Chapter 1
How Climate Change Reshuffles the Cards for Agriculture

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Nothing is permanent but change
Heraclitus

Abstract Agriculture is affected by but also contributes to climate change. Agricultural risk may be local, impacting crops, or global, impacting food security. The agricultural sector accounts for 24 % of greenhouse gas emissions. Adaptation to and mitigation of climate change are two different responses that may be reconciled in climate-smart agriculture proposals. Developing countries will have more difficulty in adapting, as the changes will have a greater impact there than in developed countries. By around 2050, the majority of African countries will experience heretofore unknown climatic conditions on over half of their arable land. Appropriate public policies, institutions and funding are needed to increase the resilience and efficiency of agricultural production systems and implement the necessary changes.

1.1 Background

Habits are hard to break. We consciously or unconsciously prefer what we know and are used to doing. The climate change the planet has experienced in recent years still has some surprises in store that will have to be dealt with. Though we know broadly what to expect, the effects are difficult to accurately predict, especially at the local level. It is not enough to say that it will be warmer. Changes in the amount of greenhouse gas (GHG) levels also affect seasonality, rainfall, biodiversity, sea level and glacier and ocean dynamics, and give rise to a complex web of interactions.

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Agriculture—no doubt the human activity most dependent on the climate—will be particularly affected. Climate change increases the frequency and magnitude of the climate hazards farmers have faced for generations. Agriculture is impacted by climate change, while also contributing to it. At the interface between climate change adaptation and mitigation, agriculture is also a part of the solution. It is the only human activity that can not only reduce greenhouse gas emissions but also sequester carbon in soil and biomass. Moreover, it can spur conservation in other sectors (energy, transport, construction) by generating products derived from agricultural or forest biomass to replace highly polluting conventional products. Agriculture will have to evolve to adapt to climate change and biodiversity loss, while also mitigating their impacts, in order to cope with the significant economic, social and environmental challenges of the 21st century and sustainably meet the needs of a predominantly urban population of approximately nine billion by 2050. We have no option but to change our habits, in this sector more than any other.

1.2 Main Thrusts of the Latest IPCC Report and the Agricultural Implications

The latest IPCC Report (IPCC 2014a) confirmed there is no possible doubt that the atmosphere and oceans are warming, snow and ice cover is decreasing, and sea levels and GHG concentrations are rising because of human activity. From 2000 to 2010, GHG emissions increased by 2.2 % per year, compared to 1.3 % between 1970 and 2000. The carbon dioxide (CO_2) concentration has risen by 40 % since pre-industrial times, mainly because of emissions from fossil fuels (energy, industry, transport) and from agriculture, forestry and land-use changes (about 24 %; Fig. 1.1).

Each of the last three decades has been successively warmer than any previous decade since 1850, and if the same trend continues, the global average land temperature may increase by between 3.7 and 4.8 °C in the course of the 21st century, whereas it rose only by around 0.85 °C from 1880 to 2012. To keep the temperature from rising more than 2 °C, GHG emissions must be reduced by 40 to 70 % by 2050 relative to 2010 levels, then to zero by 2100. In that scenario, the most optimistic one foreseen by IPCC (representative concentration pathway [RCP] 2.6; Fig. 1.2), the CO_2 concentration would reach 421 parts per million (ppm) in 2100, as compared to about 400 ppm today, with a rise in sea level of 26 to 55 cm (as compared to 19 cm from 1901 to 2010). No matter how things unfold, many changes are now inevitable. They will affect society as a whole and involve physical systems (rivers, glaciers, coastlines, etc.), natural ecosystems (biodiversity) and human activities (food production, wellbeing, health, economy, etc.). In addition, there is likely to be an increase in the variability of extreme weather events.

Many technical, institutional, regulatory and behavioural options are available to meet climate change challenges, but all are predicated on a change in our habits, and the longer we wait the costlier the response. The options are twofold, comprising

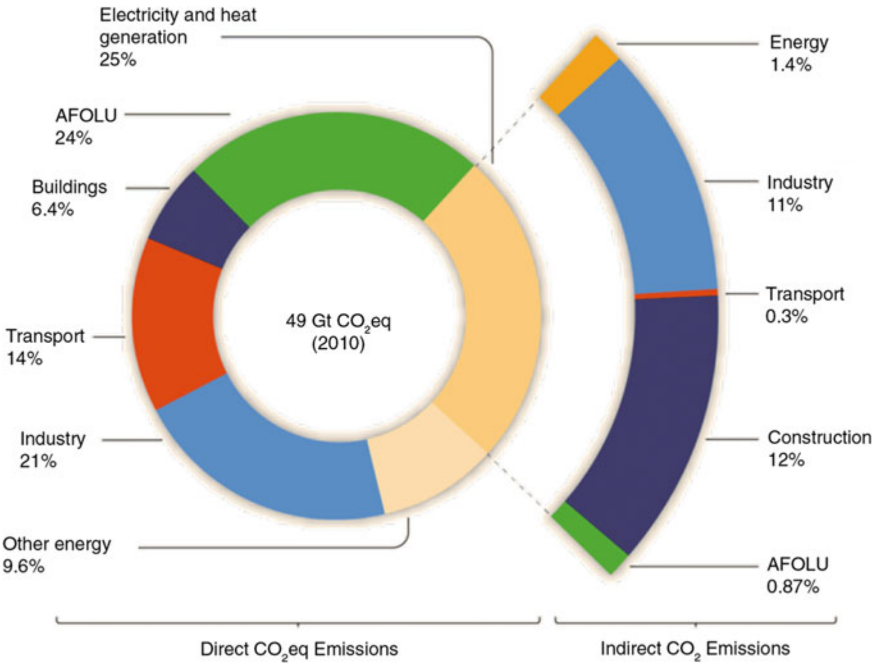

Fig. 1.1 Total anthropogenic greenhouse gas emissions (Gt CO_2-eq/year) by economic sector. *AFOLU* = agriculture, forestry and other land use (*Source* IPCC 2014a)

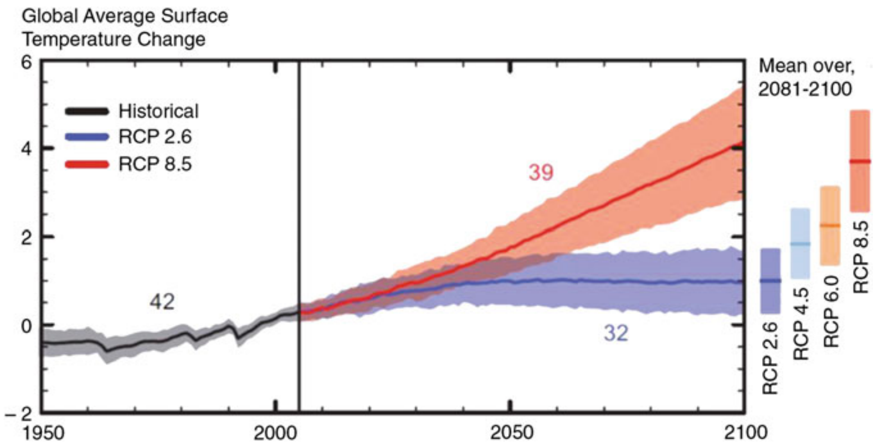

Fig. 1.2 Multi-model simulated time series from 1950 to 2100 for change in global annual mean surface temperature (°C) relative to 1986–2005. Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). Black (grey shading) is the modelled historical evolution using historical reconstructed forcings. The mean and associated uncertainties averaged over 2081–2100 are given for all RCP scenarios as coloured vertical bars. The number of models used to calculate the multi-model mean is indicated (IPCC 2013)

strategies for adaptation to climate change (changes in natural or human systems) on the one hand, and efforts to mitigate climate change (human intervention to reduce GHG sources or increase 'sinks') on the other hand.

Climate change has an impact on human activities by increasing risks that are dependent on three factors: exposure of an activity (e.g. its location in an area of increased drought), vulnerability of the population concerned (likelihood of being affected by the risk), and damage induced by exposure to climate hazards (for humans or the environment) on account of a particular weather event (Fig. 1.3). All three factors need to be considered in adapting to climate change, so adaptation is necessarily site-specific and no solution can be assumed to be workable in all circumstances. Complementarity between the different levels of society (from individuals to governments and international organizations) is essential for successful coping strategies, which are presently being applied in most countries. Those strategies should primarily target vulnerability and exposure to risk so as to help boost the resilience of affected human groups. Various economic mechanisms are needed to stimulate adaptation through incentives and impact forecasts.

In agriculture, the risk may be local, such as when seasonal rains fail, but global food security is an especially serious risk, since needs from the agricultural sector are expected to increase by 70–100 % by 2050 (Soussana 2012). Climate risk is of course combined with other factors, such as increased land-use, deforestation, degradation of some soils, biodiversity erosion and groundwater availability.

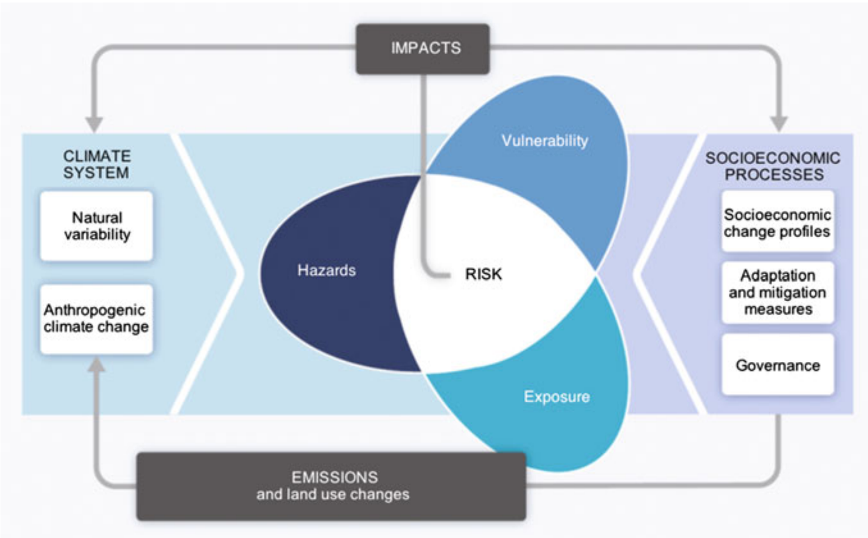

Fig. 1.3 Core concepts addressed in the contribution of Working Group II to the Fifth Assessment Report. Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability (IPCC 2014b)

The climate change issue as it affects agriculture is also analysed in terms of 'demand', namely whatever can be altered to reduce climate risk. Diet, foodstuff transport, agricultural product price regulation, management of pre- or post-harvest crop losses, and waste management are all factors to be taken into account.

1.2.1 Adaptation and Agriculture

Adaptation may involve lessening undesirable effects or taking advantage of favourable opportunities, but in agriculture, IPCC results show that negative impacts are much more common than positive ones. Lower wheat, maize and rice yields are expected if temperatures increase by 2 °C or more, thus impacting food access and use, as well as price stability. Lessening of harmful effects is a strategy very familiar to farmers—anticipating climate hazards, for example through crop diversification or changing planting dates. However, a change of strategy is necessary when the hazard occurs frequently. Then it is essential to fundamentally alter the crop management system or cultivation strategy or to start over somewhere else. Resourcefulness is needed, such as switching to a crop that is better adapted to the new conditions or moving to higher elevations to grow crops, weather permitting.

Agriculture that is adapted to climate change is said to be 'resilient', which means it allows production to continue despite unexpected disruptions. Diversity is one essential element of resilience. A farm on which monocropping is practised is less resilient than a farm where intercropping or mixed cropping prevails. A strategy that takes local biodiversity (hedges, grass strips, landscape mosaics, etc.) and agrobiodiversity (beneficial associated species, soil flora and fauna, etc.) into account enhances agricultural resilience substantially (Hainzelin 2013). Another resilience-fostering strategy is to select crops tailored to their environment, rather than modify the environment, for example through irrigation and inputs (e.g. pesticide treatments to compensate for poor plant health). Risk management can also involve insurance mechanisms, but not all farmers can afford insurance and the situation may soon become unmanageable should the targeted risk insured become widespread. What is needed, of course, is a substantial, internationally coordinated research effort—to provide farmers with plant varieties, livestock breeds and crop management systems that will be adapted to tomorrow's climate, while developing the necessary support in the form of public policy incentives or effective weather monitoring systems.

1.2.2 Mitigation and Agriculture

The land sector (AFOLU, see Fig. 1.1) includes direct emissions, emissions related to land use change to meet the needs of agriculture and livestock farming, and indirect emissions conventionally attributed to other sectors, such as agricultural

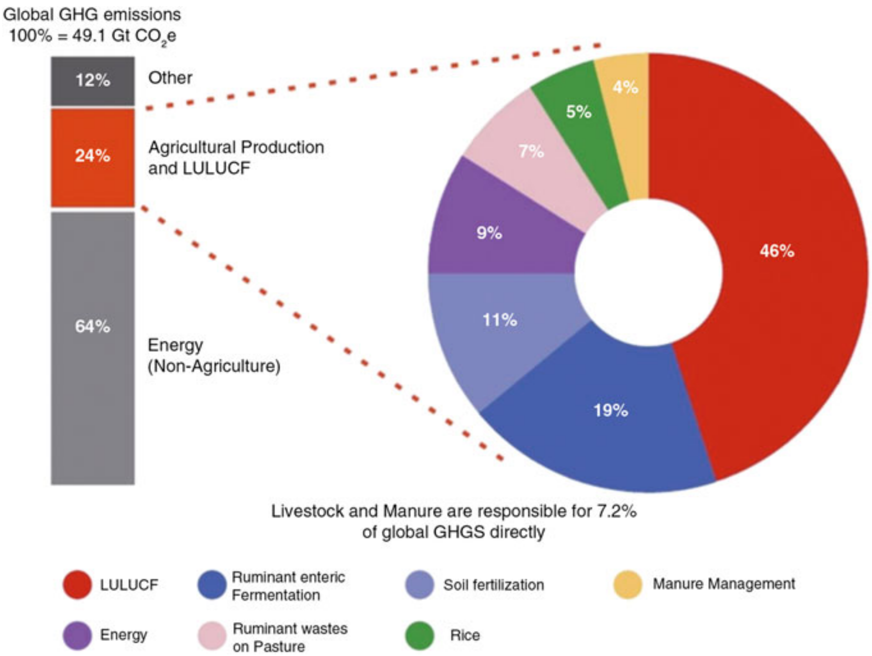

Fig. 1.4 Overall agriculture, forestry and other land use (*AFOLU*) emissions by component, 2010 (WRI 2014). *LULUCF* = land use, land use change and forestry

produce transport. GHG emissions from agriculture are increasing at a slower rate than those from other human activities (FAO 2014). Under the baseline IPCC scenario (no mitigation), while agricultural emissions other than CO_2 are increasing, net CO_2 emissions in the land sector are decreasing due to a reduction in deforestation rates and increased reforestation, but there is greater uncertainty regarding emissions in this sector than in others. The land sector should hence not be overlooked, as it accounts for almost a quarter of all emissions. These are derived from deforestation as well as agricultural emissions arising from livestock farming and soil and nutrient management. This sector is unique in that it is a domain where climate change mitigation could come via an increase in GHG capture ('carbon sinks', through carbon storage in biomass and soil) and a reduction in emissions ('carbon sources', through changes in land and herd management). Enteric fermentation, manure, synthetic fertilizers and irrigated rice are the main sources of agricultural GHG emissions, alongside emissions from farm machinery and buildings (Fig. 1.4). The primary sink in this sector is the growth of forests and trees and carbon storage in aboveground and belowground biomass. The land sector thus plays a central role in food security and sustainable development. The most cost-effective forest mitigation options are afforestation, sustainable forest management and reduced deforestation. The most cost-effective mitigation options in agriculture are the management of cultivated or grazed land and the restoration of organic soils.

There are numerous obstacles to the implementation of mitigation options in the land sector due to its nature, including the availability of funding, poverty, and institutional, environmental, technological, dissemination and transfer issues. Public policies based on sustainable development and equity principles are essential for climate change mitigation, but they assume that collective action will not be impeded by private interests. The attitude that climate change is a problem to be managed by others is rife. These policies are formulated on the basis of value judgments and ethical considerations, and economic decisions interfere with development goals. Developing countries, in particular, are often reluctant to implement mitigation policies that could hinder economic growth, as they are more vulnerable to climate change and do not feel responsible for past GHG emissions. They reject efforts by developed countries to place the onus of mitigation on developing economies. In recent discussions, however, there has been increased focus on synergy between adaptation and mitigation under the same technical and regulatory options. Climate policy design is influenced by the way individuals and organizations perceive risks and uncertainties and take them into account. The cost of mitigating climate change varies greatly depending on the selected reduction target, the zone under consideration, the technologies used and the possible positive or negative side effects. Individual behaviour, lifestyle and culture are major influences. Demand-related measures, such as dietary changes and loss reduction in food supply chains, have significant (but according to IPCC still uncertain) potential for reducing GHG emissions associated with food production.

1.2.3 The Bioenergy Issue

Bioenergy production has an important role to play in mitigation, but must be carefully gauged against other potentially conflicting forms of land use. Questions remain as to the sustainability of bioenergy practices and the efficiency of bioenergy systems, including input use. GHG emissions from bioenergy cropland (due to the intensive use of inputs or mechanization), food security (competition with food crops), water resources (irrigation) and biodiversity conservation (large mono-cropped areas) are some of the obstacles to the large-scale deployment of bioenergy production schemes. Bioenergy technologies are varied and encompass a wide range of technical options and pathways, but the scientific debate on the overall climate impact of land use competition between particular bioenergy schemes is still ongoing. Available results indicate that technologies involving options with a short emission life cycle (e.g. sugarcane, *Miscanthus*, fast-growing trees and sustainable use of biomass residue), some of which are already available, can reduce greenhouse gas emissions. Forest biomass can also be used for bioenergy generation, but only biomass from sustainably managed stands or forests has a positive impact on the carbon stock.

1.2.4 Situation of Developing Countries

The third volume of the IPCC Report indicates that the models predict a strong negative impact on agricultural productivity and global food security for scenarios involving local increases of 3–4 °C or more. The risk will be higher in tropical countries because of the greater impact, widespread poverty and adaptation difficulties. In the tropics, maize and wheat yields begin declining when temperatures rise by 1–2 °C, rice yields when the increase is 3–5 °C. However, IPCC also believes that the agricultural mitigation potential could account for as much as three quarters of total agricultural emissions and that this could be achieved by managing the soil carbon stock, mainly in developing countries, not so much by reducing emissions.

By 2050, most African countries will experience heretofore unknown climatic conditions on more than half of their arable land. By 2080, there will very likely be a negative impact on yields in the tropics, regardless of the adaptation or emission scenario considered. Africa is one of the most vulnerable areas in terms of food security, but climate change will also affect crop yields, food security and local economies in Central America, northeastern Brazil, parts of the Andean region, and South Asia. Yields of some crops could nevertheless increase in a few tropical highland areas, such as rice in Madagascar. Crops such as arabica coffee will have to be cultivated at higher elevations to benefit from lower temperatures.

In current climate change adaptation conditions, at least seven climate risks in Africa are projected to be medium-high or high by 2030: biome distribution changes, coral degradation, reduced crop productivity, detrimental effects on livestock, vector-borne diseases, malnutrition, and human migration. In Latin America, there will be significant risk to water resources, coral reefs and food production, and from vector-borne diseases, while in Asia the risks will concern crop productivity, water shortages, floods and heat-related mortality. Many drivers of change in tropical regions may therefore have a negative impact on agriculture. According to the report of IPCC Working Group III, if greenhouse gas emissions are not reduced and lead to a 4 °C increase from 2080 to 2100, food security in Africa will be threatened, even if progress has been made in adapting to climate change. While the initial effects of global warming in Africa can be offset by agroecological practices, modelling studies show that in the case of maize, only new cultivars or irrigation practices will be able to counter the effects of extreme temperatures and water stress beyond 2040 (Folberth et al. 2014).

When poverty prevails, the climate change impact exacerbates other stress factors and often depreciates the wellbeing of the most vulnerable people. There is a real risk of food insecurity and the breakdown of food supply systems in the event of sharp increases in temperature, drought, flooding or high variability in rainfall extremes. Inadequate access to safe drinking water or irrigation water obviously has negative consequences, especially on farmers and herders in semiarid regions. Impacts on marine and coastal ecosystems and their biodiversity may seriously threaten fishers.

The sectors under greatest threat in developing tropical areas are: freshwater resources (significant reduction in renewable surface water and groundwater resources in dry subtropical regions); marine systems (high local extinction rates in semi-enclosed tropical seas); food (mostly negative effect of increased temperature on yields); rural households headed by women or lacking access to land, agricultural inputs, infrastructure and education; human health and population security (risks related to displacement and migration). All of these risks imply that climate change will exacerbate poverty in already poor countries. Combating climate change is therefore tightly linked to sustainable development and equity, but there may be a contradiction between necessary adaptations and some mitigation targets. Climate policies and technical solutions should therefore transcend adaptation and mitigation objectives and focus on development pathways in the broadest sense so as to sidestep that contradiction.

Many initiatives already take climate change constraints in developing countries into account, particularly with regard to adaptation, which is often linked to development initiatives such as integrated water resource management, agroforestry or coastal mangrove reforestation. Ecosystem-based adaptation sometimes includes protected areas, conservation agreements and community management of natural areas. Resilient crop varieties are adopted, in addition to the development of climate forecasts and early warning systems. Traditional environmental knowledge is increasingly put to use in adaptation efforts.

1.3 What Climate-Smart Agriculture Proposes

1.3.1 Synergy Between Adaptation and Mitigation

There are many possible interactions between adaptation and mitigation and between different adaptation options. These interactions may involve co-benefits (influence on other societal goals such as health or biodiversity), synergies (mitigation and adaptation objectives reached simultaneously) or tradeoffs (choice between mitigation and adaptation). Agricultural and forestry policies are generally more effective when they combine mitigation and adaptation. Despite the obvious links between the two approaches, most initiatives deal with them separately—mainly mitigation under the United Nations Framework Convention on Climate Change (UNFCCC) negotiations, and adaptation in the context of the Millennium Development Goals. But things are changing. Some discussions focused on the 'land sector' during the United Nations negotiations in Warsaw in November 2013 and again in Lima in 2014, thus reconciling the former negotiations on mitigation in the forestry sector with more recent negotiations regarding agriculture, which were mainly geared towards adaptation. While forests were the main focus of earlier discussions, agriculture is progressively included in the discussions. The debates highlighted the fact that agriculture (not only forests) must play a role in mitigating climate change, while linking mitigation and adaptation approaches. Mitigation can even be one of the functions of adaptation, such as when a crop management system is developed that improves productivity while increasing the stock of biomass. Technical solutions are available that can simultaneously tackle the food security, mitigation and adaptation challenges, providing a unique opportunity for agriculture to move towards more agroecological practices.

The climate-smart agriculture (CSA) concept promoted by FAO since 2010 (FAO 2013) is based on this synergy between adaptation and mitigation. CSA is focused on three objectives: sustainable food security (production), adaptation to climate change (or agricultural resilience to climate disruptions) and mitigation of climate change (emission reduction or carbon storage). The concept was developed in response to the realization that agriculture in developing countries must undergo profound transformations to meet food security and climate change challenges.

The three main features of FAO's rationale are as follows:

- some practices fulfil the definition above, but ecosystem-oriented, landscape-scale and cross-sectoral (agriculture, livestock farming, forestry, food security, etc.) approaches are essential;
- institutional support and public policies are needed to enable smallholders to make the necessary transition, which will require a massive information and coordination effort and better streamlining of agricultural, food security and climate change policies;
- available funds are insufficient to achieve that transition, so new financial arrangements must be found that combine public and private sources and are geared towards combating climate change and enhancing food security, while taking the characteristics of the various sectors concerned into account.

Hence, rather than an agricultural technique, CSA is considered a holistic approach that takes practices, public policies and financing (Lipper et al. 2014) into account. It is intended to address all three challenges (adaptation, mitigation, food security) simultaneously. Practices and enabling conditions for their implementation must hence be described concomitantly in order to promote CSA. Otherwise, these practices could merely be existing sustainable agriculture technical options (contour cropping, integrated pest management, water retention, intercropping, etc.).

The so-called Sahel Re-greening Initiative in Niger is a concrete example of CSA. Research and development operations, decentralization initiatives, and the transfer of tree ownership rights from the State to farmers have helped revive the practice of assisted natural regeneration of field trees (agroforestry). Over just a few years, there has been a spectacular increase in tree density, which has helped change the microclimate and improve soil fertility (adaptation), increase standing biomass (mitigation), and enhance farmers' incomes and livelihoods.

Intermittent paddy rice irrigation (also known as 'sustainable rice intensification') is another example of CSA. Using that approach, water consumption can be reduced (adaptation) along with methane emissions from anaerobic decomposition of organic matter (mitigation), while boosting yields and quality (food security). The approach still needs to be validated on a larger scale, and could give rise to weed problems, but the initial results are promising.

Decentralized energy generation on farms is another example of CSA. This contributes to climate change mitigation (no fossil fuels used), adaptation, if this generation is based on locally available resources, and food security, by cutting energy expenditures. Support measures are needed for farm-scale energy generation and for sustainable management of the resource (wood or other biomass) and the potential impact of bioenergy generation on land devoted to food production. There are therefore many different options for the implementation of CSA principles. Land use characterization (Box 1.1) provides information on the necessary choices.

Box 1.1. Five complementary dimensions for land use characterization and awareness raising on decisions related to climate change.

Marie de Lattre-Gasquet and Chantal Le Mouël, Agrimonde-Terra foresight study

Agricultural potential: knowledge of this can facilitate decision-making on land allocation to various uses, the way the land is utilized in each case, property assessments, etc., leading to several types of classification. At the global level, the GAEZ model (global agroecological zones; Fischer et al. 2012) is often used. It distinguishes categories of land according to their agricultural usage potential: 'very suitable', 'suitable', 'moderately suitable', 'marginally suitable' and 'not suitable'. But not all land with sufficient agricultural potential for cultivation may be available because of restricted access (see next dimension). Verburg et al. (2013) speak of the "myth of arable land", reflecting the fact that, depending on the source, estimates and projections of arable land vary widely owing to the land use categories and methods used and the specific objectives of each study. Increases or decreases in temperature and water variations induced by climate change affect the land's agronomic potential and hence its classification. In the past, climate change tended to lessen the agricultural potential of land, whereas it could improve it in some areas in the future.

Access to land: depends on its governance, which sets the rules, processes and structures that determine how land is used and controlled, the way decisions are implemented and enforced, and how competing property interests are managed. Unequal access to land among individuals, social groups, and men and women is a major economic stratification factor in rural and urban areas. A broad array of rights must be recognized to improve access to land. Pressure due to climate change will increase competition for land access, which could in turn result in changes to land governance.

The distribution of land among different uses: refers to where the bulk of agricultural and forest production takes place. This dimension is largely a function of market access for farmers, transport and production costs, and agricultural policies for some types of production. In some sectors and regions, processing industries are questioning the sustainability of their agricultural supplies. Future climate change will alter agricultural production locations and could lead to more land 'relocation'.

Modes of production: are related to agricultural production systems, which in turn are characterized by combinations of crops, crops and livestock, crop sequences and the combination of different factors (land, labour, capital) and inputs (fertilizers, pesticides, water, energy etc.) used for crop or livestock production. Modes of production may, for instance, be characterized by the degree of intensification or the yield per hectare. They are heavily influenced by—but may also influence—hydroclimatic variations.

Multifunctionality of land: means that even land used for biomass production for energy or food purposes produces ecosystem goods and services. Farmers manage and help maintain the land. In a context of rapid climate change requiring alleviation or even mitigation measures, it is essential that multifunctional uses be considered on par with agricultural production itself.

CSA generally embodies approaches focused on sustainable water and soil conservation and management (moderate irrigation, water capture, erosion control, organic matter enrichment, soil biodiversity improvement, cover crops, tree cover in fields and landscapes, etc.). Carbon sequestration in aboveground and belowground parts of plants is frequently sought, especially to achieve 'sustainable agriculture' (Perfecto et al. 2009) based on the use of woody plants, cover crops, perennial grasses, roots and tubers. CSA cannot be reduced to monocropping, but instead should integrate various agricultural activities, such as combining crop and livestock farming, paddy fish farming, and agroforestry.

1.3.2 Efficiency, Resilience and Landscape Scale

Most agricultural GHG emissions arise from natural resource use (clearing and cropping new land, transforming permanent grassland into cropland, tapping water resources) or from production input use (fertilizer and energy). Enhancing resource-use efficiency (more volume produced per unit of input) should make it possible to reduce GHG emissions per output unit and slow the expansion of agricultural land by making more intensive use of it, thus helping to mitigate climate change (FAO 2013). That so-called 'land saving' approach contrasts with another approach whereby land serves both production and conservation purposes ('land sharing'; Grau et al. 2013). Under the latter approach, which is akin to CSA (see Chap. 24), sustainable agricultural intensification generates environmental co-benefits by broadly contributing to natural resource conservation (soil, water, biodiversity and agro-biodiversity).

Climate change alters the state of play, affecting current risks and adding other risks and uncertainties. The unpredictable nature of the changes makes forecasting difficult. 'No-regrets' approaches (of interest regardless of the change), such as the implementation of conservation agriculture proposals (zero tillage, permanent ground cover, tailored crop sequences), or input consumption reduction strategies (fuel, mineral fertilizers), while maintaining production volumes, reduce the vulnerability of territories and populations and increase resilience. A landscape-scale approach, which calls for a degree of heterogeneity in land use, is essential to enhance resilience and risk management. That scale is best suited for devising mechanisms that ensure synergy between adaptation and mitigation (Harvey et al. 2014; Duguma et al. 2014). At that scale, various land use modes may be pooled in multifunctional land areas to more effectively address a number of climate-change-related objectives. The landscape approach requires a sustainable natural resource management system that recognizes the value of ecosystem services provided to the different stakeholders while accounting for their sometimes widely varying strategies and objectives. It addresses social concerns regarding the necessary tradeoffs between conservation and development and takes poverty reduction objectives and food security issues into account. These interactions between ecology and society are able to develop within a given 'territory', i.e. a landscape of stakeholders resulting from a social construct and hence a governance mechanism. The territory has to be large enough for natural resources and areas to be managed at an appropriate level and for vital ecosystem services to function, while remaining small enough for concerned stakeholders to remain motivated by undertakings at that scale.

Hence, we can also refer to climate-smart landscapes and territories. A climate-smart landscape is characterized by a mosaic, or matrix of entities connected by a network of biotic and abiotic interactions, for example a mixture of fields, grazing lands, natural areas, woodlands and protected areas. Crops, species and crop management systems may be diversified within each entity. Between the various parts of the mosaic, green infrastructures such as hedgerows and drainage streams can be maintained, riparian forest (woodland along streams) protected, and grassy strips preserved on the edges of tilled plots, etc. That spatial diversity can also be managed on farms by staggering planting dates between neighbouring plots, mixing plots or diversifying rotations, installing honey plants or beehives, or maintaining a network of hedges.

A climate-smart territory is the ideal scale for collective action, where the initiatives of stakeholders pursuing the same climate-smart goals are coordinated. At the village or small region governance level, land management schemes that address climate change issues should clearly be implemented in coordination with the initiatives of neighbouring landowners, local authorities, and nature conservancy or watershed management agencies. That is the whole point of the 'cross-sectoral harmony' effort that FAO identified as being one of the essential conditions for CSA. This concerns the agriculture, forestry, nature conservancy and, of course, water management sectors, in addition to the public finance, insurance, land use planning, public works, energy, and even waste management sectors. Finally, the private sector may influence the situation one way or another by the law of supply and demand or through partnerships with the public sector.

The landscape and territory approach requires an understanding of how to meet the needs of local communities without affecting biodiversity or ceasing to provide ecosystem services. The participation of all parties is essential to curb conflicts that could arise on account of divergent visions, goals and interests regarding spatial development. Moreover, capacity building for local institutions and stakeholders (including rural communities) should be considered a way of boosting trust between stakeholders and encouraging them to work together, especially for land management. That will require the formulation of a public policy that unifies different sectoral policies governing agricultural productivity, ecosystem management, forests and improvement of community livelihoods. An enabling market environment is vital, as well as environmental legislation that recognizes the rights of rural populations. For instance, public incentives that could adversely affect biodiversity, such as subsidies on chemical inputs, which promote the use of simplified crop rotations, are better abandoned.

1.4 Designing and Implementing Appropriate Public Policies

Climate-smart agriculture proponents consider that appropriate public policies, institutions and funding are essential to enhance the resilience and efficiency of agricultural production systems and enable the necessary changes to be made. Agricultural development funding requirements in developing countries are sizeable and still generally unfulfilled. Those needs will likely increase in the future because of climate change, with underfunding becoming much more acute if new funding is not made available. Private stakeholders—mainly farmers—account for most investment in agriculture. Public stakeholders can, however, play a strategic role by creating an environment conducive to private investment, particularly in land management, large-scale rural infrastructure (roads and rural trails, irrigation schemes, etc.) and agricultural research, in close liaison with agricultural extension services. It is also important to help farmers overcome innovation constraints that hamper their acceptance of change. Securing access to land is thus fundamental, and the guidelines set out by FAO (Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security) are a very valuable tool.

The approach taken must be systemic and, for example, address the need, beyond farms, for extension and supply network that are accessible to all farmers, together with a marketing system that can include newly created products. Improving the efficiency and resilience of agricultural systems will require integrated governance at all levels (local, national, regional and international), involving all stakeholders (farmers, manufacturers, traders, retailers, consumers and public authorities).

Climate-smart agriculture should not be viewed as a system or a set of techniques or practices to be promoted, but rather as a new approach to “developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change.”[1] CSA proponents propose an integrated approach whereby climate change is taken into account at the global level but its consequences, and hence any adaptation measures, are defined mainly at the local level. Finally, food security must be addressed both globally and locally. On 23 September 2014, the Global Alliance for Climate-Smart Agriculture was launched at the UN Climate Summit. The objectives of the framework document, signed by many public and private partners, are threefold: knowledge building and information sharing, mobilization and improved effectiveness of public and private financing, and creation of a favourable policy environment. On the African continent, the Africa Climate-Smart Agriculture Alliance was formed in 2014 under the auspices of the New Partnership for Africa’s Development (NEPAD). These bold initiatives are meant to make climate-smart agriculture a reality.

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