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"Climate-Smart" Agriculture

Policies, Practices and Financing for Food Security, Adaptation and Mitigation

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Food and Agriculture Organization of the United Nations (FAO)
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Content

Scope of paper

Agriculture in developing countries must undergo a significant transformation in order to meet the related challenges of achieving food security and responding to climate change. Projections based on population growth and food consumption patterns indicate that agricultural production will need to increase by at least 70 percent to meet demands by 2050. Most estimates also indicate that climate change is likely to reduce agricultural productivity, production stability and incomes in some areas that already have high levels of food insecurity. Developing climate-smart agriculture[1] is thus crucial to achieving future food security and climate change goals. This paper examines some of the key technical, institutional, policy and financial responses required to achieve this transformation. Building on case studies from the field, the paper outlines a range of practices, approaches and tools aimed at increasing the resilience and productivity of agricultural production systems, while also reducing and removing emissions. The second part of the paper surveys institutional and policy options available to promote the transition to climate-smart agriculture at the smallholder level. Finally, the paper considers current financing gaps and makes innovative suggestions regarding the combined use of different sources, financing mechanisms and delivery systems.

Key messages

1) Agriculture in developing countries must undergo a significant transformation in order to meet the related challenges of food security and climate change.

PART 1

2) Effective climate-smart practices already exist and could be implemented in developing country agricultural systems.
3) Adopting an ecosystem approach, working at landscape scale and ensuring intersectoral coordination and cooperation is crucial for effective climate change responses.
4) Considerable investment is required in filling data and knowledge gaps and in research and development of technologies, methodologies, as well as the conservation and production of suitable varieties and breeds.

PART 2

5) Institutional and financial support will be required to enable smallholders to make the transition to climate-smart agriculture.
6) Strengthened institutional capacity will be needed to improve dissemination of climate-smart information and coordinate over large areas and numbers of farmers.
7) Greater consistency between agriculture, food security and climate change policy-making must be achieved at national, regional and international levels.

PART 3

8) Available financing, current and projected, are substantially insufficient to meet climate change and food security challenges faced by the agriculture sector.
9) Synergistically combining financing from public and private sources, as well as those earmarked for climate change and food security are innovative options to meet the investment requirements of the agricultural sector.
10) To be effective in channelling fast-track financing to agriculture, financing mechanisms will need to take sector-specific considerations into account.

[1] Definition of climate-smart agriculture: agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals.

Introduction

Over the past six decades world agriculture has become considerably more efficient. Improvements in production systems and crop and livestock breeding programmes have resulted in a doubling of food production while increasing the amount of agricultural land by just 10 percent. However, climate change is expected to exacerbate the existing challenges faced by agriculture. The purpose of this paper is to highlight that food security and climate change are closely linked in the agriculture sector and that key opportunities exist to transform the sector towards climate-smart systems that address both.

Estimates show that world population will grow from the current 6.7 billion to 9 billion by 2050 with most of the increase occurring in South Asia and sub-Saharan Africa. Taking into account the changes in the composition and level of consumption associated with growing household incomes, FAO estimates that feeding the world population will require a 70 percent increase in total agricultural production[2] (Bruinsma, 2009).

At the same time, climate change threatens production's stability and productivity. In many areas of the world where agricultural productivity is already low and the means of coping with adverse events are limited, climate change is expected to reduce productivity to even lower levels and make production more erratic (Stern Review 2006; Cline 2007; Fisher *et al*. 2002; IPCC 2007). Long term changes in the patterns of temperature and precipitation, that are part of climate change, are expected to shift production seasons, pest and disease patterns, and modify the set of feasible crops affecting production, prices, incomes and ultimately, livelihoods and lives.

Preserving and enhancing food security requires agricultural production systems to change in the direction of higher productivity and also, essentially, lower output variability in the face of climate risk and risks of an agro-ecological and socio-economic nature. In order to stabilize output and income, production systems must become more resilient, i.e. more capable of performing well in the face of disruptive events. More productive and resilient agriculture requires transformations in the management of natural resources (e.g. land, water, soil nutrients, and genetic resources) and higher efficiency in the use of these resources and inputs for production. Transitioning to such systems could also generate significant mitigation benefits by increasing carbon sinks, as well as reducing emissions per unit of agricultural product.

Transformations are needed in both commercial and subsistence agricultural systems, but with significant differences in priorities and capacity. In commercial systems, increasing efficiency and reducing emissions, as well as other negative environmental impacts, are key concerns. In agriculture-based countries, where agriculture is critical for economic development (World Bank, 2008), transforming smallholder systems is not only important for food security but also for poverty reduction, as well as for aggregate growth and structural change. In the latter group of countries, increasing productivity to achieve food security is clearly a priority, which is projected to entail a significant increase in emissions from the agricultural sector in developing countries (IPCC 2007). Achieving the needed levels of growth, but on a lower emissions trajectory will require a concerted effort to maximize synergies and minimize tradeoffs between productivity and mitigation. Ensuring that institutions and incentives are in place to achieve climate-smart transitions, as well as adequate financial resources, is thus essential to meeting these challenges. In this context mitigation finance can play a key function in leveraging other investments to support activities that generate synergies.

[2] These estimates refer to a specific baseline scenario which excludes, among other elements, the effects of climate change on production. For more details see FAO (2006).

The above summarized key issues are elaborated in three main sections. In section 1 examples of climate-smart production systems are provided to illustrate what can be achieved and also highlight the knowledge and technical gaps that need to be addressed. In part 2 the role that institutions and policy must play in the transformation of production systems to climate-smart production systems is examined. In part 3 we discuss the financial opportunities and the shortfalls and constraints that need to be resolved to ensure the adequate support in transitioning to climate-smart agriculture. Annex I provides examples of FAO methods and tools which can support national climate-smart agriculture.

Key message

1) Agriculture in developing countries must undergo a significant transformation in order to meet the related challenges of food security and climate change.

Part 1 - Examples of climate-smart production systems

1.1 Introduction

1.1.1 Considerations for climate-smart production systems

The production, processing and marketing of agricultural goods are central to food security and economic growth. Products derived from plants and animals include foods (such as cereals, vegetables, fruits, fish and meat), fibers (such as cotton, wool, hemp and silk), fuels (such as dung, charcoal and biofuels from crops and residues) and other raw materials (including medicines, building materials, resins, etc.). Production has been achieved through a number of production systems which range from smallholder mixed cropping and livestock systems to intensive farming practices such as large monocultures and intensive livestock rearing. The sustainable intensification of production, especially in developing countries, can ensure food security and contribute to mitigating climate change by reducing deforestation and the encroachment of agriculture into natural ecosystems (Burney *et al*, 2010 and Bellassen, 2010).

The overall efficiency, resilience, adaptive capacity and mitigation potential of the production systems can be enhanced through improving its various components, some of the key ones are highlighted below. Examples of production systems are provided at the end of the section to illustrate the feasibility and constraints of developing climate smart agriculture. Other key issues, such as access to markets, inputs, knowledge, finances and issues related to land tenure are also fundamental for ensuring food security, these issues are reviewed in part 2 of this document.

Soil and nutrient management: the availability of nitrogen and other nutrients is essential to increase yields. This can be done through composting manure and crop residues, more precise matching of nutrients with plant needs, controlled release and deep placement technologies or using legumes for natural nitrogen fixation. Using methods and practices that increases organic nutrient inputs, retention and use are therefore fundamental and reduces the need of synthetic fertilizers which, due to cost and access, are often unavailable to smallholders and, through their production and transport, contribute to GHG emissions.

Box 1: Improving soil nutrient content

Many subsistence crop production system soils are depleted and have poor nutrient content. This can be partially resolved by the use of legumes as green manures, planted in intercropping systems, as part of a scheme of crop rotation or in agro-forestry systems. For example, the haulms of the legume groundnut can be eaten by livestock or incorporated into the soil. In this latter case, the yield of the subsequent crop (e.g. maize or rice) can be much higher (as much as double), even if the groundnut yield is low. In forage legume/grass mixtures, nitrogen can be found to be transferred from legume to grass varieties (e.g. 13 to 34 percent of fixed N). Used as a livestock feed it can also increase food conversion ratios and decrease methane emissions. Legumes also provide a useful protein source for humans. [FAO, 2009c].

Water harvesting and use: Improved water harvesting and retention (such as pools, dams, pits, retaining ridges, etc.) and water-use efficiency (irrigation systems) are fundamental for increasing production and addressing increasing irregularity of rainfall patterns. Today, irrigation is practiced on 20 percent of the agricultural land in developing countries but can generate 130 percent more yields than rain-fed systems. The expansion of efficient management technologies and methods, especially those relevant to smallholders is fundamental.

Box 2: Zaï and stone bunds in Burkina Faso

In Yatenga province, farmers reclaimed degraded farmland by digging planting pits, known as zaï. This traditional technique was improved by increasing depth and diameter of the pits and adding organic matter. The Zaï concentrate both nutrients and water and facilitate water infiltration and retention. Thus lands which used to be barely productive can now achieve yields from 300kg/ha to 1500kg/ha, depending on rainfalls. In the same province, farmers, with support from Oxfam, began building stone contour bunds to harvest rainwater. The bunds allows water to spread evenly through the field and infiltrates the soil and also prevents soil and organic matter being washed away. Thanks to local networks of farmers these techniques are now used on 200 000 to 300 000 ha (Reij 2009).

Pest and disease control: There is evidence that climate change is altering the distribution, incidence and intensity of animal and plant pests and diseases as well as invasive and alien species. The recent emergence in several regions of multi-virulent, aggressive strains of wheat yellow rust adapted to high temperatures is a good indication of the risks associated with pathogen adaptation to climate change. These new aggressive strains have spread at unprecedented speed in five continents resulting in epidemics in new cropping areas, previously not favourable for yellow rust and where well-adapted, resistant varieties are not yet available. The wheat disease Spot Blotch, caused by Cohliobolus sativus, is another example, causing heavy losses in Southern Brazil, Bolivia, Paraguay, and Eastern India, due to a lack of resistance to the disease. As wheat growing areas of Asia become warmer, the pathogen is likely to spread even further and cause further losses.

Resilient ecosystems: Improving ecosystem management and biodiversity can provide a number of ecosystem services, which can lead to more resilient, productive and sustainable systems that may also contribute to reducing or removing greenhouse gases. Services include, control of pests and disease, regulation of microclimate, decomposition of wastes, regulating nutrient cycles and crop pollination. Enabling and enhancing the provision of such services can be achieved through the adoption of different natural resource management and production practices.

Genetic resources: Genetic make-up determines a plants and animals tolerance to shocks such as temperature extremes, drought, flooding and pests and diseases. It also regulates the length of growing season/production cycle and the response to inputs such as fertilizer, water and feed. The preservation of genetic resources of crops and breeds and their wild relatives is therefore fundamental in developing resilience to shocks, improving the efficient use of resources, shortening production cycles and generating higher yields (and quality and nutritional content) per area of land. Generating varieties and breeds which are tailored to ecosystems and the needs of farmers is crucial.

Box 3: Seed systems

Efficient seed production systems are required to ensure rapid access of farmers to varieties adapted to their new agro-ecological conditions.

In northern Cameroon, local varieties of millet, sorghum and maize were not adapted to lower rainfall and increased drought. The agriculture research institute developed adapted earlier maturing varieties of these crops and with the support of FAO farmer seed enterprises were organized to produce certified seed for sale to farmers in the surrounding villages. The new varieties produced good yields in spite of the unfavourable agro-ecology which has resulted in its hi demand and led in the creation of 68 community seed enterprises with over 1 000 member (both women and men) producing over 200 Tons of seed per year. There are similar projects in other countries [Guei, 2010].

FAO has supported the introduction of new seed varieties in Haiti to increase food production and facilitate the transition from emergency to rehabilitation. One of the success stories has been the introduction from Guatemala of the bean variety ICTA Lijero, which is very early-maturing and is resistant to one of the major disease problems in Haiti, the Golden Mosaic Virus. This variety allows farmers in irrigated plains to have two harvests of beans before the starting of the hot season. Since 2007, FAO has supported community seed producer groups in seed production of ICTA Lijero. In 2009, the FAO seed multiplication programme has supported 34 seed producers groups that have produced 400T of bean seed including ICTA Lijero.

Harvesting, processing and supply chains: Efficient harvesting and early transformation of agricultural produce can reduce post-harvest losses (PHL) and preserve food quantity, quality and nutritional value of the product. It also ensures better use of co-products and by-products, either as feed for livestock, to produce renewable energy in integrated systems or to improve soil fertility. As supply chains become longer and more complex it becomes evermore important to increase the operational efficiency of processing, packaging, storage, transport, etc to ensure increased shelf life, retain quality and reduce carbon footprints. Food processing allows surplus to be stored for low production years or allows a staggered sale. This ensures greater availability of food and income throughout the season and in years of low production. Food processing creates jobs and income opportunities, especially for women.

Box 4: Improved technologies for reducing post harvest losses in Afghanistan

In the northern region of Afghanistan where more than half of the country's cereals are produced, many farmers store their crop in plastic and fibre bags or in farm buildings without proper flooring, doors and windows. This offers limited protection, resulting in significant post-harvest losses. The Government requested support from FAO to provide silos for communities and farming households for grain storage. With funds provided by the Government of the Federal Republic of Germany, FAO implemented a project from 2004 to 2006 with the objectives reducing post-harvest losses and enhancing the technical capacity of local tinsmiths, blacksmiths and craftsmen for construction of metallic grain silos. Seven main grain producing provinces were selected as focus areas. Technical personnel from the Ministry of Agriculture and NGOs trained 300 local artisans in the manufacture of silos, while contracts were issued to over 100 tinsmiths who built metallic silos ranging from 250 to 1 800 kilogram capacity for distribution in local communities. The project also oversaw the construction of grain warehouses for community use in 12 sites and trained beneficiaries on how best to operate and manage the facilities. It was found that the use of the metallic silos had reduced storage loss from 15-20 percent to less than 1-2 percent, grains were of higher quality (as protected from insects, mice and mould) and could be stored for longer. Based on the training received, tinsmiths, blacksmiths and craftsmen are now fabricating silos as a profitable enterprise.

1.1.2 Achievements and constraints

Modern technologies and advances in the agriculture sector, such as inorganic fertilizers, pesticides, feeds, supplements, high yielding varieties, and land management and irrigation techniques have considerably increased production. This has been fundamental in meeting the food needs of a growing population and in generating economic growth needed for poverty reduction. However in certain circumstances these practices and techniques have caused ecological damage, degradation of soils, unsustainable use of resources; outbreak of pests and diseases and have caused health problems to both livestock and humans. Such unsustainable practices have resulted in lower yields, degraded or depleted natural resources and have been a driver of agriculture's encroachment into important natural ecological areas such as forests. The quest to increase yields and to do this without expanding the amount of land under cultivation has often heightened the vulnerability of production systems to shocks such as outbreaks of pests and diseases, droughts and floods and changing climate patterns. In addition, there are many production systems in developing countries that due to a lack of finance, resources, knowledge and capacity are well below the potential yield that could be achieved.

1.1.3 Existing systems, practices and methods suitable for climate-smart agriculture

There are several challenges in transitioning to high production, intensified, resilient, sustainable, and low-emission agriculture. However, as shown in the examples below, careful selection of production systems, adoption of appropriate methods and practices and use of suitable varieties and breeds, can allow considerable improvements to be made. There are numerous FAO resources, guidelines, tools, technologies and other applications to assist policy makers, extension workers and farmers in selecting the most appropriate production systems, undertaking land use and resource assessments, evaluating vulnerability and undertaking impact assessments. Recently, FAO has developed a carbon balance tool (EX-ACT) to appraise mitigation impact of newly proposed food security, agriculture policies and projects. The tool is now being used in over 20 countries with IFAD, World Bank and GTZ. FAO methods and tools are provided in Annex I.

However, there are still considerable knowledge gaps relating to the suitability and use of these production systems and practices across a wide variety of agro-ecological and socio-economic contexts and scales. There is even less knowledge on the suitability of different systems under varying future climate change scenarios and other biotic and abiotic stresses. However, in many cases even existing knowledge, technologies and inputs have not reached farmers, especially in developing countries. For this to be achieved there is a need for polices, infrastructures and considerable investments to build the financial and technical capacity of farmers (especially smallholders) to enable them to adopt climate-smart practices that could generate economic rural growth and ensure food security. The last two sections of the document therefore specifically address these institutional, policy (page 17) and financial (page 24) issues.

1.2 Crops: rice production systems

Rice is fundamental for food security with approximately three billion people, about half of the world population, eating rice every day. Many of the poorest and most undernourished in Asia depend on rice as their staple food. Approximately 144 million ha of land is cultivated under rice each year. The waterlogged and warm soils of rice paddies make this production system a large emitter of methane. Rice production is and will be affected by changes in climate. Irregular rainfall, drier spells in the wet season (damaging young plants), drought and floods are all having an effect on yields. This has also caused outbreaks of pests and diseases, with large losses of crops and harvested products. Peng *et al.* (2004) have analyzed 6 years of data from 227 irrigated rice farms in six major rice-growing countries in Asia, which produces more than 90 percent of the world's rice. They found that rising temperatures, especially night temperatures, have had a severe effect on yields causing losses of 10 -20 percent of harvests in some locations.

A number of methods and practices are being adopted to address these challenges. For example, production systems have been adapted by altering cropping patterns, planting dates and farm management techniques. For instance, embankments have been built to protect rice farms from floods and new drought and submergence tolerant varieties of rice are being produced and distributed by government institutions and the private sector. In addition, many farmers are diversifying their production systems, growing other cereals, vegetables and rearing fish and animals (such as pigs and chickens). The residues and waste from each system are being composted and used on the land, thereby reducing the need for external inputs. This diversification has increased incomes, improved nutrition, built resilience to shocks and minimized financial risks. The development of advanced modeling techniques, mapping the effect of climate change on rice-growing regions and providing crop insurance are other examples of managing risks and reducing vulnerability. Research on rice cultivation has identified that emissions mainly occur in the few months of the year when the ground is fully waterlogged. A more integrated approach to rice paddy irrigation and fertilizer application has therefore been found to substantially reduce emissions. The use of ammonium sulphate supplements have also been used to promote soil microbial activity and reduce methanogens. In addition, urea deep placement (UDP) technology has been developed where urea in the form of super granules or small briquettes is placed under the soil near the plant roots and out of the floodwater where it is susceptible to loss. In Bangladesh, this practice has shown 50-60 percent savings in urea use and yield increases of about 1 ton per ha.

Box 5: Mitigating methane emissions through new Irrigation Schemes (Bohol, Philippines)

Bohol Island is one of the biggest rice-growing areas in the Philippines' Visayas regions. Before the completion of the Bohol Integrated Irrigation System (BIIS) in 2007, two older reservoirs (Malinao and Capayas Dam) were beset by problems and unable to ensure sufficient water during the year's second crop (November to April), especially for farmers who live farthest downstream from the dam. This problem was aggravated by the practice of unequal water distribution and a preference by farmers for continuously flooded rice growing conditions.

In the face of declining rice production, the National Irrigation Administration (NIA) created an action plan for the BIIS. This included the construction of a new dam (Bayongan Dam; funded by a loan from the Japan Bank for International Cooperation) and the implementation of a water-saving technology called Alternate-Wetting and Drying (AWD) which was developed by the International Rice Research Institute (IRRI) in cooperation with national research institutes. The visible success of AWD in pilot farms, as well as specific training programmes for farmers, were able to dispelled the widely held perception of possible yield losses from non-flooded rice fields. Ample adoption of AWD facilitated an optimum use of irrigation water, so that the cropping intensity could be increased from ca. 119 % to ca. 160 % (related to the maximum of 200 % in these double-cropping systems). Moreover, according to the revised IPCC methodology (IPCC 2006), 'multiple aeration', to which the AWD corresponds, potentially reduces methane emissions by 48 % compared to continuous flooding of rice fields. AWD therefore generates multiple benefits related to methane emission reduction (mitigation), reducing water use (adaptation where water is scarce), increasing productivity and contributing to food security (Bouman *et al.* 2007).

1.3 Crops: Conservation Agriculture

Conservation Agriculture (CA) is a term encompassing farming practices which have three key characteristics: 1. minimal mechanical soil disturbance (i.e. no tillage and direct seeding); 2. maintenance of a mulch of carbon-rich organic matter covering and feeding the soil (e.g. straw and/or other crop residues including cover crops); and 3. rotations or sequences and associations of crops including trees which could include nitrogen-fixing legumes. There are currently some 117 million hectares (about 8 percent of global arable cropland) in such systems worldwide, increasing by about 6 million hectares per year (www.fao.or/ag/ca). They cover all agro-ecologies and range from small to large farms. CA offers climate change adaptation and mitigation solutions while improving food security through sustainable production intensification and enhanced productivity of resource use.

Management of soil fertility and organic matter, and improvement of the efficiency of nutrient inputs, enable more to be produced with proportionally less fertilizers. It also saves on energy use in farming and reduces emissions from the burning of crop residues. Moreover it helps sequester carbon in soil. Avoidance of tillage minimises occurrence of net losses of carbon dioxide by microbial respiration and oxidation of the soil organic matter and builds soil structure and biopores through soil biota and roots. Maintenance of a mulch layer provides a substrate for soil-inhabiting micro-organisms which helps to improve and maintain water and nutrients in the soil. This also contributes to net increase of soil organic matter - derived from carbon dioxide captured by photosynthesis in plants, whose residues above and below the surface are subsequently transformed and sequestered by soil biota.

Rotations and crop associations that include legumes are capable of hosting nitrogen-fixing bacteria in their roots, which contributes to optimum plant growth without increased GES emissions induced by fertiliser's production.

Conservation Agriculture also contributes to adaptation to climate change by reducing crop vulnerability. The protective soil cover of leaves, stems and stalks from the previous crop shields the soil surface from heat, wind and rain, keeps the soil cooler and reduces moisture losses by evaporation. In drier conditions, it reduces crop water requirements, makes better use of soil water and facilitates deeper rooting of crops; in extremely wet conditions, CA facilitates rain water infiltration, reducing soil erosion and the risk of downstream flooding. Conservation Agriculture also contributes to protect crops from extreme temperatures. Crop rotation over several seasons also minimises the outbreak of pests and diseases.

CA thus offers opportunities for climate change adaptation and mitigation solutions, while improving food security through sustainable production intensification and enhanced productivity of resource use.

Box 6: Country examples of conservation agriculture

In **Uzbekistan**, where monocropping of cotton is common place, FAO has contributed to enhance the productivity of cotton through CA including no-till, diversification (rotation with wheat and grain legumes) and selected cover crops. This involved the establishment of demonstration plots and training in soil water dynamics, organic matter improvement and related soil stability measures, methodologies and techniques. The technologies introduced during the project in Tashkent resulted in improved soil quality, crop development and yields. The project also showed that farmers were willing to use the CA practices step by step with a well-tested crop rotation system.

In **Egypt**, CA was introduced in the rice-cropping systems of the Nile Delta, where more than 50 percent of the 3-5 million tones of rice straw residues produced annually are burnt in the field as a practical means of disposal. Rice in rotation with berseem (a forage legume) or wheat achieved yields under CA equal to those grown under conventional practices with savings in time, energy (fuel) and labour needed for land preparation and crop management. The project also demonstrated the advantages of CA practices for weed control, crop water consumption and improvement of soil conditions for crop development.

Farmers in **Lesotho** have been able to boost agricultural yields and increase food production by adopting CA. The practice, locally known as likoti, also contributes to combating soil erosion and to enhancing fertility. The socio-economic and environmental benefits help poor households to rehabilitate and strengthen their livelihood capital base and ultimately help rural communities to build system resilience in the face of widespread poverty and increasing vulnerability that affect the country. Results show that attending appropriate training is a crucial prerequisite for the correct adoption of likoti. However, training is more effective when trainers pursue true participation and when social capital among farmers is stronger. Further important determinants of adoption are the level of education and the economic incentives provided to vulnerable households (Silici 2010).

In Lempira, **Honduras**, farmers moved from a traditional slash and burn system to the *Quesungual* system. This CA system uses trees and mulch. An economic analysis of this transition showed that during the first two years maize and sorghum yields were about equal to those obtained with the traditional slash and burn system. From the third year, however, their yields increased, in addition, the system provided the farmer with firewood and posts, which gave an extra value to the production. Because of the increased production of maize, the quantity of stover increased as well; this could be sold as livestock fodder. Additionally, from the first year onwards, the farmer could rent out the land for livestock grazing, because of the increased biomass production. Usually this was done for two months. The application of the Quesungual system not only meets the household subsistence needs for fruit, timber, firewood and grains, but also generates a surplus which can be sold providing an additional source of income.

1.4 Livestock production efficiency and resilience

Livestock provide food and livelihoods for one billion of the world's poor, especially in dry and infertile areas where other agricultural practices are less practicable. They play an important multifunctional role in many developing regions providing food, income, draught power for ploughing and transport. They can also provide valuable asset functions, such as collateral for credit, and emergency cash flow when sold in times of crisis.

The livestock sector has expanded rapidly in recent decades and will continue to do so as demand for meat and dairy products continues to grow. An increase of up to 68 percent by 2030 from the 2000 base period has been estimated and this is mainly driven by population and income growth in developing countries (FAO, 2006). Livestock is also the world's largest user of land resources, with grazing land occupying 26 percent of the earth's ice-free land surface, and 33 percent of cropland dedicated to the production of feed (FAO, 2009). The quick expansion of the sector is a cause of overgrazing and land degradation and an important driver of deforestation. It is also responsible for methane and nitrous oxide emissions from ruminant digestion and manure management, and is the largest global source of methane emissions. However, the carbon footprint of livestock varies considerably among production systems, regions, and commodities, mainly due to variations in the quality of feed, the feed conversion efficiencies of different animal species and impacts on deforestation and land degradation (FAO, 2010b).

Significant productivity improvements are needed for developing countries to meet growing food security and development requirements, while minimizing resource use and GHG emissions from production. Past productivity gains in the sector have been achieved through the application of science and advanced technology in feeding and nutrition, genetics and reproduction, and animal health control as well as general improvements in animal husbandry. The extension of these approaches, particularly in developing countries where there are large productivity gaps, can play a key role in mitigation and in building resilience to climate change. This is especially important in marginal lands in semiarid areas, which are particularly vulnerable to climate change. Improved forecasting of risks, determination of the effects of climate change, early detection and control of disease outbreaks are also fundamental to allow prompt responses and build resilience.

The efficient treatment of manure can also reduce emissions and raise productivity of the sector. For example, the anaerobic digestion of manure stored as a liquid or slurry can lower methane emissions and produce useful energy, while the composting solid manures can lower emissions and produce useful organic amendments for soils. The substitution of manure for inorganic fertilizers can also lower emissions and improve soil condition and productivity. The reintegration of livestock with crop activities, the strategic location of intensive livestock production units and enhanced processing techniques to reduce production losses are also effective strategies for boosting productivity.

In addition to measures that focus directly on animal productivity, feed and manure management, there are a range of grassland management practices that can address mitigation and improve resilience. Grasslands, including rangelands, shrub lands, pasture lands, and croplands sown with pasture, trees and fodder crops, represent 70 percent of the world's agricultural area. The soils under grasslands contain about 20 percent of the world's soil carbon stocks (FAO, 2010a), however, these stocks are at risk from land degradation. The Land Degradation Assessment in Drylands (LADA) recently estimated that 16 percent of rangelands are currently undergoing degradation. Arresting further degradation and restoring degraded grasslands, through grazing management and revegetation are important mitigation strategies. This can include set-asides, postponing grazing while forage species are growing or ensuring even grazing of various species, to stimulate diverse grasses, improve nutrient cycling and plant productivity. These practices along with supplementing poor quality forages with fodder trees, as in silvopastoral systems, can all contribute to increase productivity, resilience and boost carbon removals.

Box 7: Improving milk production in Cajamarca, Peru

FONCREAGRO (http://foncreagro.org/) in association with the private sector is undertaking a number of pro-poor livestock initiatives with the aim to increase milk production in poor and vulnerable areas of Peru, such as the Cajamarca region. Production efficiency is achieved through: breeding programmes (using crosses from Brown Swiss); improved pasture and manure management; decrease in the use of synthetic fertilizers, and improving livestock health through the provision of veterinary services and the sanitation of canals and treatment of animals for diseases such as liver fluke. Such practices have increased milk production per cow by 25 percent with significant improvement in quality. In addition, weaning age has decreased, calves reach 280kg in 20 months instead of 30 months and time between births has been reduced from 16.5 months to 14.9 months. These efficiency improvements has resulted in increases in production and income (by approximately 60 percent) but with a smaller more efficient herd. This has resulted in reduced greenhouse gas emissions and smaller impact on the resource base. Continuity of the system is ensured through training of all members of the community on all aspects of the production system.

Box 8: Multinutrient blocks improve digestibility of fibrous feeds

Livestock production in developing countries is largely dependent on fibrous feeds – mainly crop residues and low quality pasture – that are deficient in nitrogen, minerals and vitamins. However, these feedstuffs can be better used if the rumen diet is supplemented with nitrogen, carbohydrate, minerals and vitamins. One of the most suitable methods used to supply animals with the nutrients not found in fibrous feed (in tropical smallholder conditions) is to feed the animals urea and molasses in the form of urea-molasses mineral blocks. These mineral blocks increase productivity of meat and milk production and promote higher reproductive efficiency in ruminant animal species, such as cattle, buffalo, sheep, goats and yak. The success of the technique has resulted in its adoption in over 60 countries (FAO 2007a).

Box 9: Control of animal diseases related to climate changes: Rift valley fever

The recent outbreak of Rift Valley Fever (RVF) in Madagascar in 2008 provides an example of how principles and tools such as rapid disease detection, early warning, early response, as promoted in the EMPRES programme, can be used for the control of emerging diseases. The virus, which causes high livestock losses and is also a severe threat to human health, was found in test samples which triggered a country wide survey of livestock and the establishment of surveillance systems. Sentinel screening of herds in thirteen locations were establish through the contracting of local, private veterinarians to undertake field surveillance and undertake weekly visits to communities. Mosquitoes and other samples were collected in the infected areas in order to identify vector species. To prevent human contamination, information campaigns were organized and protective equipment was distributed to professionals working in slaughterhouses. In autumn 2008, a month after the first training, a veterinarian in a remote area launched an alert. The implementation of local measures immediately after detection of the first cases prevented the outbreak from spreading. (EMPRESS Transboundary Animal Diseases Bulletin No 35).

1.5 Agroforestry

Agroforestry is the use of trees and shrubs in agricultural crop and/or animal production and land management systems. It is estimated that trees occur on 46 percent of all agricultural lands and support 30 percent of all rural populations (Zomer et. al 2009). Trees are used in many traditional and modern farming and rangeland systems. Trees on farms are particularly prevalent in Southeast Asia and Central and South America. Agroforestry systems and practices come in many forms, including improved fallows, taungya (growing annual agricultural crops during the establishment of a forest plantation), home gardens, growing multipurpose trees and shrubs, boundary planting, farm woodlots, orchards, plantation/crop combinations, shelterbelts, windbreaks, conservation hedges, fodder banks, live fences, trees on pasture and tree apiculture (Nair, 1993 and Sinclair, 1999).

The use of trees and shrubs in agricultural systems help to tackle the triple challenge of securing food security, mitigation and reducing the vulnerability and increasing the adatability of agricultural systems to climate change. Trees in the farming system can help increase farm incomes and can help diversify production and thus spread risk against agricultural production or market failures. This will be increasingly important as impacts of climate change become more pronounced. Trees and shrubs can diminish the effects of extreme weather events, such as heavy rains, droughts and wind storms. They prevent erosion, stabilize soils, raise infiltration rates and halt land degradation. They can enrich biodiversity in the landscape and increase ecosystem stability.

Trees can improve soil fertility and soil moisture through increasing soil organic matter. Nitrogen-fixing leguminous trees and shrubs can be especially important to soil fertility where there is limited access to mineral fertilizers. Improved soil fertility tends to increase agricultural productivity and may allow more flexibility in the types of crops that can be grown. For example agroforestry systems in Africa have increased maize yields by 1.3 and 1.6 tons per hectare per year (Sileshi *et al*. 2008). Fodder trees have been traditionally used by farmers and pastoralists on extensive systems but fodder shrubs such as calliandra and leucaena are now being used in more intensive systems, increasing production and reducing the need for external feeds (Franzel, Wambugu and Tuwei, 2003). Agroforestry systems for fodder are also profitable in developed countries. For example, in the northern agricultural region of western Australia, using tagasaste (Chamaecytisus proliferus) has increased returns to farmers whose cattle formerly grazed on annual grasses and legumes (Abadi *et al*., 2003).

Agroforestry systems are important sources of timber and fuelwood throughout the world in both developing and developed countries. For example, intercropping of trees and crops is practiced on 3 million hectares in China (Sen, 1991) and in the United Kingdom, a range of timber/cereal and timber/pasture systems has been profitable to farmers (McAdam, Thomas and Willis 1999). Trees produced on farm are major sources of timber in Asia (e.g. China, India, Pakistan), East Africa (e.g. Tanzania) and Southern Africa (e.g Zambia), Increasing wood production on farms can take pressure off forests, which would otherwise result in their degradation.

Agroforestry systems tend to sequester much greater quantities of carbon than agricultural systems without trees. Planting trees in agricultural lands is relatively efficient and cost effective compared to other mitigation strategies, and provides a range of co-benefits important for improved farm family livelihoods and climate change adaptation. There are several examples of private companies supporting agroforestry in exchange for carbon benefits.

Agroforestry is therefore important both for climate change mitigation as well as for adaptation through reducing vulnerability, diversifying income sources, improving livelihoods and building the capacity of smallholders to adapt to climate change. However, agroforestry in many regions is still constrained by local customs, institutions and national policies. There is an urgent need for capacity building, extension and research programmes to screen and to match species with the right ecological zones and agricultural practices. There is a need to support and develop private public sector partnerships to develop and distribute agroforestry germplasm, like there is for the crops sector.

Many success stories demonstrate that with appropriate access to market and value added opportunities, initial funding mechanisms to kick off processes and transition, and other initiatives and enabling conditions, rural producers and farmers get to produce on a large scale with impact at sub-national and national level. For instance, under the Clean Development Mechanism (CDM) of the Kyoto Protocol, Ethiopia will qualify for carbon credits for reforestation and afforestation projects. The Humbo Regeneration Project will enable the future sale of 338,000 tonnes of carbon credits by 2017 (World Bank, 2010). The benefits of Faidherbia albida agroforestry systems in sub-Saharan Africa have been highly documented (box 10).The carbon project in the Nhambita community in Mozambique (box 11) also advocates for agroforestry.

Box 10: Faidherbia albida agroforestry/agrosilvipastoral system

Faidherbia albida is a tree commonly found in agroforestry systems in sub-Saharan Africa. This tree, which is widespread throughout the continent, thrives on a range of soils and occurs in ecosystems from, deserts to wet tropical climates. It fixes nitrogen and has the special feature of 'reversed leaf phenology' meaning it is dormant and sheds its leaves during the early rainy season and leafs out when the dry season begins. This feature makes it compatible with food crop production, because it does not compete for light, nutrients and water. Farmers have frequently reported significant crop yield increases for maize, sorghum, millet, cotton and groundnut when grown in proximity to Faidherbia. From 6 percent to more than 100 percent yield increases have been reported in the literature.

Like many other agroforestry species, Faidherbia tends to increase carbon stocks both above-ground and in the soil (8) and improves soil water retention and nutrient status. Faidherbia trees are currently found on less than 2 percent of Africa's maize area and less than 13 percent of the area grown with sorghum and millet. With maize being the most widely cropped staple in Africa, the potential for adopting this agroforestry system is tremendous. Further research is needed to better explore the potential benefits Faidherbia can provide, including for crop productivity in different agro-ecosystems; wood and non-wood products for household use or sale on the market; and possibilities for engaging with carbon markets.

Box 11: The Nhambita community carbon project, Mozambique

Initiated in 2003, the project pays 1000 smallholder farmers in the buffer zone of the Gorongosa National Park in Sofala Province for sequestering carbon through adoption of agroforestry practices and for reduced emissions from deforestation and degradation (REDD) of miombo woodlands. Farmers are contracted to sequester carbon on their machambas (farmlands) through adoption of agroforestry practices from a 'menu' that includes horticultural tree species, woodlots, intercropping food crops with Faidherbia albida, planting native hardwoods around the boundary of the machambas, and planting fruit trees within the homestead. In all, different project activities yield carbon offsets equal to 24,117 tCO_2e per annum over an area of about 20 000 hectares. Farmers receive carbon payments at a rate of US$4.5 per tCO_2 or in the range of US$433/ha to $808/ha over seven years. The project shows that carbon sequestration through land use, land use change and forestry (LULUCF) can both promote sustainable rural livelihoods as well as generate verifiable carbon emissions reductions for the international community.

1.6 Fisheries and aquaculture

Over 500 million people depend, directly or indirectly, on fisheries and aquaculture for their livelihoods. Fish also provides essential nutrition for 3 billion people and at least 50 percent of animal protein and essential minerals to 400 million people in the poorest countries. However, climate change is bringing about huge challenges to these resources. Production systems and livelihoods, already in crisis from over-fishing, poor management and impacts from other terrestrial anthropogenic influences, are likely to succumb further as the frequency and intensity of storms increase and extreme weather events become more common. Fishers, as well as other community members, will be at greater risk of losing their lives and assets, such as boats, fishing equipment and aquaculture infrastructures. Adaptation strategies will need to be context and location specific and to take into account both short-term (e.g. increased frequency and intensity of extreme events) and long-term (e.g. reduced productivity of aquatic ecosystems) phenomena. Strategies to increase resilience and adaptive capacity will require wide-scale implementation and adoption of measures and practices that adhere to the principles of the Code of Conduct for Responsible Fisheries.

Climate resilient sustainable intensification of aquaculture must occur to meet growing consumption needs and is being achieved by improving management approaches and through the selection of suitable stock (for example through saline resistant species in zones facing sea level rise). Improved energy efficiency and decreased use of fish meal and fish oil feeds are essential mitigation strategies as these inputs are the main carbon footprint in aquaculture systems. Increasing feeding efficiency or switching to herbivorous or omnivorous species, such as carp, greatly reduces the need for fish feed inputs and achieves much higher input/output ratios than other protein sources, such as salmon. The integration of aquaculture within broader farming landscapes provides further opportunities, for example sludge produced during the treatment of aquaculture wastewater or pond sediments can be used to fertilize agricultural crops. More strategic location of aquaculture infrastructure can also avoid potential climate change risks and minimize the impacts on natural systems such as wetland, mangroves and reefs. In addition, replanting mangroves in many aquaculture areas in tropical regions can restore important ecosystem services, protect the coastline from inundations and, along with other plants and seagrasses, can sequester carbon, increasing marine “blue carbon” sinks. Mariculture farming systems such as filter-feeders and seaweeds are excellent production systems as they require little, if any, external inputs and can even provide ecosystem services such as filtering and absorbing excess nutrients in the water. In some cases, these systems far exceed efficiency and carbon uptake levels when compared to land agricultural activities. Moreover, seaweeds can be used for feed, food products and have the potential for biofuel production.

Adaptation will also require private sector adjustments in fishing practices as abundance and availability of traditional species decline and opportunities for catching novel species grows. Significant levels of re-investment in facilities, equipment and training will be required as fisheries supply chains adapt. In all cases, this transition will need to be achieved with improvements in the safety and reductions in the loss of life and accidents while minimizing energy use and reducing waste. Low Impact Fuel Efficient [LIFE] fishing vessels, fishing gears and fishing practices adapted to each specific fishery can reduce the sector’s greenhouse gas emissions from the estimated 2.1 million powered fishing vessels which consume an estimated 41 million tones of fuel, buffer the sector from future oil shocks and improve the overall safety and environmental sustainability of fishing operations. In addition, there is an urgent need to reduce fishing capacity in many fisheries around the world, to reduce the incentives to overfish and to improve the economic performance of those fisheries. This would have the added benefit of further reducing greenhouse gas emissions.

Box 12: Low energy efficient aquaculture

The farming of seaweeds, oysters and clams constitute the largest proportion of mariculture production worldwide. The culture of these groups requires minimal energy inputs and, therefore, has a relatively small carbon footprint. Moreover, the rapid turnover in seaweed culture, approximately three months per crop (in the tropics) with yields of over 2 500 tonnes per ha, far exceeds the potential carbon uptake that could be obtained through other agricultural activity for a comparable area. Additionally, such systems can filter nutrients and provide a “cleaning service” to coastal marine environments.

The farming of seaweed has expanded rapidly in recent decades as demand has outstripped the supply available from natural resources. Annual production value are estimated at US$5.5-6 billion; with commercial harvesting occurring in about 35 countries, spread between the Northern and Southern Hemispheres, in waters ranging from cold, through temperate, to tropical. China is the largest producer of edible seaweeds. About five million tonnes (mostly for kombu) is produced from hundreds of hectares of *Laminaria japonica* that is grown on suspended ropes in the ocean. Other seaweeds, such as *kappaphycus alvarezii* and *Eucheuma denticulatum,* originally harvested from natural stocks in Indonesia and the Philippines for the production of thickening and gelling agents (Carrageenan), are now cultivated and production has also spread to other countries, including Tanzania (Zanzibar), Viet Nam and some of the Pacific Islands.

Box 13: Aquasilviculture

Another environmentally-friendly and GHG mitigating mariculture system is aquasilviculture, the integration of aquaculture and mangrove forestry. Such systems are commonly used in Indonesia and Vietnam and in the early stages of development in other countries such as Hong Kong, the Philippines, and Malaysia. The approaches differ among and within countries but mainly constitute the integration of mangrove ponds and pens for fish and crabs (Primavera, 2000). Such systems not only sequester carbon, but they are also more resilient to shocks and extreme events and also lead to increased production due to improved ecosystem services. A good example of the benefits of aquasilviculture can be seen in the introduction of the system in the tambak region of Java, an area of over 300 000 ha of extensive ponds which lacked mangroves. The introduction of mangroves led to the increase in production, in food supplies and contributed significantly to the socio-economic well-being of the coastal rural population (Sukardjo 1989). The system was therefore more profitable than just direct planting of mangrove trees, and the net financial benefits to the reforestation programme of the State Forestry Corporation was considerable (Sukardjo, 1989).

Box 14: Low Energy Fuel Efficient (LIFE) Fishing

Well-designed and responsibly-used passive fishing gears such as gill nets, pots, hook and lines and traps can reduce the requirement for fossil fuel consumption by as much as 30-40 percent over conventional active fishing gears, such as trawls. Moreover, the use of bio-degradable materials can minimize the amount of ghost fishing when fishing gears are inadvertently lost as a result of bad weather. New designs of selective fishing gear can reduce the capture of juveniles and other forms of bycatch as well as reducing discards. Innovative technologies such as GPS and echosounders can also be used to ensure that fishing gears are not set on vulnerable or sensitive habitats. Other innovations in design of vessels and fishing equipment coupled with safety training can minimize accidents and loss of life at sea and assist with fishing losing its reputation of being the most dangerous occupation in the world.

1.7 Urban and peri-urban agriculture

50 percent of the global population now lives in cities and this is expected to rise to 70 percent by 2050. Such large expansion causes the encroachment of the city into surrounding natural ecosystems and agricultural lands.

Cities are often unable to provide sufficient employment opportunities to their growing populations which leads to a rapid increase in urban poverty rates and food insecurity. These urban poor often lack the money to purchase food or the land to grow it. It is estimated that these individuals spend up to 60 percent of their incomes to buy food. For example, the recent food crisis increased food prices and the global economic downturn reduced employment opportunities and incomes especially within urban areas. Climate change and higher incidences of natural and human-made disasters have also caused disruptions in food-supply chains into cities further increasing food insecurity.

Although cities will continue to largely depend on rural agriculture, urban and peri-urban agriculture is providing significant quantities of food (especially of perishable items) and improving food security of the urban poor. It is estimated that up to 15 percent of the world's food is produced by urban agriculture and 70 percent of urban households in developing countries participate in agricultural activities. Vegetables, fruits, mushrooms, herbs, meat, eggs, milk and even fish are being produced in community gardens, private backyards, schools, hospitals, roof tops, window boxes and vacant public lands (including at the side of roads and rail tracks). This home production can provide up to 60 percent of a families food requirements. This not only greatly improves nutrition it also allows families to spend more of their incomes on other expenses, such as education and health. In addition, urban agriculture also generates micro-enterprises such as the production of compost, food processing and sale.

Other advantages of urban agriculture are the "greening" of cities, improving air quality, and lowering temperatures. These benefits has led many cities (such as Beijing Hanoi, Kampala Shanghai, Java, Dakar, Accra, Havana, Buenos Aires, Bogotá, Lima, Curitiba, Quito, Managua, Tegucigalpa and Rosario) to develop considerable urban agricultural capacity, producing a large percentage of their milk, eggs, meat, fruit and vegetable requirements (up to 90 percent for the last).

However if the full potential of urban agriculture is to be achieved there are a number of key constraints and issues which need to be addressed. For example, the lack of access to water and other productive resources. Competition for land and issues related to tenure rights have been found to be major constraints. The environmental impact of urban agriculture, the food safety concerns of using waste water and organic material and the risk of the spread of diseases and contamination of toxic pollutants are all of major concerns. City planners therefore require technical guidance for the integration of agricultural activities into urban development and training needs to be provided on urban sustainable production systems. There is urgent need to revisit food distribution systems and ensure resilient urban-rural linkages, especially with regard to new shocks caused by climate change.

Box 15: Micro-Gardens in Dakar

FAO and the Government of Senegal have initiated Micro-Gardens in Dakar in 1999. This initiative has reduced poverty by providing fresh vegetables to poor families, thereby improving their food supply and nutrition. The project also promotes income generation through the sale of production surplus. The project facilitates access to urban and peri-urban horticultural production for city-dwellers who do not have access to farmland, mobilizes human resource in the fields of administration and research, and promotes the use of agricultural waste such as peanut shells and rice chaff. The micro-garden technology has been adopted across all social sectors: poor, wealthy, men, women, young, old and physically handicapped. More than 4,000 families have been trained in micro-garden technology.

The main challenges in the implementation of the project included training and organization of beneficiaries, access to equipment and inputs, and marketing of produce. The micro-gardens benefited from local means and equipment, housed at the Horticultural Development Centre (CDH) of the Senegalese Institute of Agricultural Research (ISRA), including an office, laboratory and national reference micro-garden.

In the absence of territorial planning for the allotment of production spaces to micro-gardeners, some city halls, schools and hospitals have made their backyards available for micro-gardeners. The micro-gardens project has also established outlets in all the regional capitals to provide access to alternatives to high-cost chemical fertilizers, including tea manure, manure, and Biogen. Annual yields have increased and costs of inputs reduced through the use of alternative materials and drip irrigation kits promoted by the FAO. The project is collaborating with Italian NGOs in Dakar to establish a specific supply chain mechanism for micro-gardeners' produce to strengthen financial autonomy of the beneficiaries and ensure sustainability of the project. Micro-gardners' produce is promoted via television programmes and advertising; and with the introduction of a certificate of vegetable analysis, established by the Institute of Food Technology (ITA). The goal is to create a label for micro-gardeners' produce.

Box 16: Rooftop gardens in Cairo, Egypt

The population explosion and the tendency to build on agricultural land have acted to limit the resources of city families and their access to healthy products. With a little effort and money, rooftops can contribute in improving the families' quality of life and provide them with healthy food and increased income. Although the idea is not new, rooftop gardens in Egypt has only recently been implemented. In the early 1990s at Ain Shams University, a group of agriculture professors developed an initiative of growing organic vegetables to suit densely populated cities of Egypt. The initiative was applied on a small scale until it was officially adopted in 2001 by the Food and Agriculture Organization (FAO).terraces and balconies, even on civil construction walls, and for not requiring big investments in capital or long hours of work.: sugarcane waste, polyethylene bags, tires, containers and cylinders, and soil. fruit such as mangos, figs, guavas, bananas, and sugarcane stalks in his terrace of 1,200 sq ft (110 m2) in Bandra.

Box 17: Further information and examples

The urban producer's resource book: A practical guide for working with Low Income Urban and PeriUrban Producers Organizations provides a useful reference with guidelines and the issues that have to be addressed. Country examples are provided for each issue to show how UPA can be developed in cooperation with a number of stakeholders. Accessed at: www.fao.org/docrep/010/a1177e/a1177e00.htm

1.8 Diversified and Integrated Food - Energy Systems

As can already be seen in the above production systems, diversification can both increase the efficiency of systems and build their resilience to climate change. It can spread risk, increasing economic resilience at the farm and at the local level. Diversified rotations, including crop varieties and species with different thermal/temperature requirements, better water use efficiency and resistance to pest/disease, and lower yield variability are an effective way to reduce risks and increase efficiency. Introducing new types of crops (such as vegetables), trees (fruit and wood products) and other plants can increase and diversify production and improve overall nutritional levels. Integrated crop and livestock systems also increase the efficiency and environmental sustainability of both production systems. The waste products of one component serve as a resource for the other (e.g. manure increases crop production and crop residues and by-products are used as animal feeds). Animals also play various roles, they can provide energy for farm work or transportation and constitute a capital to be converted into cash when needed. These systems, which exist under various forms and levels of integration, provide opportunities for increasing overall production and economic resilience of farmers.

Developing production systems which also meet the energy requirements of smallholders is also important. However, three billion people – about half of the world's population - rely on unsustainable biomass-based energy sources to meet their basic energy needs for cooking and heating, and 1.6 billion people lack access to electricity (IEA 2002). In rural communities in developing countries this often results in encroachments into natural ecosystems, for example the cutting down of forests for fuel, leading to major sources of emissions. Integrated Food Energy Systems (IFES) aim at addressing these issues by simultaneously producing food and energy. This generally translates into two main methods. The first combines food and energy crops on the same plot of land, such as in agroforesty systems for example: growing trees for fuelwood and charcoal. The second type of IFES is achieved through the use of by-products/residues of one type of product to produce another. Examples include biogas from livestock residues, animal feed from by-products of corn ethanol, or bagasse for energy as a by-product of sugarcane production for food purposes. While simple IFES systems such as agroforestry or biogas systems are widespread, more complex IFES are less frequently implemented due to the technical and institutional capacity required to establish and maintain them, and the lack of policy support. Solar thermal, photovoltaics, geothermal, wind and water power are other options and can be included in IFES, despite the high start-up costs and specialized support required for their installation and servicing.

Box 18: National Biogas Programme, Viet Nam

Viet Nam embarked on an integrated land management scheme, following land rights being given to individual farmers. This is supported by the Vietnamese Gardeners' Association (VACVINA), which works at all levels, and has national responsibility to promote this concept – called the VAC integrated system. It involves gardening, fish rearing and animal husbandry, to make optimal use of the land. Traditional fuels such as wood and coal for cooking are becoming increasingly scarce and expensive, and can contribute to deforestation. Increasing livestock production in rural communities with high population density leads to health and environmental issues from the quantity of animal dung being produced. Biogas digesters are part of the solution offered by this initiative, using the waste to generate energy, and the resultant slurry can be used as a fertilizer to improve soil quality. A market-based approach has been adopted to disseminate the plants and the service provided to those buying the digesters is comprehensive. The customer must have at least four to six pigs or two to three cattle that provide the animal dung. They pay the total installation cost for the digesters to local service providers, and operate the biodigester using instructions provided by them. A biodigester produces enough daily fuel for cooking and lighting. It improves the surrounding environment, whilst livestock produces meat, milk and fish products for local consumption and subsistence farming.

Source: FAO/Practical Action, 2009.

Box 19: Sustainable food and charcoal production in agroforestry systems, DRC

Kinshasa, the capital of the Democratic Republic of Congo, has a population of eight million inhabitants and consumes up to 6 million tonnes of bioenergy equivalent per year. The city is surrounded by grasslands and patches of forest. The bioenergy used by the urban households consists mainly of fuelwood (charcoal and firewood). Charcoal needs, but also most of the staple starchy foods in the diet (cassava and maize), are provided by slash-and-burn shifting cultivation and by carbonization of the patches of forest and tree savannahs, which continue to deteriorate. Production obtained from these tree stands is becoming scarce and expensive. Soil fertility is declining, crop yields after fallow are decreasing, springs are drying up and fires are increasingly frequent. Slash-and-burn cultivation gives rise to tree fallow after one to three years of cropping, due to the exhaustion of soil reserves. Improving tree fallow consists in planting tree legumes, whose roots combined with microorganisms fix atmospheric nitrogen. Organic matter and nitrogen storage in the soil is thereby accelerated. This is especially true for acacias, trees that are also known for their large biomass/wood production. The trees can already be planted during the cropping period and continue to grow rapidly after harvesting, during the fallow phase (CIRAD 2010; Bisiaux *et al*. 2009 and Hans Seidel Foundation 2009).

Box 20: Biogas in Thailand

Methane from pig waste represents the largest source of livestock GHG emissions in Thailand with the number of pigs in the country expected to more than double between 2000 and 2020. A pilot project on ten pig farms with a total annual average pig population of around 131 200 pigs will reduce methane emissions from pig waste management by the installation of anaerobic treatment systems that recover biogas for use as energy. The total emission reductions are estimated at about 58 000 tons of Carbon Dioxide (CO_2) equivalent per year (tCO_2e/year). The project is partly financed by these reductions through a Clean Development Mechanism of the Kyoto Protocol. The electricity produced is expected for on-farm consumption. Sludge material will be dried and sold as fertilizer and soil amendment. In addition the project includes specific component activities for the community such as street lighting, access to drinking water, scholarships, mosquito spray machine, community shop, capacity building. This project is implemented by the World Bank and FAO. It is part of the Livestock Waste Management in East Asia project which global environment objective is to reduce livestock-induced, land-based pollution and environmental degradation.

Key messages for part 1

2) Effective climate-smart practices already exist and could be implemented in developing country agriculture systems.

3) Adopting an ecosystem approach, working at landscape scale and ensuring intersectoral coordination and cooperation is crucial for effective climate change responses.

4) Considerable investment is required in filling data and knowledge gaps and in research and development of technologies, methodologies, as well as the conservation and production of suitable varieties and breeds.

Part 2 – Institutional and policy options

Ensuring food security and development under climate change in some parts of the world, will involve increasing yields, income and production, which can generally be expected to lead to increased aggregate emissions, although emissions per unit product may decline. While agricultural production systems will be expected first and foremost to increase productivity and resilience to support food security, there is also the potential for developing low emission development trajectories without compromising development and food security goals.

To meet these multiple challenges, it has been suggested by FAO that a major transformation of the agriculture sector will be necessary and this will require institutional and policy support. Better aligned policy approaches across agricultural, environmental and financial boundaries and innovative institutional arrangements to promote their implementation will be needed. This section covers critical institutional and policy adjustments required to support the transition to climate-smart agriculture.

2.1 Enabling policy environment

Key requirements for an enabling policy environment to promote climate-smart smallholder agricultural transformations is greater coherence, coordination and integration between climate change, agricultural development and food security policy processes. Policies in all three of these areas have both impacts on smallholder productions systems and on GHG emissions. Lack of coherence can prevent synergy capture and render the pursuit of the stated policy objectives ineffective.

2.1.1 National policy-making

Climate change policies at the national level are expressed through the National Action Plan for Adaptation (NAPAs) and the Nationally Appropriate Mitigation Actions (NAMAs) as well as through national or regional climate change strategies. Agricultural development and food security plans are expressed in national development strategies and poverty reduction strategy papers (PRSPS). In the case of African countries, agricultural development and investment strategies are being developed under the CAADP (Comprehensive African Agricultural Development Programme) umbrella. Recently countries have been called upon to develop CAADP compacts that outline their agricultural development priorities and investment requirements. These strategies will be supported by 20 USD billion in funds, which the L'Aquila G8 Summit in 2009 agreed to mobilize over three years for food security.

FAO recently conducted a survey of a sample of these countries to compare the policy objectives stated in the NAPAs, NAMAs and CAADP compacts. The policy statements made for CAADP are generally focused on improving productivity and returns to small-scale agriculture, and generally include some emphasis on sustainable land management and soil restoration. Policy statements made for NAPAs and NAMAs that have been submitted by LDCs focus on smallholder agriculture –increasing reliance of the sector by better management of land and soil resources, whereas CAADP statements often focus on agricultural productivity target increases. IIED 2010 also noted a discrepancy between African agricultural productivity targets, as set out in national and regional policy documents, and the projections of how climate change will impact upon agriculture. Better alignment of the technology approaches envisioned in these different policy dialogues, and in particular better integration of sustainable land management factors into mainstream agricultural development planning will facilitate a more holistic approach to considering agricultural development, adaptation and mitigation.

Better integration of food security, safety nets and adaptation policies offers the potential to reap significant benefits. Better use of climate science information in assessing risks and vulnerability and then developing the safety nets and insurance products as an effective response is already being piloted in some areas with fairly positive results (Barrett *et al*. 2007). Policies related to price stability are also key to both adaptation and food security, including the use of buffer stocks of food.

2.1.2 Coordinated international policies

At the international level, better integration of food security, agricultural development and climate change policies and financing is also needed. Two parallel global dialogues on reducing food insecurity and responding to climate change have until now had remarkably little substantive integration of issues under consideration. Likewise the agricultural community has only recently become active in the discussions and negotiations of international climate change policies that could have profound impacts on the sector. Creation of mechanisms that allow dialogues between food security, agricultural development and climate change policy-makers is fundamental.

2.2 Institutions: information production and dissemination

One key role of institutions is the production and dissemination of information, ranging from production and marketing conditions to the development of regulations and standards. Climate change, by increasing uncertainty, as well as the value of rapid and accurate response (or costs of not doing so) increases the value of information and the importance of institutions that generate and disseminate it. It will be critical that national and international agricultural research programmes focused on developing countries incorporate climate change into their programming. For example there is a clear lack of consistent and coherent projections specifying the effects of climate change on the different determinants of African food security (IIED 2010). Access to information is seen as a priority area for many countries as highlighted in Figure 1.

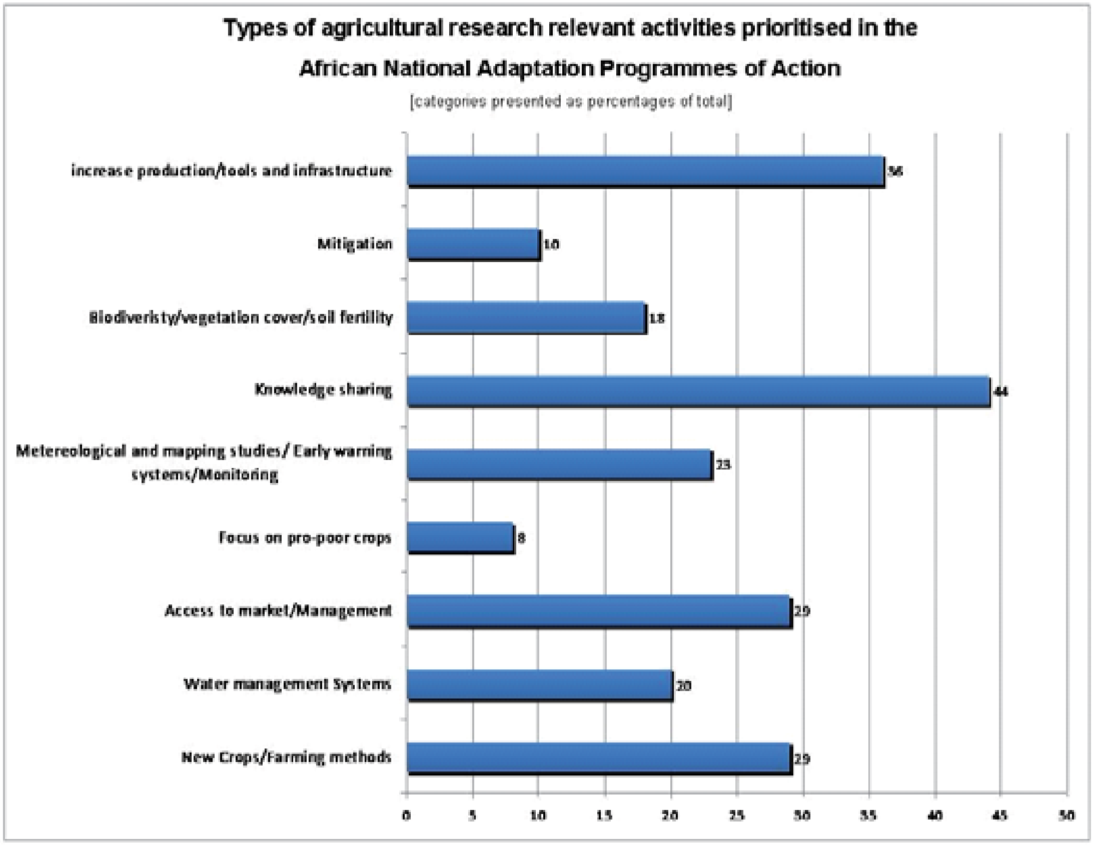

Figure 1: The types of activities prioritized in African NAPAs, clearly indicate that in the African context designing national adaptation plans of action, information dissemination and coordination are equally or more important than research on new technologies.

Source: IIED 2010 Anderson *et. al.* (p. 18).

2.3 Climate data and information gaps

Improving the use of climate science data for agricultural planning can reduce the uncertainties generated by climate change, improve early warning systems for drought, flood, pest and disease incidence and thus increase the capacity of farmers and agricultural planners to allocate resources effectively and reduce risks (see annex 1). SEI 2008 cites the need for more "translators" of climate information, who can bridge the divide between science and field application, assisting communities and planners to understand the implications of results for their immediate planning decisions. Enhancing communication between producers and users of climate science is also clearly a requirement. Institutions to facilitate this exchange can be existing communications and information dissemination networks, including extension (see Box 21 below on Climate Field Schools). Capacity building of policy makers as well as technical staff is another avenue. Finally, platforms for collaborative action and information sharing, such as the weAdapt platform, which unites modelers, practitioners and donors, can enhance the development and use of climate science information for agricultural decision-making (SEI 2008).

2.4 Dissemination mechanisms

The imperative of climate change requires increased capacity of farmers to make both short and long term planning decisions and technology choices. Agricultural extension systems are the main conduit for disseminating the information required to make such changes. Yet, in many developing countries, these systems have long been in decline (FAO 2008). Resources have been severely curtailed and services increasingly outsourced to the private sector or dropped. Another weakness has been the heavy focus on inputs (seeds and fertilizer) and less attention to marketing or commercial services (FAO 2008). Problems with delivering information at a relevant spatial and time scale, difficulty in communicating the information and lack of user participation in development of information systems are all problems that have been encountered (Hansen *et al.*; SEI 2008).

Farmer Field Schools (FFS) are a participatory approach to farmer education and empowerment. They have spread rapidly in recent years, promoted mainly by FAO with support from donors, as a way of resolving both the need to correct information failures and of providing initial forms of farmer organization. The aim of the FFS is to build farmers' capacity to analyze their production systems, identify problems, test possible solutions and eventually adopt the practices and technologies most suitable to their farming system. The criticism of the schools is that they reach only a small group of farmers and do so at a relatively high cost both financially and in management time. In a number of countries however, including Kenya and Sierra Leone, FFS have been active in marketing and have proven to be sustainable even in the absence of donor funding (see Box 21) which contains examples of how FFS are being used to facilitate the use of climate information).

Box 21: Climate field schools building on FFS success in Indonesia

Integrated pest management field schools have been one of the technology transfer and capacity building mechanisms that have been part of FAO's development work for many years. The department of agricultural extension in West Java, Indonesia, has converted the integrated pest management schools into climate field schools for the benefit of farmers, incorporating climate information within the farm decision making process. Climate forecast technology has undergone substantial improvements during the last 15 years which could increase farmers' effectiveness in coping with extreme climate events by tailoring cropping management to forecast information. However, farmers' awareness of seasonal climate forecasts and their capacity to use to it to tailor their crop management strategies is still low. Experience in Indonesia has shown that the use of farmer field schools can be an effective way of bridging this gap and this has led to the introduction of climate field school (CFS). The programme was facilitated by Bogor Agricultural University in collaboration with the Directorate of Plant Protection, Department of Agriculture, National Agency for Meteorology and Geophysics (BMG) and Asian Disaster Preparedness Center (ADPC). *Source:* FAO, www.fao.org/teca/content/climate-field-school-farmers.

2.5 Institutions to improve access coordination and collective action

Input supply, e.g. access to fertilizer and seeds, is an activity that requires coordination beyond the farm. "Given the market failures that lead to socially suboptimal use of seed and fertilizer, governments frequently step in to distribute them directly. Government-led distribution programmes have often increased input use, but the fiscal and administrative costs are usually high and the performance erratic" (World Bank, 2007). Yet, cutbacks have often simply resulted in leaving smallholders without reliable access to seed and fertilizer. Producer organizations may offer a promising avenue to improving input supplies to smallholders. One example is *Boutiques d'Intrants* in Niger consisting of a network of more than 300 input distribution shops which are managed by farmer organizations. Improving the capacity of smallholders to improve their marketed returns via the establishment of marketing platforms, such as the Plataformas project in Ecuador for small potato producers, was found to lead to a significant increase in household incomes and welfare for producers who participated in the marketing group (Cavatassi *et al*., 2009).

Many of the biophysical improvements to increase resilience in smallholder agricultural production systems identified above require action and coordination amongst many stakeholders in the rural landscape. Restoration of degraded areas to improve soil quality, improved management of communal water resources, and informal seed systems to facilitate the exchange of plant genetic resources are all examples of collective resource management activities that are likely to become more important under climate change. In many cases, local institutions exist to govern collective action and access to collective natural resources, but they are often coming under increased pressure due to population growth, conflicts, changes in market patterns and state intervention (McCarthy and Swallow, 2000; Niamir-Fuller, 1999; Barkes and Folke, 1998).

Effective systems of use and access rights and, in general, property rights are essential to improve management of natural resources including land, water and genetic resources. In many cases these rights are poorly specified, overlapping or not formalized. Improving them is a priority for providing farmers – especially women – with the incentives needed to make long term investments in transformations. However, formalizing rights does not necessarily improve security of overall resource access since ambiguous rights often serve as an insurance mechanism, especially important where other safety nets are not available – and likely to become even more important as weather becomes more variable. In some cases, better security of rights to resource use could be achieved through a system for identifying, coordinating and recognizing informal rights, strengthening customary tenure systems. However, in other cases, when the pressure of commercial agriculture on resources is particularly high, customary systems may come under stress, thus requiring the adoption of more formalized approaches.

Box 22: Informal seed systems and climate change

Most farmers in developing countries access their seeds from what is known as the "informal seed system". Essentially this includes all non-certified seed sources, which is primarily farmers' own saved seed, but also includes seed obtained through exchanges through social networks or in rural markets. Advantages of the informal seed system are low costs and ease of access. In traditional systems of seed exchange, trust and reciprocity are essential to the functioning of the system and they serve to ensure quality standards. In general these networks are confined to a very local level, with little interchange with outside sources. Recent research work by FAO indicates that for many crops, local agricultural markets are becoming an increasingly important source of seeds in the informal sector, and these include exchanges of seeds sourced both locally and from external sources. However often there is a lack of information on the quality and genetic content of varieties, support is therefore required in generating this information to assist farmers in selecting the appropriate seeds, including those that may have attributes important for climate change. This may include organizing local seed and genetic diversity fairs, alternative labeling systems such as quality declared seed or farmer-based labeling schemes, and certification and training of traders.

Source: Lipper *et al.* 2009.

2.6 Institutions to support financing and insurance needs

2.6.1 Credit

Climate change creates new financing requirements both in terms of amounts and financial flows associated with needed investments, which will require innovative institutional solutions. In synthesizing potential synergies between adaptation and mitigation in smallholder agricultural transitions, FAO 2009 found that for several options and locations, synergies would be generated in the long term, but in the short run (which could last up to ten years) tradeoffs in the form of income losses or increased income variability were experienced.

Crop and grassland restoration projects, for instance, often take land out of production for a significant period of time, reducing cultivated or grazing land available in the short run, but leading to overall increases in productivity and stability in the long run. A different type of trade-off may occur with incorporating crop residues that are expected to increase soil fertility and water retention capacity, thereby increasing yields at least over the medium-long term. However, where livestock are an important component of the food production system, there is a potential trade-off between residues used for the food crop system versus its use as livestock feed. Solutions to support these long term transitions are needed, and financing is clearly one key aspect. Two important issues emerge: exploring the possibility of non-traditional sources of finance to support the needed transitions and potential links to insurance instruments.

2.6.2 Insurance

Various forms of insurance mechanisms already exist in many rural communities in developing countries (Fafchamps, 2002). However, these mechanisms can involve high opportunity costs in the form of foregone development (Hansen *et al*. 2007). Selection of less risky, but less profitable crop varieties, under-use of fertilizers, engaging less household labor in farming enterprises and shifting from productive to liquid assets as precautionary savings are all examples of insurance mechanisms that may constrain development (Hansen *et al*. and references therein). The increasing incidence of "generalized" weather shocks (shocks that affect all/most members of a community) are even further reducing efficacy of local insurance arrangements. Index insurance programmes are one potential response to the insurance gap in developing country agriculture. Index insurance insures against an objectively-measured index – such as a rainfall deficit. The key is the degree to which the indicator is correlated with losses and this requires careful attention (Barrett *et al*. 2007). Basis risk arises where correlations are not well calibrated and in heterogenous regions with poor data and varied climates, index insurance may not be viable. Contract design and transactions costs are important issues in programme effectiveness and have implications for design of appropriate institutional settings. Index-insurance programmes can be managed through social safety net programmes or commercial financial institutions, but in either case capacity building is required. Improved use of climate related information is also important in increasing effectiveness of such programmes (Hansen *et al.* 2008; Barrett *et al.* 2009). Index based insurance reduces the problems of moral hazard and adverse selection, and generates greater willingness of lenders to extend credit to farmers.

2.6.3 Social Safety Nets

Safety nets are a form of social insurance comprising programmes supported by the public sector or NGOs that provide transfers to prevent the poor from falling below a certain poverty level. These programmes include cash transfers, food distribution, seeds and tools distributions, conditional cash transfers (Devereaux, 2002). Several new initiatives for safety net programmes have recently emerged, including Ethiopia's Productive Safety Net Programme (see box 23) and the Kenya Hunger Safety Net Programme. There has been a continuing debate about the role of such programmes vis-à-vis development activities. However, recent evidence indicates tradeoffs between protection and development are not pronounced (Ravallion, 2006). Instead, safety net programmes can actually be a form of social investment into human capital (e.g. nutrition, education) and productive capital (e.g. allowing households to adopt higher risk and higher productivity strategies; SOFI, 2010). Safety nets are increasingly being linked to rights based approaches to food security moving from a charity to entitlements. Safety nets are likely to become increasingly important in the context of climate change as increased incidence of widely covariate risks will require the coverage and financing that these sources may provide (World Bank, 2010).

2.6.4 Payments for environmental services

Payments for environmental services are one potential source of alternative financing for agricultural transitions (FAO, 2007a). As discussed in more detail below, mitigation of climate change is an environmental service that smallholders can provide and is often synergistic with improvements to agricultural productivity and stability. Examples are also given in Boxes (11) on the Nhambita project in Mozambique and Box (25) on the Three Rivers Sustainable Grazing Project in China. Emerging carbon markets and payments for emissions removals or reductions have attracted much interest and anticipation of such financing as a source of income for some agricultural activities and producers. However, high transactions costs, as well as low potential mitigation benefits in many smallholder systems seriously limit the potential of carbon market offsets to smallholders. Public financing for mitigation at a sub-sectoral or regional level is more likely to have an impact on smallholder agriculture in the near future (FAO 2009; Lipper et. al. 2009; Cacho and Lipper 2006).

PES experiences suggest that the following are useful: (i) formal and informal institutional arrangements that can facilitate aggregation amongst a large number of smallholders (e.g. group credit schemes, existing community-based natural resource management programmes, farmer field schools and other farmers' organizations and women's groups), (ii) policies in the agriculture, financial and environmental sectors that encourage the flow of public and private financing to farmers, (iii) capacity building, including on accessing financing mechanisms and (iv) an agreed system for payments to farmers.

Box 23: The Ethiopia Productive Safety Nets Programme

The Productive Safety Net Programme (PSNP) targets people facing predictable food insecurity and offers guaranteed employment for five days a month in return for transfers of either food or cash - US$4 per month for each household member. The purpose of the programme is to build resilience to shocks amongst vulnerable households. The programme differs from other food-for-work programmes in that the transfer is predictable and regular. This facilitates in building assets at the household level as well as local economic development. The PSNP is funded by donors under a multiyear arrangement, unlike food aid which is based on emergency appeals. The programme started with five million people in 2005 and intends to cover eight million by 2009. Community assets such as schools, health posts, feeder road and small scale irrigation and natural resource conservation have been built under the programme. It has been found that households involved in the scheme were now consuming more or better food. Three in five beneficiaries said they had avoided selling assets to buy food, while around a quarter had acquired new assets; almost all attributed this directly to the PSNP. The programme intends to "graduate" participants after they build sufficient resilience to cope with shocks without the threat of falling back into food insecurity.

Source: IRIN news www.irinnews.org/report.aspx?ReportId=7570

Box 24: Integrated silvopastoral approaches to ecosystem management project

The Regional Integrated Silvopastoral Approaches to Ecosystem Management Project was funded by GEF and involved CATIE, FAO and other partners. The objective was to assess silvopastoral (forest grazing) systems to rehabilitate degraded pastures to protect soils, store carbon, and foster biodiversity. Other objectives was to develop incentives and mechanisms for payment for ecosystem services (PES) that would result in benefits for farmers and communities and distil lessons for policy making on land use, environmental services and socio-economic development. From 2003 to 2006, cattle farmers, from Colombia, Costa Rica and Nicaragua, participating in the project received between US$2 000 and US$2 400 per farm, representing 10 to 15 percent of net income to implement the programme silvopastoral systems. This resulted 60 percent reduction in degraded pastures in the three countries, and the area of silvopastoral land use (e.g. improved pastures with high density trees, fodder banks and live fences) increased significantly. The environmental benefits associated with the project include a 71 percent increase in carbon sequestered (from 27.7 million tonnes of CO_2-eq in 2003 to 47.6 million tonnes in 2006), increases in bird, bat and butterfly species and a moderate increase in forested area. Milk production and farm income also increased, by more than 10 to 115 percent respectively. Herbicide use dropped by 60 percent, and the practice of using fire to manage pasture is now less frequent. Other demonstrated environmental benefits of Silvopastoral systems included the improvement of water infiltration; soil retention; soil productivity; land rehabilitation, and the reduction of fossil fuel dependence (e.g. substitution of inorganic fertilizer with nitrogen fixing plants). The project has successfully demonstrated the effectiveness of introducing payment incentives to farmers and in increasing the awareness of the potential of integrated ecosystem management for providing critical environmental services including the restoration of degraded pasture.

Key messages for part 2

5) Institutional and financial support will be required to enable smallholders to make the transition to climate-smart agriculture.

6) Strengthened institutional capacity will be needed to improve dissemination of climate-smart information and coordinate over large areas and numbers of farmers.

7) Greater consistency between agriculture, food security and climate change policy-making must be achieved at national and international levels.

Part 3 – Financing and Investments for Climate-smart Agriculture

3.1 Why financing is needed

Sustainable transformation of the agriculture sector, necessitating combined action on food security, development and climate change, will not be costless and will require large-scale investments to meet the projected costs. Uncertainties about potential losses, catastrophic risks and increased costs of inaction associated with climate change indicate that immediate and more aggressive transformative action is needed. Financing is thus urgent.

Yet, resources for agriculture, both from ODA and climate change financing, have not been forthcoming in the amounts needed over the last decades and financing gaps are projected for the future. The share of agriculture in official development assistance, which declined from 19 percent in 1980 to 3 percent in 2006, is now around 6 percent (FAO 2009d). This has led over the last few decades to agriculture suffering drastic declines in development investment and assistance. FAO has called upon the international community to resolutely reverse this long-term negative trend.

Meeting the financing challenge will require innovation, cooperative action and political will to address urgently and adequately current and projected shortfalls for adaptation and mitigation generally, including through the use of multiple funding sources, new and existing mechanisms, and better ways of connecting action to financing**.** These issues are briefly examined below.

3.2 Financing gaps

The annual costs of adaptation in the agriculture sector in developing countries have been recently estimated by the World Bank to be US$2.5-2.6 billion a year between 2010 and 2050 (World Bank, 2010). Annual incremental investments and financial flows needed for adaptation of agriculture in developing countries have been estimated at US$7 billion a year in 2030 (UNFCCC, 2007 and IIED, 2009). In the latter study it was acknowledged that this estimate was "on the low side of adaptation costs of the sector". It further indicated that that the cost of achieving the relevant Millennium Development Goal was estimated at US$40–60 billion per year and that without this non-climate investment, the estimated levels of investment needed for adaptation within the agriculture sector would be insufficient to avoid serious damage.

The UNFCCC (2007) estimated that additional investment and financial flows needed in developing countries for mitigation from the agriculture sector would be about US$12.25-14 billion a year in 2030. Yet, the costs of soil carbon sequestration do not seem to be included. McKinsey and Company (2009) stated that "in forestry and agriculture, both costs and investments are relatively low". However, calculations in this document excluded transaction and programme costs and levers are assumed not to require any substantial capital investment. Costs for measurement and monitoring, capacity and infrastructure building and carbon-credit-monetization are estimated to be 3.8 billion euros for the agriculture sector in 2030 and total expenditures for abatement levers over 2010-2030 is estimated to be 13 billion euros. Transaction costs, without aggregation mechanisms, could be high for the multitude of smallholders involved and incentive programmes to ensure adoption of abatement technologies may also be required. Costs of adoption and implementation vary by locality and can be significant in terms of both investment and opportunity costs (FAO, 2009a).

The Copenhagen Accord committed developed countries to provide US$30 billion in fast-start financing from 2010 to 2012 (divided equally between adaptation and mitigation) and set a goal to mobilize US$100 billion by 2020 in the context of mitigation. Pledged resources for fast-track financing are estimated to be between US$27.9 and US$29 billion as of August 2010, however past performance on climate financing shows large gaps among resources pledged, deposited and disbursed (ODI-Henrich Boell Foundation website on climate financing and WRI, Summary of Developed Country "Fast Start" Climate Pledges, last updated 12 August 2010).

Comparing overall estimated costs for adaptation and mitigation in 2030 and available resources over the short term shows a sizeable financing gap. Resources for mitigation in developing countries from major multilateral (CDM, World Bank, GEF) and bilateral funds are estimated to be around US$8 billion a year to 2012. If Copenhagen Accord commitments are met, this figure could reach US$15 billion a year between 2010 and 2012 and US$100 billion in 2020. This is against estimated mitigation costs of US$140-175 billion a year by 2030, with associated financing requirements of US$265-565 billion. Against estimated funding requirements averaging US$30-100 billion a year, between 2010 and 2050, available resources for adaptation are estimated to be US$2.2-2.5 billion from 2010 to 2012, excluding private finance, which could reach US$15 billion, if Copenhagen Accord commitments are fulfilled (World Bank, WDR, 2010). A very indicative summary of financing gaps, based on approximate figures and drawn from various sources, is provided in the graph below.

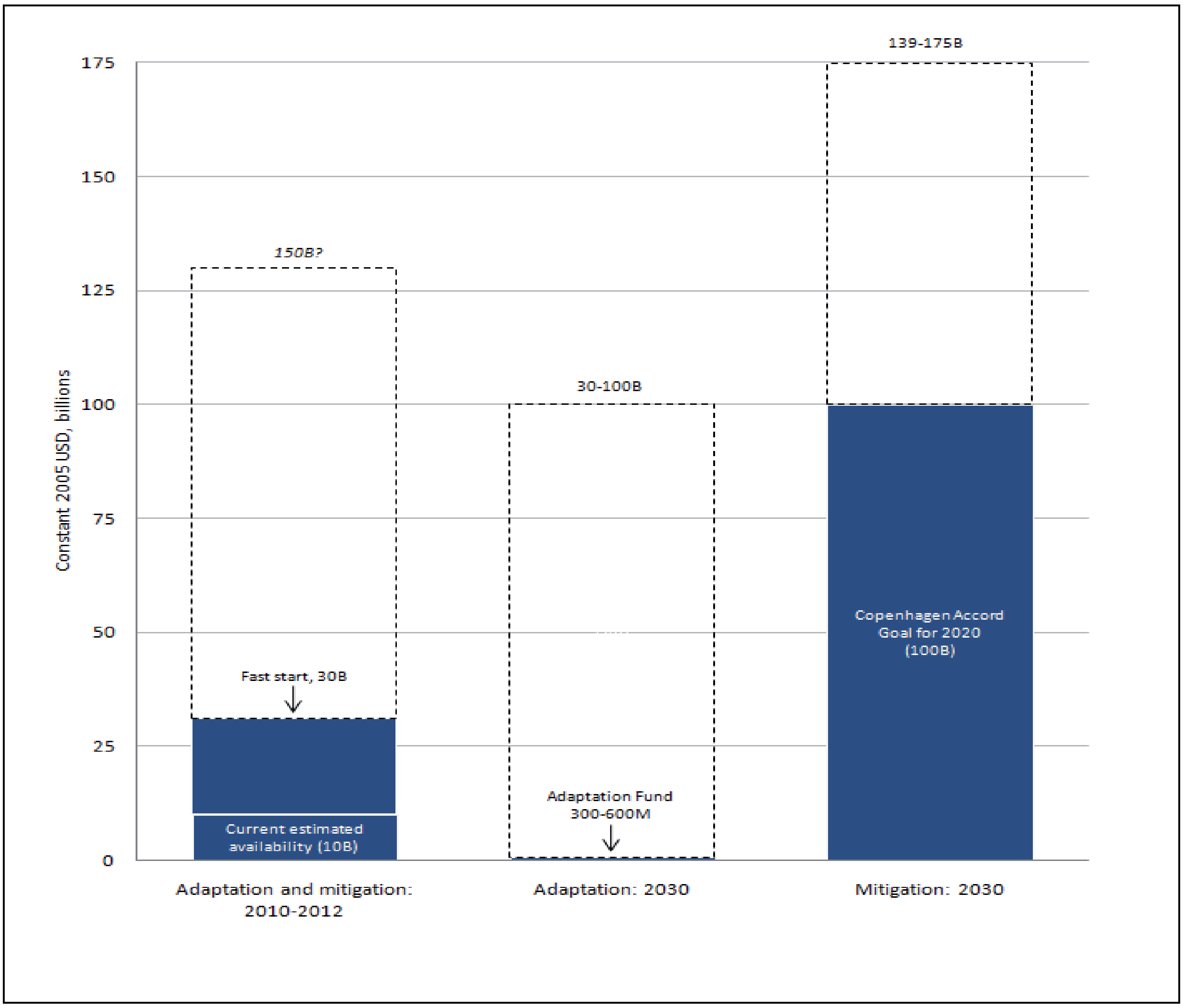

Figure 2: Investment needs vs available resources (in blue) in developing countries: A funding gap

While the share of current climate change flows to agricultural mitigation and adaptation are not yet known at this time, it is doubtful that they would meet the sector's overall investment requirements, given the exclusion of agriculture from the main climate change financing mechanisms (see below).

Overall, the vast majority of the investment in agriculture comes from private domestic sources, including from farmers themselves and funds they borrow. Remittances from abroad also constitute an important financial flow in many developing countries. Public spending on agriculture in developing countries has been low: in agriculture-based economies 4 percent of agricultural GDP, while the sector generates 29 percent of GDP and employs 65 percent of the labour force (World Bank, WDR, 2008). The remaining public investment comes from ODA. Governments of low-income food-deficit countries could consider increasing the share of agriculture in their national budgets from their current levels to at least 10 percent.

Total ODA commitments in 2008 from DAC donors was US$158 billion, with US$4 billion (only about 3 percent) committed to the agriculture sector (OECD, online International Development Statistics). Following the food price crisis in 2008, two new instruments have emerged: the Global Agriculture and Food Security Programme (GAFSP) and the Global Food Crisis Response Programme (GFRP). These programmes will be supported from the US$20 billion in funds, which the L'Aquila G-8 Summit in 2009 agreed to mobilize over three years for food security.

In its work on "How to Feed the world in 2050" FAO estimated that cumulative gross investment requirements for agriculture in developing countries add up to nearly US$9.2 trillion until 2050 or nearly US$210 billion annually (FAO, 2009a). These estimates were for investments in primary agriculture and downstream services, most of which will come from private sources. Essential public investments e.g. roads, irrigation, communication and education were not included. Available resources to support the necessary transformation of agricultural systems to ensure food security and development in developing countries are thus currently insufficient and funding from the private sector including that in developing countries, will continue to be important.

