversity of plants, greater soil coverage and more perennial cultivation may lend greater resilience to the agroecosystem (e.g. resistance to noxious species). Good farming practices that follow ecosystem-based approaches should:

- maintain and sustainably utilize a high level of crop genetic diversity, both on farms and in seed banks, which will help to increase and sustain production levels and nutritional diversity throughout the full range of different agro-ecological conditions, and provide opportunities for crop breeding;
- integrate, through ecosystem-approach strategies, the planned biodiversity (crop sequences and associations) that is maintained with the associated diversity (for example, wild pollinators);
- adopt production system management strategies, such as not disturbing soil, maintaining mulch covers from crop residues and cover crops that increase the biological activity and diversity of the production system;
- consider the benefits of having fragmented land (riparian areas, forest land within the agricultural landscape) on the agricultural yield, through improved biological processes such as pollination; and
- improve the adaptation of good farming practices (i.e. pest management strategies, etc.) that follow ecosystem-based approaches designed to improve the sustainability and agricultural biodiversity of production systems.(PAR, 2012).
Box 1: Biological Nitrogen Fixation

Nitrogen is commonly the most limiting plant nutrient in arable farming and also the most expensive element as a mineral fertilizer. Biological nitrogen fixation (BNF), whereby atmospheric nitrogen (N\textsubscript{2}) is reduced to ammonia (NH\textsubscript{3}) in the presence of an enzyme called nitrogenase, holds great promise for smallholder farmers. In agricultural areas, about 80 percent of BNF is achieved by such a symbiotic association, between the legumes and the nodule bacteria, the \textit{rhizobia} (FAO, 2009a). Farmers, through legume genotype selection, legume/grass seed proportion in forage mixtures, inoculation with bacteria such as \textit{rhizobia}, crop nutrition (especially N and P), weed, disease and pest controls, planting time, cropping sequence and intensity, and defoliation frequency of forage swards, have some scope to influence BNF, and some legume species are better at fixing nitrogen than others. In perennial temperate forage legumes, red clover and lucerne can typically fix 200–400 kg N/ha (whole plant fixation, above and below ground) (FAO, 2009a). However, some factors affecting BNF such as soil acidity, P deficiency, excess mineral N, deficiency of Ca, Mo, Co and B and the possible effects of climate change – excessive soil moisture and drought – limit BNF.

Box 2: Managing plant genetic resources for food and agriculture for adaptation

Management of plant genetic resources for food and agriculture (PGRFA) for adapting to climate change includes strategies such as diversification of crops and varieties, the growing of varieties tolerant to the effects of climate change, such as drought and flooding or early-maturing ones adapted to changes in cropping seasons, as well as alterations in cropping patterns and rotations. Another major form of adaptation is transitioning to more resilient production systems such as conservation agriculture or systems with integrated nutrient and soil management. It is important to note that managing PGRFA is not just one more option among a list of adaptation tools, but rather a key catalyst for making other agricultural adaptation tools and strategies work better.

Some of these biodiversity-based adaptation measures can be implemented readily at the level of individual farms or households, others need broader infrastructural and political support and have much longer timeframes, such as the low level of investment in the conservation of grasslands, that have an enormous potential to, for example, sequester carbon, provide food and feed (e.g. honey, grazing livestock, wild cereals, hunting, medicinal plants) and energy (solar, charcoal, hydro-power, wind-power).
Soil health

Agricultural intensification requires fertile and healthy soils, because nutrient deficiencies and soil-borne pests and diseases are major limiting factors for crop production, notable on degraded soils in large areas of Africa and Southeast Asia. For example, the parasitic weed, *Striga* (Box 3), is far less of a problem when found in healthy soils. Even the damage caused by pests not found in the soil, such as maize stem borers, is reduced in fertile soils.

**Box 3: *Striga***

*Striga* is considered to be one of the biggest obstacles to food production in Africa and includes about 40 species, of which 11 species are parasites on agricultural crops (FAO, 2003). It is a parasitic weed that enters the roots of other plants and removes their essential nutrients, therefore reducing growth and is one of the major constraints to the production of cereals and legumes in sub-Saharan Africa. On average, *Striga* infests as much as 40 million ha of farmland in sub-Saharan Africa, causes a yield loss of up to 100 percent (IAASTD, 2009) and an average reduction in productivity of 12 to 25 percent. In Africa, it affects the livelihood of about 300 million people (FAO, 2003).

*Striga* is strengthened by the practice of monoculture of cereals that promotes its formation owing to the continuous cropping and poor agronomic practices such as the lack of rotation. This applies in particular to agro-ecosystems where a high human population density imposes a strong pressure on arable land. It has been known to have devastating effects on many food crops, specifically maize (*Zea mays*), sorghum (*Sorghum bicolor*) and sugar cane (*Saccharum officinarum*) (Eplee, 1992), which represents a real threat to cereal production and food security of affected countries.

People perform hand weeding but in extreme cases have to abandon their agricultural land because of heavy infestation. However, this only increases the parasite pressure in contaminated fields, as the seed can remain dormant and viable in the soil for at least 5–10 years (Parker and Riches, 1993). The pest control methods practised by farmers (organic manure, crop rotation, fallow) are varied but the results can be unsatisfactory. A combination of pest control methods (biological, chemical and cultural) to prevent the spread of pests through the use of reduced-risk products gives better protection for the crops and improves yields. Projects have been implemented in Benin, Burkina-Faso, Niger, Mali and Senegal comparing different management methods to alleviate the problem (FAO, 2008b).

*Striga* thrives in temperatures of 30–35 °C under semi-arid conditions; thus any future climate change resulting in temperature rise or affecting rainfall patterns may influence the geographic distribution and invasive potential of *Striga* as habitats suitable for *Striga* growth might expand and/or shift to new areas (Cotter, de la Pena-Lavander and Sauerborn, 2012).
Conservation agriculture is a concept for resource-saving agricultural crop production that aims at achieving competitive agricultural yields while helping to reduce degradation of natural resources. Undisturbed soil with a sufficient supply of organic matter provides a good habitat for soil fauna. Avoidance of mechanical soil tillage results in increasing population of earthworms, millipedes, mites and other animals living in the soil. This macro fauna takes over the tillage task and builds soil porosity and structure. It incorporates organic matter from the soil surface; the excrements provide stable soil aggregates and the vertical macro-pores created by the worms serve as drainage channels for excess water. This makes the land less susceptible to flooding and erosion, since water infiltration deep into the ground is improved. The organic matter incorporated by soil fauna into the soil improves soil structure and water storage capacity, which in turn helps plants to survive longer during drought spells. Both are important strategies for farming adapted to climate change.

Increased levels of organic matter in soil also help mitigate climate change by storing carbon from atmospheric carbon dioxide in soil organic matter. The formation of stable organic matter through the process of humification is mediated by soil micro-organisms. Another element of biological tillage is the introduction of crops including trees and shrubs with deep penetrating tap-roots. Some of these “pioneer” crops such as lupine, jack-beans (canavalia) or radish can break subsoil compactions if, for example, planted in the crop rotation or in intercrop association as green manure cover crops.

Approaches and practices
The achievement of sustainable crop production intensification needs to take into consideration all aspects of sustainability (social, economic, political and environmental) in conjunction with the overall context. Global, regional and national instruments, treaties, conventions, codes and policies are an essential component in the enhancement and sustainable use of natural resources. At a technical level, there are a wide range of agricultural practices, approaches and technologies that are currently available that help to increase production while still focusing on environmental sustainability (Table 2). However, improving market linkages, reducing post-harvest losses and conserving agricultural biodiversity will assist in the improvement of the impacts of farming practices.
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<td>Plant breeding – developing improved and adapted varieties</td>
<td>Restoration of cultivated peaty soils and degraded lands</td>
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<td>Integrated systems (e.g. crop-livestock, agro-forestry)</td>
<td>Improved rice cultivation techniques to reduce CH$_4$ emissions</td>
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<td>Intercropping</td>
<td>Improved nitrogen fertilizer application techniques to reduce N$_2$O emissions</td>
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<td>Integration of the use of climate forecasts into cropping decisions</td>
<td>Efficient management of carbon and nitrogen flows</td>
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<td>Developing strong seed systems: improving seed production and distribution</td>
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<td>Soil management practices</td>
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<tr>
<td>Plant breeding (develop and adopt new cultivars)</td>
<td>Promotion of legumes in crop rotations</td>
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Sources: FAO, 2008a; FAO, 2009b and FAO, 2012

**CASE STUDIES**

**Case Study 1: Managing ecosystem services – the case of pollination**

In multiple agro-ecosystems and ecologies, pollinator-friendly management practices have been identified that serve to enhance yields, quality, diversity and resilience of crops and cropping systems. Examples include:
- preserving wild habitat;
- managing cropping systems, flower-rich field margins, buffer zones and permanent hedgerows to ensure habitat and forage;
- Cultivating shade trees;
- managing for bee nest sites, e.g. by leaving standing dead trees and fallen branches undisturbed;
- reducing application of pesticides and associated risks;
- establishing landscape configurations that favour pollination services.

Pollination management practices can also be undertaken to respond to climate change. Examples of how farming communities may best adapt to climate change impacts on pollinators include giving consideration to the seasonal availability of resources needed by pollinators, and ensuring connectivity of natural habitats in farming areas (allowing easier pollinator dispersal for range shifts in response to changing climates).