While agriculture and food security are more recently attracting greater funding (than over the last decades), they are not widely considered to be key "crunch" issues within the climate change negotiations and within climate financing mechanisms (see below). The extent to which agriculture could attract climate finance in future will depend on better recognition of its significant mitigation potential, its role as a driver of deforestation, the importance of its adaptation to climate change for food security and development and the feasibility and costs of implementing action and measuring results. More robust analyses of costs, investment needs, financial flows and MRV methodologies for measuring action and support are needed for the agriculture sector.

3.3 Sources of financing

It is apparent from the financing gaps mentioned above, that business-as-usual will not be an option for financing. For agriculture to contribute in line with its potential to address the dual challenges of food security and climate change, both higher levels of financing and more innovative approaches will be required. It is also evident that public resources alone will not suffice and how such resources could be used to leverage or be combined with other sources of funding is likely to shape future financing for the sector.

3.3.1 Blending different sources of financing

Financing to support the response of developing countries to climate change could be drawn from public, private and innovative sources of financing. Public finance, for example in REDD pilots, has often acted as a catalyst for action or to fund activities or areas neglected by the private sector. Expanding and diversifying the sources used could provide greater flexibility and the opportunity to tap additional sources of funding. Proposals made for innovative sources of financing include a percentage of GNP from developed countries, levies on international transport emissions or financial transactions, carbon taxes, issuing bonds to raise significant resources, auctioning of allowances (AAUs) within cap-and-trade schemes and an eventual global carbon market.

The use of public-private partnerships is also being explored. FAO has facilitated a public-private partnership that seeks to generate productivity increases and removal of greenhouse gases through the restoration of rangelands in the Tibetan Highlands of China. Carbon finance is used to compensate the temporary loss of income from taking land out of production or reduction in herd size (see box 25 on 3 Rivers Project below).

ODA for agriculture is not intended for financing agricultural adaptation or mitigation. It could be used, however, to provide budget or sectoral financing support for capacity building, access to information/technologies or to cover upfront expenditures necessary for making changes in agricultural production systems that support both food security and climate change objectives. More synergistic use of ODA and multiple climate change financing streams could help to bring together efforts to transform agricultural systems to meet food security and agricultural development goals, with those aimed at making these systems more resilient and emission-reducing/removing over the long-term.

National policies to encourage appropriate private and domestic government investment could help in achieving synergies across different financing sources and in spreading risk across private and public investors. Combining financing streams, for example long-term international ODA and carbon finance may benefit funding of agricultural programmes aiming to achieve multiple objectives, including changes in behavior and investment decisions. This may merit consideration in the context of agricultural planning and policy formulation, while potential areas of overlap/additionality and greater cost-effectiveness would require identification and quantification.

Box 25: The three Rivers Project

The 3 Rivers Project, situated in the Qinghai province of China (North) is a pilot project using carbon financing to facilitate grassland restoration and increase livestock productivity. Carbon finance, from a voluntary scheme, will be used to compensate costs and foregone income during the transition period and to increase productivity. Under the proposed pilot, herders will be offered a menu of options designed to fit their specific land use, which includes a combination of grassland restoration zoning and stocking rate management, in an incentive-based system. Given the current overstocking rates (about 45 percent), considerable reductions in income are expected during the first years of the project, for which herders will receive compensation. In the following years, as incomes are expected to grow in response to increased livestock productivity (and possible other small business support measures), compensation will decrease progressively until year 10.

Overall, in the first 10 years of the project, households will have fewer but more productive livestock. From 10-20 years, they can increase herds beyond the level of the first ten years, without the risk of overgrazing. Increased availability of forage will enable higher incomes and higher levels of production over the long-term, providing an incentive for long-term sustainable management. In addition, the project will develop a number of activities aiming at improving the profitability of livestock rearing, in order to improve herders' livelihoods. This will include the improvement of animal production (e.g. feeding, winter housing and breeding) as well as the development of processing activities and marketing associations.

This model hopes to break the vicious cycle of overstocking-degradation, building in, and demonstrating, sustainable management options during the project's lifetime, while generating a reduction of approximately 500,000tCO_2e, over a period of ten years. It also aims to address some of the key barriers to smallholder access to carbon finance, which include the lack of appropriate methodologies for crediting, as well as methodologies for cost effective monitoring, reporting and verification.

3.3.2 Leveraging

According to IPCC (2007a and 2007b), a maximum of US$30 billion could be obtained annually through agricultural mitigation from the estimated total annual value of the four major mitigation categories (crops, grazing land improvements, organic soil and degraded land restoration) in non-OECD countries (1.5 Gt/CO_2e/yr[13], valued at US$20/t CO_2e). This figure is not insignificant, but is only approximately 15 percent of the overall agricultural investment required for food security (US$210 billion a year to 2050). However, assuming that agricultural investment can leverage five times its value in carbon revenues (World Bank, 2009), carbon finance may provide incentives to leverage US$150 billion worth of climate-smart agricultural investments in developing countries. Mitigation finance could thus provide significant incentives to leverage agricultural investments that generate productivity increases, reduction/removal of greenhouse gases and increased climate resilience.

Considering the size of the overall agricultural investments required, versus the potential income from carbon markets, it is perhaps of greater importance to shift agricultural investments towards climate-smart agricultural development that provides multiple benefits in addressing food security and climate change challenges. High transaction costs, as well as the need for high levels of coordination and management, greatly limit the potential of agricultural mitigation financing from carbon offset markets. This indicates that public financing for mitigation will be required and could be channeled through existing financing mechanisms or through a climate change fund currently under discussion within the UNFCCC negotiations.

Using mitigation finance to support transformation of smallholder agricultural systems may require going beyond carbon-offset financing from developed countries to the establishment of mitigation financing for developing country agricultural activities that generate co-benefits, e.g. the development of climate-smart sustainable agricultural production systems. In this sense, mitigation finance could facilitate adoption of desired transitions that have been impeded by lack of financial resources. In this context mitigation finance can be a precious resource, especially when used as an incentive to capture synergies.

3.4 Financing mechanisms

3.4.1 Weaknesses of existing mechanisms

While a number of existing financing mechanisms have been instrumental in mobilizing resources for climate change mitigation and adaptation, FAO has underlined that the main mechanisms have generally not enabled agriculture (or forestry) to contribute fully to adaptation and mitigation efforts, in accordance with its potential (FAO, 2009b).

The *Clean Development Fund (CDM)* largely excludes agriculture, as soil carbon sequestration (representing 89 percent of agriculture's mitigation potential) is not eligible. The European Union Emissions Trading Scheme (EU-ETS) also excludes agriculture. This contrasts with voluntary carbon markets and the World Bank's *BioCarbon Fund* which include soil carbon sequestration. Although 4.49 percent of all registered CDM projects are designated as relating to agriculture (UNFCCC 2010, CDM website), these mainly address energy (bioenergy) through the use of agricultural residues, biofuels from crops and manure management. (RISOE database of CDM projects, updated 1 August 2010).

CDM's project-based and offset approaches may be inadequate to generate the breadth and scale of incentives required for agricultural mitigation. CDM incentives appear too weak to stimulate transformation in the economy and have not enabled developing countries to move towards low-emission development pathways that do not threaten economic growth. CDM projects also tend to have high transaction costs for many developing countries, long approval periods and a narrow geographic spread. Efforts to correct these weaknesses are under discussion and implementation. New approaches, such as programmatic CDM, sectoral CDM, sustainable development policies and measures, may enable scaling up of funding but vary in the degree to which they (i) can provide incentives for mitigation on a large-scale, (ii) are linked to sustainable development and (iii) in terms of their transaction costs.

The *Adaptation Fund* has recently become operational and ten projects have been submitted, two of which related to agriculture: (i) WFP submitted a project proposal, entitled An Integrated Approach to Building Climate Resilience in Uganda's Fragile Ecosystems to assist vulnerable populations in adapting to the impacts of climatic changes in two fragile ecosystems characterized by relatively high agricultural productivity and (ii) UNEP submitted one on vulnerability of the rice sub-sector to climate variability and projected climate change.

Agriculture and food security merit only a footnote (along with other sectors) in the draft AWG-LCA negotiating text on adaptation (UNFCCC, 2010) The latter contrasts with the large number of National Adaptation Plans of Action (NAPAs) of Least Developed Countries (LDCs) focusing on agriculture that have remained largely unfunded.

Developing countries, especially Least Developed Countries, have complained that accessing resources from the *Global Environment Facility* (GEF) has been complicated and project approval takes a long time. They have indicated that this has inhibited implementation of NAPAs and preparation of national communications. They have also drawn attention to under-funding of the Special Climate Change Fund and the Least-developed Countries Fund, which are funded on a voluntary basis.

3.4.2 New mechanisms

As climate change has moved up the policy agenda, finance mechanisms targeting climate change have multiplied. Currently about 20 different climate change-related finance initiatives exist. In 2007 alone, 14 new initiatives were launched (World Bank, WDR, 2010). This proliferation of new financing mechanisms has raised concerns about fragmentation, with high transaction costs (each initiative has its own governance structures and regulations), which in turn can reduce capacity to avoid duplication and inefficient allocation of resources.

Strengthening national ownership, transparency and accountability will be important for international mechanisms as well for national mechanisms receiving resources, including through direct access**.** For agriculture, coordination across different financing mechanisms is needed in order to reach the scale required to meet agricultural production and climate change challenges and to ensure an adequate link between national action and international support.

National funds**,** such as Brazil's *Amazon Fund*, the *Indonesian Climate Change Trust Fund* (ICCTF) or the proposed national Mexican Green Fund, provide opportunities for greater national ownership and better integration with national policies and programmes.

3.4.3 Architecture that enables action, including by agriculture

Discussion of financing mechanisms within the climate change negotiations has not tackled sector-specific aspects. Form currently tends to precede function, as attention is focused on architecture rather than on what will be financed and how finance would be linked to developing country actions. There is a risk that, due to their specificities, land-based activities may yet again find that they do not fit within the parameters of financing mechanisms (as was the case with the CDM). A separate funding arrangement for REDD has been proposed within future financing mechanisms, but it is unclear at this time whether agriculture, as a main driver of deforestation, would be able to receive funding from this window. For agriculture to be part of the solution to climate change, financing approaches and mechanisms need to make sure that agriculture is eligible to receive resources from existing or future climate funding mechanisms, that the specificities of agriculture are taken into account and that agricultural producers are rewarded for the generation of multiple services benefiting food security, development, adaptation and mitigation.

Certain agricultural practices can contribute to both adaptation and mitigation; however funding mechanisms (as well as policy frameworks) have remained separate and are still exploring how to reward action that can achieve both. Finding ways to overcome what is sometimes a false dichotomy between adaptation and mitigation (which can be the case with agriculture, especially where soil carbon sequestration is concerned), as well as the integration of adaptation and mitigation finance with agricultural development financing channels and activities, will be a challenge faced by financing mechanisms in future.

Broader approaches that look beyond current silos to forms of financing that could support high productivity/resilience and low emission agricultural development and development/food security-responsible climate change responses will be needed. Mechanisms must also be flexible enough to fund options adjusted to the specific agro-ecological, institutional and technological situations of different countries, including their different capacities. They may also be called upon to address the potential for establishing long-term and reliable funding sources, rewarding synergies and resolving potential conflicts or trade-offs due to multiple fund objectives.

3.5 Connecting action to financing

3.5.1 National level

Adequate investment in national climate-smart agricultural policy formulation, research, and extension, including related capacity building, is important in supporting action by farmers. Ministries of Agriculture, national research institutes and extension systems in many cases need to be built back following the decline in resources allocated to agriculture both internationally and domestically. While domestic resources may suffice for these activities in some countries, in others external support will be necessary.

Nationally-owned instruments that can promote coherence and coordination in priority setting for climate-smart agriculture action and financing may be useful to governments. The Indonesian Ministry of Agriculture has already formulated an Agriculture Sector Climate Change Road Map. The road map is written in the form of guidelines *"for creating synergies between climate change adaptation and mitigation programmes and action plans among sub-sectors."* Better clarification of how financing might be linked to nationally-owned action frameworks, including NAPAs/adaptation frameworks and NAMA/registries, is still required.

3.5.2 Linking to farmers

Linking financing to farmer-generated climate change responses requires a better understanding of mitigation and adaptation benefits that can be obtained from different sustainable agricultural options, the incentives that may be required to adopt them, and the costs. Incentives may be monetary in the form of credit or payments but could also be in-kind, including access to land, markets or seeds, fertilizers and other production inputs.

Experiences with payments for environmental service (PES) and microfinance could be drawn upon in building incentive systems for the adoption of relevant practices and technologies (see section 2). Where payments for mitigation and adaptation activities are economically viable, they may provide the stimulus for farmers to adopt sustainable agricultural land management practices. In some instances, payments of limited duration could provide incentives for soil carbon sequestration and also encourage transition towards productive and resilient production systems, while fitting with the saturation of soil carbon pools. Most soil carbon sequestration activities are expected to reach saturation at a certain point in time, i.e. after 20 to 100 years and therefore do not provide sustainable income in perpetuity. If carbon sequestration incentives also lead to more productive and sustainable forms of agriculture, there will be a lower risk of non-permanence (compared to baseline conditions).

It is important, however, to underline that beyond considerations of historical responsibility some forms of mitigation from smallholder agriculture will not be cost effective for international offset compliance markets, due to low returns, high transactions costs or high risks, which constitute investment barriers. The current low price for carbon credits and lack of capacity to participate in compliance markets are other barriers that need to be taken into account when considering mitigation action. These aspects and differing national capacities and circumstances suggest that a stepwise approach may be useful to build confidence, capacity and experience in linking financing for both adaptation and mitigation to smallholders at ground level.

3.5.3 MRV

A key issue associated with financing for mitigation is measurement, reporting and verification (MRV) of emission reductions and removals, as well as of international support provided. There is currently no consensus on the specific parameters of MRV for international financing, but eventual decisions in this regard could affect the costs and viability of different agricultural mitigation activities. The type and cost of MRV systems are likely to vary by the financing source used and over time (as capacity is built). Simpler and less expensive forms of MRV that are more readily useable by farmers could be utilized where off-sets are not involved. Developing countries and farmers are more likely to undertake action to build MRV capacity, where there is confidence and direct access to adequate and predictable financing for capacity building, and technology development/transfer.

More robust measurement of soil carbon sequestration may require combining actual soil samples, with modeling and/or default values for emission-reducing/removing activities. MRV of international support could include information on allocation by sectors, which would help in having a better picture of financial flows to the agriculture sector and differentiation of ODA and climate financing therein. Finally considerably less attention has been given to measuring results from adaptation activities. This may receive greater attention in future.

3.5.4 Pilots

Pilot activities, tailored to country-specific agricultural conditions/capabilities and supporting strategy formulation, technology development/transfer and capacity building, could enable country readiness to implement agricultural mitigation and adaptation action in the context of enhanced sustainable agricultural development and food security. Such pilots could offer possibilities for linking early climate-smart action with fast-start financing in the predominantly agriculture-based economies of many developing countries.

Key messages for part 3

8) Available financing, current and projected, are substantially insufficient to meet climate change and food security challenges faced by the agriculture sector.

9) Synergistically combining financing from public and private sources, as well as those earmarked for climate change and food security are innovative options to meet the investment requirements of the agricultural sector.

10) To be effective in channelling fast-track financing to agriculture, financing mechanisms will need to take sector-specific considerations into account.

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Acronyms

AAU	Assigned Amount Unit
ADPC	Asian Disaster Preparedness Center
ARD	Agricultural Research and Development
AWD	Alternate Wetting and Drying
BIIS	Bohol Integrated Irrigation System
BMG	National Agency for Meteorology and Geophysics
CA	Conservation Agriculture
CAADP	Comprehensive African Agricultural Development Programme
CATIE	Tropical Agriculture Research and Higher Education Centre
CDM	Clean Development Mechanism
CDH	Horticultural Development Centre
CERF	Central Emergency Response Fund
CFS	Climate Field School
CGE	Computable General Equilibrium
CIPAV	Centre for research on sustainable agricultural production systems
CM	Crop Monitoring
CSD	Commission on Sustainable Development
DAC	Development Assistance Committee
ECMWF	European Centre for Medium-Range Weather Forecasts
FADO	Farm Adaptive Dynamic Optimization
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer Field Schools
FONAFIFO	Costa Rican Forestry Fund
GAFSP	Global Agriculture and Food Security Programme
GCM	Global Climate Model
GEF	Global Environmental Facility
GFRP	Global Food Crisis Response Programme
GHG	Greenhouse Gas
GNP	Gross National Product
HLPE	High Level Panel of Experts for food security and nutrition
ICCTF	Indonesian Climate Change Trust Fund
ICTA	Instituto de Ciencia y Tecnología Agrícolas
IIED	International Institute for Environment and Development
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated pest management
IRLCO	International Red Locust Control Organization
IRRI	International Rice Research Institute

ISRA	Senegalese Institute of Agricultural Research
LADA	Land Degradation Assessment in Drylands
LDC	Least Developed Country
LIFE	Low Impact Fuel Efficient
LULUCF	Land Use, Land Use Change and Forestry
MPE	Multi-censor Precipitation Estimate
MRV	Measurement, Reporting and Verification
NAMA	Nationally Appropriate Mitigation Actions
NAPA	National Adaptation Programmes of Action
NGO	Non-Governmental Organization
NIA	National Irrigation Administration
ODA	Official Development Assistance
OIE	World Organisation for Animal Health
PES	Payment for Environmental Service
PHL	Post Harvest Losses
PRSP	Poverty Reduction Strategy Paper
PSNP	Productive Safety Net Programme
QDS	Quality Declared Seed
REDD	Reducing Emissions from Deforestation and Forest Degradation
RFE	Rain Fall Estimate
RVF	Rift Valley Fever
SEI	Stockholm Environment Institute
SRI	Sustainable Rice Intensification
UDP	Urea Deep Placement
UNFCCC	United Nations Framework Convention on Climate Change
UPA	Urban and Peri-urban Agriculture
UPH	Urban and Peri-urban Horticulture
VACVINA	Vietnamese Gardeners' Association
WDR	World Development Report

Annex I: Methods and Tools

The following annex provides a number of useful methods and tools developed by FAO and its partners for undertaking various assessments and monitoring which provides fundamental information for informed planning of climate change adaptation practices.

Weather based indices for crop insurance

FAO tools help to derive an effective weather-based crop yield index for crop insurance. The approach proposes to compute a crop specific water balance to derive value-added crop-weather variables that can be combined with other data (e.g. remote sensing inputs, farm inputs such as fertilizer use). The methodology uses gridded information that is not too sensitive to individual missing stations, provided sufficient data points are available. The methodology has demonstrated the possibility of producing weather based maize yield index for crop insurance for any point in Malawi every ten days starting from planting time. Real-time maize yield indices covering the whole country can be objectively produced. The maize yield index satisfies all the desirable criteria for maize crop insurance in Malawi. First estimates of Index can be provided at planting time and updated in real time throughout the season. More specific products for crop insurance can be prepared using criteria provided by insurance experts, and the methodology can easily be extended to other crops.

Details at: www.fao.org/nr/climpag/aw_2_en.asp

Crop monitoring and yield forecasting for early warning systems

The "CM Box" (Crop Monitoring Box) is a toolbox for agrometeorological crop monitoring and yield forecasting. It is an automated software suite with a "visual menu" that offers easy access to database that holds all the data needed to analyse the impact of weather on crops. The tool is useful for risk analysis, monitoring and forecasting crop production, which is an essential input to food security planning. The tool can compare maps of current yield expectations with historical average conditions. The CM Box is meant to offer an easy solution to rapidly setting up an operational crop monitoring and forecasting system. In the initial phase, reference data as well as real-time satellite and weather data can be provided by FAO based on international sources, but over the period, more and more national data can be used. Interested countries receive a combination of training, hardware, software customized for local use, as well as the real-time data required to operate the system in-country. The package can be tailored to suit the countries' specific requirements, based on national preferences as well as available expertise, methods and data.

Details at: www.fao.org/nr/climpag/aw_6_en.asp or www.foodsec.org/tools_cw_01.htm

Climate Change Impact Assessment Toolbox

FAO is developing an integrated methodology (toolbox) to asses climate change impacts on agriculture. The methodology comprises four main software components: a downscaling method for processing Global Climate Model (GCM) output data, a hydrological model for irrigation water resources estimation, a crop growth model to estimate crop yields and a Computable General Equilibrium (CGE) Model to simulate the effect of changing agricultural yields on national economies. The integrated toolbox for country wide implementation will be available together with user manual, tutorials and sample data in 2011 and validation will be carried out in two countries in Africa. The methodology is based on a study conducted by FAO, together with the World Bank and Morocco national institutions, to assess the impact of climate change on Moroccan agriculture. The study covers fifty crops, major agroecological zones, and climate change scenarios. For complete document visit: . www.fao.org/nr/climpag/pub/FAO_WorldBank_Study_CC_Morocco_2008.pdf

Local Climate Estimate Tool

The Local Climate Estimate Tool (New_locClim), is a software program and database, provides estimates of average climatic conditions at any location on earth based on the FAOCLIM database. The programme can create climatic maps, extract data in various formats from the database for further processing and can display graphs showing the annual cycle of monthly climate and the crop calendar. The tool provides growing season characteristics based on a comparison of rainfall and potential evapotranspiration and estimates of monthly, 10-day and daily values of common climate variables. The programme includes the current updated version of the FAOCLIM database of almost 30 000 stations worldwide, but users can also process their own data and prepare maps at any spatial resolution. Computer application programs (in Microsoft Excel) are included in the CD-ROM to help simplify complex calculations.

Access and download the tool at: www.fao.org/nr/climpag/data_5_en.asp

Farm Adaptive Dynamic Optimization (FADO)

Farm Adaptive Dynamic Optimization (FADO) refers to a combination of methodology that helps to identify, analyze and prioritize the climate related vulnerabilities and risks and optimize the adaptation practices to effectively respond to climate variability and change. The approach combines the historical climate data and modern data transmission and information sources for real-time analysis of impacts. It provides opportunities to generate viable options for farm decision making to manage the risks and opportunities at the farm level. The four major components of the FADO methodology are: exploring knowledge on local situation of farmers' decision problems, analysing the vulnerability and climate risks to optimize the management options, decide appropriate adaptation practices relevant to local situation and facilitate local action by communicating climate information and suitable adaptation practices to farmers.

Additional information as: www.fao.org/nr/climpag/aw_5_en.asp

FAO-Rain Fall Estimate Routine

FAO Rain Fall Estimate (FAO-RFE) for Africa is a new independent method to estimate the rainfall amount, particularly, for certain regions where the coverage of the weather stations is scarce. FAO RFE is based on the Meteosat Second Generation IR channel combined with data coming from ECMWF global forecast model and EUMETSAT MPE. A local calibration is performed using the ground gauges, directly received as SYNOP messages and after a data validation. FAO-RFE offers 10-day and monthly rainfall totals for whole of Africa and for four regions. The importance of the FAO-RFE is that it can be implemented at national level to improve rainfall estimate provided by National Meteorological Services. FAO is now supporting the transfer of the methodology to Sudan Meteorological Authority.

Additional information as: http://geonetwork3.fao.org/climpag/FAO-RFE.php

CLIMPAG

CLIMPAG (Climate impact on agriculture) is a web portal bringing together the various aspects and interactions between weather, climate and agriculture in the context of food security. CLIMPAG contains data, maps, methodologies and tools for better understanding and analysis of the effect of the variability of weather and climate on agriculture. The web portal covers six major thematic areas: advice and warnings, climate change, climate indicators, data and maps, hotspots and natural disasters. User friendly drop-down menu provides access to all publications, tools and methods relevant to all the thematic areas.

The portal can be accessed at: www.fao.org/nr/climpag/

Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases (EMPRES)

Protection against animal and plant diseases, pests and food safety threats and preventing their spread is one of the keys to fighting hunger, malnutrition and poverty. The Emergency Prevention Systems (EMPRES) has the mandate to address prevention and early warning across the entire food chain. Its mission is to promote the effective containment and control of the most serious epidemic pests, diseases and food safety threats through international cooperation involving early warning, early reaction, enabling research, and coordination. This is done through the following systems:

- EMPRES Animal Health: animal diseases, including aquatic animal diseases
- EMPRES Plant Protection: plant pests and diseases including desert locust and forest plant pests and diseases
- EMPRES Food Safety

The portal can be accessed at: www.fao.org/foodchain/prevention-and-early-warning/en/

Disaster Risk Reduction (DRR) programme

FAO launched a programme in 2003 focusing on the role of local institutions in disaster risk reduction (DRR). It addresses DRR as an integral part of sustainable development, while applying an agricultural perspective as entry point. The programme assists countries in their efforts towards better planned, long-term disaster risk prevention and preparedness strategies, which address the root causes of vulnerability of local stakeholders to natural hazards in a demand responsive and sustainable way.

The portal can be accessed at:

www.fao.org/emergencies/current-focus/institutions-for-disaster-risk-management/en/

EX-ACT

EX-ACT is a land-based accounting system, measuring C stocks and stock changes per unit of land, expressed in tCO_2e/ha and year. This ex-ante C-balance appraisal will guide the project design process and the decision making on funding aspects, complementing the usual ex-ante economic analysis of investments projects. EX-ACT will in fact help project designers to select project activities with higher benefits both in economic and climate change mitigation terms and its output could be used in financial and economic analysis of the projects. It is an easy tool to be used in the context of ex-ante project/program formulation, it is cost effective, it requires a minimum amount of data, and it has resources (tables, maps) which can help finding the information required to run the model. Also, EX-ACT works at project level but it can easily be up-scaled at programme/sector level.

The portal can be accessed at: www.fao.org/docs/up/easypol/768/ex-act_flyer-nov09.pdf

MASSCOTE

MASSCOTE is a step-wise procedure for auditing performance of irrigation management, analyzing and evaluating the different elements of an irrigation system in order to develop a modernization plan. The modernization plan consists of physical, institutional, and managerial innovations to improve water delivery services to all users and cost effectiveness of operation and management. Masscote is founded on a rigorous on site approach of the physical water infrastructure (canals and networks) and introduces service oriented management as a normal practice.

Additional information at: www.fao.org/nr/water/topics_irrig_masscote.html

AquaCrop

AquaCrop is the FAO crop-model to simulate yield response to water of several herbaceous crops. It is designed to balance simplicity, accuracy and robustness, and is particularly suited to address conditions where water is a key limiting factor in crop production. AquaCrop is a companion tool for a wide range of users and applications including yield prediction under climate change scenarios. AquaCrop is mainly intended for practitioners such as those working for extension services, governmental agencies, NGOs, and various kinds of farmers associations. It is also of interest to scientists and for teaching purposes, as a training and education tool related to the role of water in determining crop productivity.

Additional information at: www.fao.org/nr/water/aquacrop.html

TECA

TECA is an FAO initiative that aims at improving access to information and knowledge sharing about proven technologies in order to enhance their adoption in agriculture, livestock, fisheries and forestry thus addressing food security, climate change, poverty alleviation and sustainable development. TECA also provides web-based communication tools to better document, share good practices and customize its use to each user's characteristics. It is interactive, and has a great potential to improve linkages among extension staff, researchers, farmer organizations and other stakeholders involved in agricultural innovation.

Additional information at: www.fao.org/teca

FAO Best Practices Portal

The FAO Best Practices Web site provides a series of summaries that introduce some best practices in FAO's areas of expertise. It also provides links to further resources with supporting technical information. The practices have been divided by theme. They have been adopted successfully in more than one region and are interdisciplinary, reflecting the complex nature of the problems addressed.

FAO Best Practices Portal: www.fao.org/bestpractices/index_en.htm

WOCAT

The World Overview of Conservation Approaches and Technologies (WOCAT) is an established global network of Soil and Water Conservation (SWC) specialists, contributing to sustainable land management (SLM). WOCAT's goal is to prevent and reduce land degradation through SLM technologies and their implementation approaches. The network provides tools that allow SLM specialists to identify fields and needs of action, share their valuable knowledge in land management, that assist them in their search for appropriate SLM technologies and approaches, and that support them in making decisions in the field and at the planning level and in up-scaling identified best practices.

Additional information at: www.wocat.org

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