Pollination management practices can also be applied to mitigate climate change. Many good farming practices that sustain the ability of agroecosystems to deliver ecosystem services involve measures to increase ground cover and crop-associated biodiversity. Hence, measures to promote pollinators include providing more non-crop flowering resources in fields, such as cover crops, strip crops or hedgerows.
Case Study 2: Conservation Agriculture with ripper-furrower system in Namibia

Farmers in the north of Namibia are using conservation agriculture practices to grow drought-tolerant crops, including millet, sorghum and maize. The farming system uses a tractor-drawn ripper-furrower to rip the hard pan to a depth of 60 cm and form furrows for in-field rainfall harvesting. The harvested water is concentrated in the root zone of crops, which are planted in the rip lines together with a mixture of fertilizer and manure. Tractors are used in the first year to establish the system. From the second year, farmers plant crops directly into the rip lines using an animal-drawn direct seeder.

Crop residues are consumed mainly by livestock, but the increased biomass produced by the system also provides some residues for soil cover. Farmers are encouraged to practise crop rotation with legumes. These techniques lengthen the growing season and improve soil structure, fertility and moisture retention. Average maize yields have increased from 300 kg/ha to more than 1.5 tonnes.

Case Study 3: System of Rice Intensification in Afghanistan

The System of Rice Intensification (SRI) is a set of farming practices developed to increase the productivity of land and water, as well as other resources. SRI is based on the principle of developing healthy, large and deep root systems that can better resist drought, waterlogging and rainfall variability – all possible effects of climate change. It has proved particularly beneficial in some areas worldwide as it requires only intermittent water application to create wet and dry soil conditions, instead of continuous flood irrigation. The average increase in income from SRI in eight countries (Bangladesh, Cambodia, China, India, Indonesia, Nepal, Sri Lanka and Vietnam) has been shown to be around 68%, with yield increases of 17–105% and decreases in water requirement between 24% and 50% (Africare, Oxfam America, WWF-ICRISAT Project, 2010).

Considering the better growth and performance of rice plants and subsequent increase in yields and productivity of the rice field with SRI elsewhere. An attempt was made in 2011 in Afghanistan to introduced SRI in the context of intensified production system, through a Farmer field Schools (FFS) national project. With SRI, yields of up to 6 tonnes per hectare were achieved – double the farmers’ average yields in the area – using 50% less water than used in conventional rice cultivation practices in Afghanistan. It has also reduced the use of chemical fertilizers, and there has been no insect or disease infestation at all in SRI fields. The use of SRI is now being extended throughout a number of provinces in Afghanistan as one way to mitigate the effects of unreliable rainfall.

Case Study 4: Integrated crop–livestock
In conventional farming systems, there is a clear distinction between arable crops and pastureland. With sustainable crop production intensification, this distinction no longer exists, since annual crops may be rotated with pasture without the destructive intervention of soil tillage (FAO, 2011). Practical innovations have harnessed synergies between crop, livestock and agroforestry production to improve the economic and ecological sustainability while at the same time providing a flow of valued ecosystem services. Through increased biological diversity, efficient nutrient recycling, improved soil health and forest conservation, these systems increase environmental resilience, and contribute to climate change adaptation and mitigation. They also enhance livelihood diversification and efficiency by optimizing production inputs, including labour, and increase resilience to economic stresses (FAO, 2011).

An integrated crop–livestock system implies a diverse range of integrated ecological, biophysical and socio-economic conditions (FAO, 2010b), aims to increase profits and sustain production levels while minimizing the negative effects of intensification and at the same time preserves the natural resources (IFAD, 2009). It has environmental, economic and social benefits. It is based on the principle of enhancing the natural biological processes above and below the ground, the integrated system representing a winning combination that: (a) reduces erosion; (b) increases crop yields, soil biological activity and nutrient recycling; (c) intensifies land use, improving profits; and (d) can therefore help reduce poverty and malnutrition and strengthen environmental sustainability (IFAD, 2009).

There are numerous examples of how crop–livestock systems are already implemented. For example, in the Southern Caucasus region, the integration of grain and livestock production in a system of mixed farming – in which cereals and pulses are grown in flatter, better-watered lowland soils and sheep and goats grazed and browsed on rougher upland terrain (whether locally or by means of seasonal transhumance) – proved to be effective, both ecologically and nutritionally, in sustaining the growing number of sedentary villages (FAO, 2010c). Also specifically in Azerbaijan, near Xudat, farmers have adapted to the great diversity of morphology, climate and soils by developing a mosaic of crops and livestock systems, by alternating annual and perennial crops, and by avoiding cultivation of fragile environments in order to protect wild biodiversity, soil and water resources (FAO, 2010c).
References:


