Climate Learning for African Agriculture: Working Paper No.2

Exploring the linkages and guiding concepts relevant to Climate Change, Agriculture and Development: A Detailed Resource Document

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Climate learning
for African agriculture

Summary

This paper explores the linkages between climate change, agriculture and development. It reviews and analyses the relevance of key climate change concepts which currently inform thinking and interventions relating to agriculture and overall development pathways. It teases out the overlaps and similarities between the different conceptual frameworks – many of which have varying interpretations – focusing specifically on the agriculture sector.

The paper is intended as a resource to inform debate in the Climate Learning for African Agriculture project. As part of this project two E-discussions are being facilitated with the aim of eliciting current practices, the predominant conceptual frameworks that are guiding the activities of research and advisory service stakeholders and identifying ideas and practical steps for the future.

Cover picture is from a Climate Change Adaptation for Africa (CCAA) project '*Strengthening local agricultural innovation systems in less favoured and more favoured areas of Tanzania and Malawi to adapt to the challenges and opportunities arising from climate change and variability* (jointly funded by DFID and IDRC).

- Sanjaranda village (Tanzania) climate change learning group members in group learning plot (improving access to crop varieties and soil and water management).

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1. Introduction

Agriculture is one of the most important drivers of global warming, as well as a critical sector that will be affected by climate change. The Climate Learning project is a joint partnership between AFAAS, FARA and the NRI, funded by the CDKN[i]. The project aims to support a shared learning process with agricultural research and advisory service stakeholders across Africa on responding to climate change and the implications for policies, practices and roles In this paper we explore the most important climate change concepts and frameworks relevant to agriculture and development, seeking to identify how each might be applied to agriculture.

Agriculture is a mainstay of many developing country economies and forms the basis of millions of people's livelihoods. Agriculture (occupying over a third of the Earth's land area) both provides and is a major threat to ecosystem services (ES) - broadly defined as "the benefits people obtain from ecosystems" (Millennium Ecosystem Assessment MA2005). There is increasing recognition of the important role that agriculture may play as a provider not only of food and fibre, but also supporting the provision of a range of others ecosystem services. Growing domestic and global demands on agriculture and land resources in the developing world are creating major challenges, as well as opening up some opportunities, for the future direction of agriculture. Reconciling the need for major increases in agricultural productivity, with farming landscapes that also support the provision of other ES will require major responses to shape the key drivers that influence policy and practices at all levels.

Table 1 below provides a summary of the ways in which agriculture contributes to climate change, how it might contribute to mitigation, and how, as a sector, it may be affected by climate change (direct and indirect impacts).

Table 1: Climate change and agriculture: Contributions and Impacts

The Contribution of Agriculture to Climate Change
GHG emissions from agriculture
an estimated 10–12 percent of total global anthropogenic emissions of GHGs (5.1–6.1 Gt CO_2e per year) in 2005, including about 50 percent of global anthropogenic methane emissions (in total, methane contributed 3.3 Gt CO_2e) about 60 percent of nitrous oxide (in total, nitrous oxide contributed 2.8 Gt CO_2e). These emissions had increased by nearly 17 percent from 1990 to 2005.

Potential to contribute to mitigation	
Agriculture has the potential to contribute to mitigation through: (a) reducing GHG emissions, (b) enhancing removal (storing or sequestering/capturing) of carbon, (c) avoiding or displacing fossil fuels	
The Impacts of Climate Change on Agriculture	
Direct climate change impacts upon smallholder livelihoods	
Biological processes affecting crops and animals at the levels of individual organisms or fields;	Direct impacts of changes in temperature, carbon dioxide, and precipitation on yields of specific food and cash crops and productivity and health of livestock. Can include impacts of variability in temperature and precipitation e.g. hot or dry spells at key stages in crop development. Also includes changed patterns of pests and diseases
Environmental and physical processes affecting production at a landscape, watershed or community level;	Smallholder agriculture will be affected by direct impacts at the level of communities, landscapes, and watersheds (some overlaps with studies on extreme events). e.g. decreased availability of water in the irrigation systems of the Indo-Gangetic plain; impacts on soil processes from complex global warming impacts and associated hydrological changes (accelerated decomposition of organic matter, depression of nitrogen-fixing activity), soil fertility and water holding properties affected, and overall soil erosion exacerbated by increased erosivity of rainfall.
Impacts of climate change on human health	The above impacts on agriculture will be combined with impacts on human health and the ability to provide labour for agriculture, such as increased malaria risk
Impacts of climate change on non-agricultural livelihoods.	Impacts on important secondary non-farm livelihood strategies, e.g. tourism, for many rural people in developing countries.
Secondary or indirect impacts of climate change	
Distant, off-site impacts of climate change on a particular smallholder system	Impacts of climate change in other distant areas may create changes which affect a smallholder system. For example, decreased supply of grain in one location might affect specialist cash-crop producers in another area as the latter are net grain buyers.
Impacts of climate change adaptation and mitigation policies, programmes and funds	The secondary impacts of climate change occur as governments, civil society, the private sector etc gear up to respond to climate change and institute new policies, programmes, and funds – all of which may impact upon smallholders (positively or negatively). An example would be leasing of agricultural lands to agri-business for biofuel production

Source: Adapted from Nelson et al, 2010, Smith et al 2007.

2. Key Climate Change Concepts in Agriculture

2.1 Sustainable Agriculture

The concept of sustainable agriculture has evolved from rising concerns in past decades with the environmental and social impacts of conventional agriculture. These concerns emerged primarily in industrialized countries, as biodiversity losses and pollution from pesticides were observed, but these impacts are emerging as issues of more widespread global concern. Conventional agriculture has led to significant increases in productivity (returns per unit of land and labour) through a number of developments: rapid technological innovation; large capital investments in order to apply production and management technology; large-scale farms; single crops/row crops grown continuously over many seasons; uniform high-yield hybrid crops; extensive use of pesticides, fertilizers, and external energy inputs; high labour efficiency and dependency on agribusiness. In the case of livestock, most production comes from confined, concentrated systems (Gold, 2007). However, some of the underlying assumptions of conventional agriculture are challenged by those promoting sustainable agriculture[ii], who suggest that environmental problems are largely intertwined with socio-economic and political forces external to agriculture and that we have a great deal still to learn about the complex interactions between farming systems and soil, water, biota and atmosphere. Critics of conventional agriculture might suggest that although efficiency is often seen as its defining feature, that in fact when considering energy use it is actually inefficient and assessment of its performance ignores negative external impacts.

Amongst those supporting sustainable agriculture, definitions vary and are contested: Pretty (Pretty 2008, p452) offers the following definition: '*Sustainable agricultural systems tend to have a positive effect on natural, social and human capital, while unsustainable ones feedback to deplete these assets, leaving fewer for future generations. For example, an agricultural system that erodes soil while producing food externalizes costs that others must bear. But one that sequesters carbon in soils through organic matter accumulation helps to mediate climate change*. The key principles of sustainable agriculture are: Pretty (2008):

- Integration of biological and ecological processes such as nutrient cycling;
- Minimizing the use of non-renewable inputs;
- Making productive use of the knowledge and skills of farmers and substituting human capital for external inputs;

- Making productive use of people's collective capacities to work together to solve common agricultural and natural resource problems.

A recent agri-food industry initiative, the Sustainable Agriculture Initiative Platform,

(SAI Platform) and Sustainable Food Lab publication (2009) follows the common, three pillars approach (environmental, social and economic) – which are seen as being intertwined. The SAI Platform defines sustainable agriculture as "*a productive, competitive and efficient way to produce safe agricultural products, while at the same time protecting and improving the natural environment and social/economic conditions of local communities." (See* http://www.saiplatform.org/about-us/who-we-are-2). See Figure 1 below.

Figure 1 Sustainable Agriculture Source: SAI Platform/Sustainable Food Lab (2009)

Climate change impacts on agriculture are noted, by SAI Platform, including the potential disruption to raw material supply for food businesses and impacts on price and quality. A number of case studies are provided of industry responses. However, there is very little analysis of power relations and the trade-offs that might be involved in achieving sustainable agriculture and in responding to climate change. This agrifood initiative promotes pre-competitive collaboration between companies to understand climate change impacts on agriculture and to develop mitigation and adaptation strategies.

Panell and Schilizzi (1999, cited by Gold 2007) discuss the lack of attention to trade-offs in sustainable agriculture literature, and suggest that it is part of the lack of consensus on definition: '*Sustainability' is at once extremely important and practically useless. It consists of a set of concepts which are fundamentally different* *in nature. That is why there has been no success in attempt to identify THE definition of sustainability. There can be no satisfactory definition which is not multifaceted'.* The authors suggest that it is this inherent characteristic of multiple dimensions, which creates barriers to practical application. Instead, decision-makers should focus on aspects of sustainability that are of priority importance and present information *'about the trade offs between these aspects within a multiple criteria decision making formula'* (Pannell and Schilizzi, 1999).

Similarly, the US Department of Agriculture Sustainable Agriculture Research and Education (SARE, 2007) programme suggests that sustainable agriculture is not about a *prescribed set of practices*, but is a means of challenging '*producers to think about the long-term implications of practices and the broad interactions and dynamics of agricultural systems. It also invites consumers to get more involved in agriculture by learning more about and becoming active participants in their food systems. A key goal is to understand agriculture from an ecological perspective—in terms of nutrient and energy dynamics, and interactions among plants, animals, insects and other organisms in agroecosystems—then balance it with profit, community and consumer needs'* (www.sare.org).

Other interpretations of sustainable agriculture focus on *process* and *landscapes*, rather than dividing analysis along disciplinary components. The Journal of Sustainable Agriculture suggests that rather than focus on separate disciplinary components of agriculture and food systems, it is more important to adopt an *interdisciplinary approach to food production as one process in a complex landscape of agricultural production, conservation, and human interaction* (see http://www.tandf.co.uk/journals/WJSA).

Some in conventional agriculture, have seen the notion of sustainable agriculture as an implicit criticism and a threat (Gold, 2007), while others may interpret it as meaning a *'return to either the low yields or poor farmers that characterized the 19thcentury'* (Union of Concerned Scientists, 1999). But it should be seen as an approach *'building upon current agricultural achievements, adopting a sophisticated approach that can maintain high yields and farm profits without undermining the resources on which agriculture depends'* (Union of Concerned Scientists, 1999).

Hill (1992) distinguishes between shallow (short-term, symbolic) sustainability and deep (long-term, fundamental) sustainability. *'Shallow sustainability focuses on efficiency and substitution strategies with respect to the use of resources. It usually accepts the predominant goals within society without question, and aims to solve problems by means of curative solution. Deep sustainability, in contrast, re-evaluates* *goals in relation to higher values and redesigns the systems involved in achieving these goals to that this can be done within ecological limits'* (Hill, 1992).

Dobbs (2008) suggests that there are two types of implicit visions underpinning the majority of policy proposals regarding food and farming in the US in 2007/8. These include: i) the global competitiveness vision, and ii) the sustainable agriculture vision. In the former, policies are export-oriented, aimed at supporting the competitiveness of US agriculture in world markets, and based on comparative advantage economic theory. Often implied in this system is high input, high yielding production of 'commodity crops', which enables the US to compete in markets with reduced trade barriers and market distortions. In the latter, sustainable agriculture vision, the approach is more inward looking, with a concern for environmental quality, ecological sustainability, and the economic viability of small and moderate-sized family farms. Sustainable agriculture policy advocates are not 'anti-trade' *per se,* according to Dobbs (2008), but support independent family farms and sustainable resource use, and are more aligned to a 'European Union multifunctionality view of agriculture'. Kassie and Zikhali (2009) outline the multiple benefits that can be achieved including reducing production costs, environmental benefits, and increasing food production and the factors influencing uptake of sustainable agriculture by resource poor farmers (Box 1).

According to Gold (2007) the lack of sharp, uncontested definition has not actually lessened the authenticity of the concept of sustainable agriculture, or the sense of urgency and direction that is entailed and it is being widely taken up by governments, companies and NGOs.. However, Gold (2007) also suggests that Youngberg and Harwood's 1989 statement is still relevant: *'We are yet a long way from knowing just what methods and systems in diverse locations will really lead to sustainability... In many regions of the country, however, and for many crops, the particular mix of methods that will allow curtailing use of harmful farm chemicals or building crop diversity, while also providing economic success, are not yet clear. The stage is set for challenging not only farm practitioners, but also researchers, educators, and farm industry'.* Gold cites a USDA project[iii] that concludes that the most effective route for sustainable agriculture is promoting the 'just-do-it' approach, and profiling successful farmers and ranchers (Gold, 2007). Many of these insights are relevant when also weighing up the definitions of climate change concepts and how to implement them.

Box 1: Drivers and constraints for sustainable agriculture adoption by resource poor farmers

Factors affecting uptake by resource poor farmers include:

Heterogeneity in agro-climatic environments: no single approach can be used

Amount and availability of biomass (e.g. crop residues, animal dung)

Economic incentives: Profitability (short and long term) of sustainable agriculture practices

Final demand also drives adoption of technologies.

Lack of integration into input and output markets by farmers in developing countries. Better infrastructure and market access impacts positively.

Access to information to build awareness and attitudes towards technology adoption.

Land issues: Tenure insecurity is an investment barrier, but is variable across countries.

Fragmentation of land means inputs transported between isolated and dispersed plots

Formal and informal institutions needed to facilitate promotion and adoption (e.g. applied research, extension services, and NGO networks). Social capital is crucial: Farmers' awareness and understanding of the potential benefits of sustainable agriculture practices relies on better access to and quality of information, plus education and training programmes.

Lack of proper extension services constrains adoption of existing productivity-enhancing technologies. Need for a system of training and organizational development that constantly upgrades the capacity of extension workers to ensure their technical competence

Rural institutions important to enable farmers to access credit, information and marketing, when they are often outside the cash economy. Farmer associations and unions constitute important sources of information for farmers.

Political constraints. At the national and international level, the policy environment may be more or less conducive to the widespread adoption of sustainable agricultural practices. Policy-maker awareness varies and can constrain significant departures from previously accepted paradigms. Potential resistance from agrochemicals industries and other traditional actors in intensive agricultural supply chains. For sustainable agriculture at scale requires understanding of different layers of local and global institutions, as well as of political and economic factors that might threaten its sustainability.

Source: Kassie and Zikhali (2009)

2.2 Adaptation in Agriculture

Adaptation to climate change in agriculture is beginning to gain serious attention, with increased efforts at practical learning as well as conceptualisation[iv].

A number of potential areas of agricultural adaptation are outlined by Ifejika Speranza (2010):

- Adaptations of whole farming systems (eg, conventional, conservation and organic agriculture)

- Adaptation of agricultural practices (eg, soil and water management, seed management, crop management, agroforestry, reforestation and avoided deforestation, pest and disease management)
- Adapting livestock, pasture and rangeland management practices
- Farm-level climate change mitigation practices
- On- and off-farm diversification in livelihood practices
- Diversification of species and varieties grown
- Farmer organisation and social networking
- Taking up new climate finance, value-chain and learning opportunities

Howden (2007) distinguishes between farm level changes in farming practices to *maintain* an existing system and wider institutional and policy changes which may be more significant and *systemic* in nature.

- *Farm level changes:* Examples of farm level changes could include changes in varieties, planting times and use of conservation tillage. These changes are made at the management unit decision level in cropping, livestock, forestry and marine systems.
- *Broader scale changes*: These might involve redistribution of resources, changes in land use, support for new livelihood options etc. These broader changes involve changes in the decision environment (e.g. policy changes to encourage behavioural and institutional change amongst enterprises and farmers). See Appendix 1.

Agricultural adaptation can thus be thought of as modifications to an existing system or a wider set of changes, but in fact both will be required, alongside new approaches and social learning to respond to climate change (Howden et al. 2007).

According to some authors there are technical possibilities for adaptation, particularly for smaller temperature increases accompanied by rainfall increase. For example, studies show that agricultural or agronomic adaptations (including many based on existing practices by which farmers adapt to/cope with climate variability) will have some efficacy in the face of climate change. Howden et al. (2007), work with a large sample of simulation studies for wheat yields under climate change (for details see Easterling et al. 2007) to summarise the benefits of adaptation in terms of the difference between percentage yield decreases with or without agronomic adaptation. Climate change is likely to alter countries' comparative advantages in agriculture, and thereby alter the pattern of international trade (Tamiotti *et al.* 2009[v]). Studies suggesting that agricultural trade facilitates adaptation and brings global welfare benefits emphasise the importance of removing trade distortions, e.g. subsidies (Huang et al. 2011). However, other authors, such as Cline (2007) point out that adaptation in developing countries through increasing trade would be severely constrained by limited buying power.

Many projects and programmes responding to climate change impacts in agriculture have sought to enhance innovation and improve farmers' access to technologies and practices using climate variability as an entry point. This is because of the need to engage with currently perceived issues such as increasing variability and unpredictability in weather patterns and uncertainty in climate change projections which mean it can be difficult to predict future conditions. However, it is critical to look at longer-term changes because of the broad changes in soil, water and economic environment which may make current responses 'maladaptive'. Risbey et al, (1999) emphasize the importance of different scales, times and types of decision making: short-term modifications in the farming environment (e.g. droughts, market fluctuations) may have limited efficacy depending on longer term shifts in climate.

The Meridien Report (2011, p49) on agriculture and climate change details the financial, capacity building and technology transfer investment that will be needed to deliver on the multiple objectives increasingly demanded of agriculture: *'Adopting agricultural practices that are able to withstand changes in climate and contribute to the reduction of GHG emissions requires the application of new technologies, the modification of existing ones, and changes to relevant laws and policies, as well as additional capacity at the farm, policy, and scientific levels to implement such measures. Technology deployment and related capacity building in agriculture comes with significant costs, for which developing countries, in particular, need financial support. Therefore, finance, technology transfer, and capacity building are essential focus areas for the successful implementation of climate change mitigation and adaptation activities'.*

Clearly adaptation to agriculture is not just an issue for farmers, and it is worth considering the different types of decisions and policies that will be taken to achieve adaptation: *different actors* will need to be involved in decisions depending upon whether they are *tactical, strategic or structural (*Risbey et al (1999)

- *Tactical decisions* about practices in the next season or year may involve farmers, insurance agencies, markets, and regional agricultural agencies.

- *Strategic decisions* which cover multiple years (1-5 years) may involve farmers and regional agricultural agencies.
- *Structural decisions* (concerning multiple decades) are more likely to be in the domain of national governments and regional agricultural agencies.

Pelling (2011) critiques narrow conceptualizations of adaptation, and suggests that adaptive actions can differ in scope and scale along a continuum:

- *Resilience: narrow adaptive actions* focus on technologies and management changes;
- *Transition: incremental changes* in governance practices and implementation of legal responsibilities;
- *Transformation: whole-scale changes in overarching political-economic*

Exploring scale issues in relation to agriculture is important and there are increasingly moves towards *integrated* landscape thinking and action, rather than individual farm level interventions and consideration of different outcomes in terms of sustainability at different scales. More integrated approaches look to the environmental services requiring protection which may cross-cut administrative boundaries, approaches such as agricultural development corridors which seek to coordinate interventions, interventions cognisant of questions of social identity, rural institutions and increased participation in a territory.

Adaptations are undertaken in the light of specific normative goals and decisions imply trade-offs with implications for different social groups (Nelson, Adger and Brown 2007): this raises the question of 'adaptation for whom?'

2.3 Mitigation in Agriculture

Not only is climate change having an impact upon agriculture, but agriculture is also a significant contributor to climate change. The agricultural sector is a source of GHGs, which contribute to global warming (*see* Box 2 and Figure 2). Agriculture has the potential to contribute to mitigation through: (a) reducing GHG emissions, (b) enhancing removal (storing or sequestering/capturing) of carbon, and (c) avoiding or displacing fossil-derived emissions through production of biofuel feedstocks.

Box 2: The contribution of agriculture to climate change

The sector accounted for 10-12% of total global anthropogenic emissions of GHGs in 2005, including about 50% of global anthropogenic methane emissions and about 60% of nitrous oxide. These emissions had increased by nearly 17% from 1990 to 2005.

Between 1990 and 2005, the five regions composed of Non-Annex 1[vi] countries, which are mainly developing countries, showed a 32% increase in GHG emissions and were, by 2005, responsible for about three-quarters of total agricultural emissions. The other five regions, mostly Annex I countries, showed a 12% decrease in the emissions of these gases. GHG emission rates may escalate in the future due to population growth and changing diets. Greater demand for food could result in higher emissions of methane and nitrous oxide if there are more livestock and greater use of nitrogen fertilisers. The global technical mitigation potential from agriculture by 2030 is estimated to be about 5500–6000 Mt CO_2e. A key determinant of how much of this potential is converted into action is the price of carbon. About 70% of the potential is in Non-Annex 1 countries, i.e., mostly developing countries.

Source: Smith et al. (2007).

The diagram below shows global sources of GHGs from agricultural production. The two major sources are nitrous oxide from industrial fertilizer application and methane from livestock. Crucially, conversion of land to agricultural use adds a further 5,900 Mt CO_2e. Deployment of new mitigation practices for livestock systems and fertiliser applications will be essential to prevent an increase in emissions from agriculture after 2030.

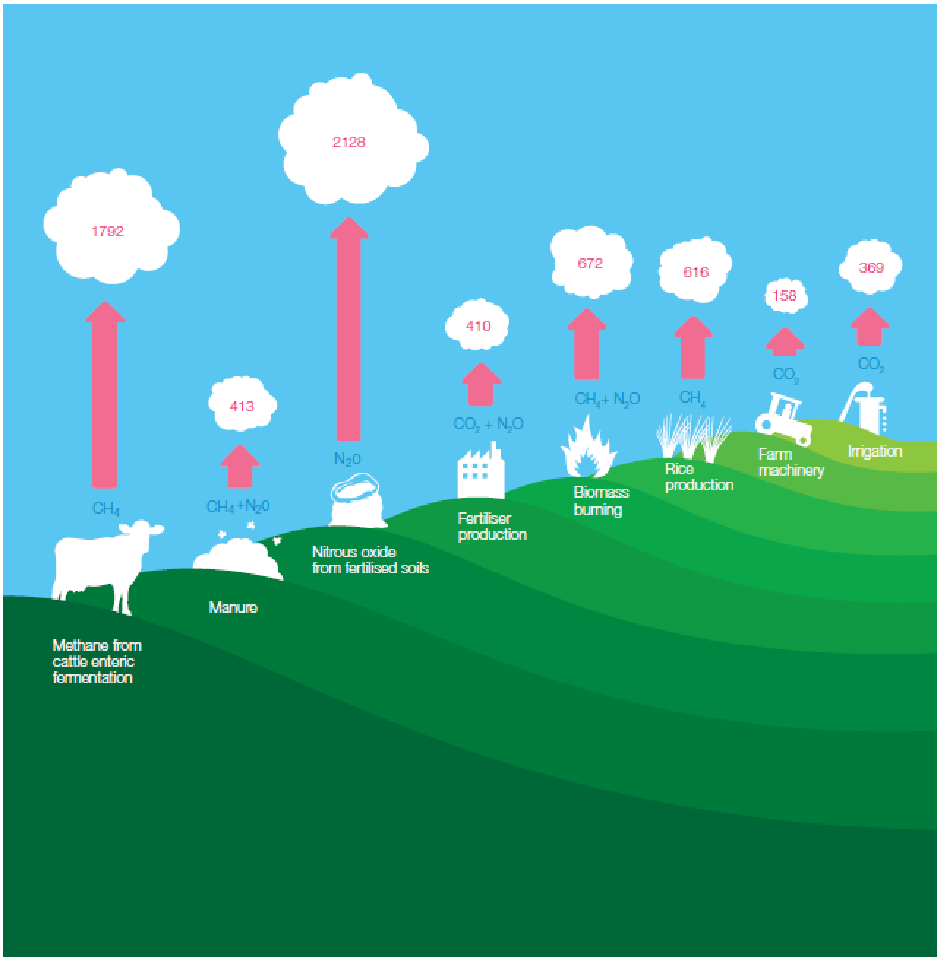

Figure 2: Sources of agricultural GHGs (Mt CO_2e) (Source: redrawn from Greenpeace International 2008, cited in Seeberg-Elverfeldt 2010).

Note: Conversion of land to agriculture use adds a further 5900 Mt CO_2e.

The most promising options for mitigating GHG emissions in agriculture include (Smith *et al.* 2008):

- improved crop and grazing land management (e.g. improved agronomic practices, nutrient use, tillage, and residue management);
- restoration of organic soils that are drained for crop production, and restoration of degraded lands.

Lower, but still significant, mitigation is possible with:

- improved water and rice management;
- set-asides, land use change and agroforestry;
- improved livestock and manure management.

Many mitigation opportunities are based on existing technologies and could be implemented immediately, but technological development will be a major factor influencing the efficacy of additional mitigation measures in the future.

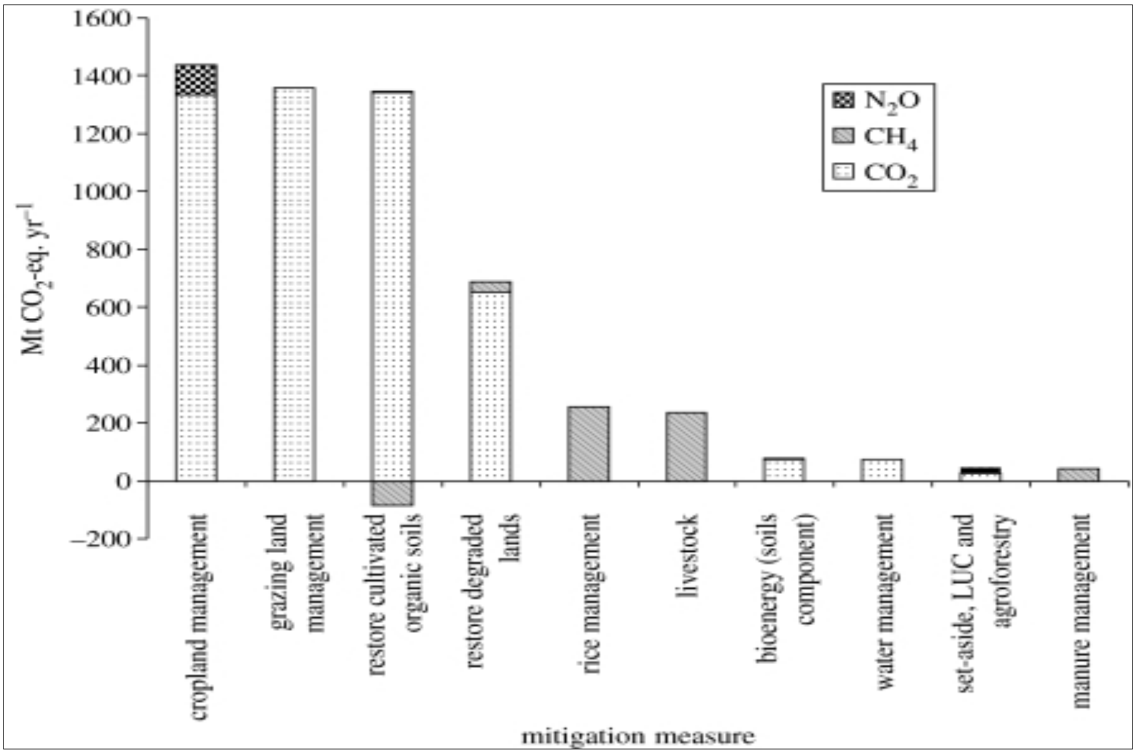

Figure 3: Global biophysical mitigation potential (Mt CO_2e/year) by 2030 of each agricultural management practice showing the impacts of each practice on each GHG stacked to give the total for all GHGs combined (B1 scenario shown though the pattern is similar for all SRES scenarios) (Source: redrawn from Smith et al. 2008)

Soil carbon sequestration offers most of the mitigation potential, with an estimated 89% contribution to the technical potential. Mitigation of methane and nitrous oxide emissions from soils account for 9% and 2%, respectively, of the total mitigation potential (Smith *et al.* 2007).

As with adaptation strategies, there is no universally applicable list of mitigation practices – all practices need to be evaluated for appropriateness to individual agricultural systems on the basis of climate, soil-related factors, social setting, and historical patterns of land use and management (Smith *et al.* 2007; Smith and Olesen 2010).

The price of carbon is a key determinant of mitigation strategies. At low prices, farmers may adjust existing production practices such as tillage, fertiliser application, livestock diet formulation, and manure management. Higher prices are needed to provide sufficient incentives for major land-use changes. Agricultural mitigation measures often have synergy with sustainable development policies. Further mitigation and adaptations in agriculture can overlap, but macro-economic, agricultural and the environmental policies may have a greater impact on agricultural mitigation than explicit climate policies *per se*.

Despite significant technical potential for mitigation in agriculture, there has been relatively little progress made in the *implementation* of mitigation measures. Barriers to implementation are not likely to be overcome without clear incentives and the tackling of other issues, such as capacity strengthening of farmers and other actors in the agricultural innovation system (AIS).

Wollenberg and Negra (2011) propose that action is needed in six areas to take

Box 3: Action required to achieve mitigation in agriculture

- *International and national policy support* – GHG emission targets agreed under the Kyoto protocol have so far provided very limited opportunities for agriculture. Under Reduced Emissions from Deforestation and forest Degradation (REDD+) agriculture is mentioned as a driver of deforestation and is eligible for finance. Nationally Appropriate Mitigation Actions (NAMAs) establish country commitments to reducing emissions, including emissions from agriculture and developing countries can seek finance for these activities.
- *Implementation options and effective governance* - Mechanisms for agricultural mitigation include carbon markets, government regulations such as cap-and-trade programmes, corporate supply chains and livelihood options that include mitigation co-benefits. Yet few examples of these mechanisms exist and more pilot projects are needed to demonstrate how they will work.
- *Developing tools and technical guidelines* - Robust monitoring, reporting and verification are needed to ensure that changes in land management result in reduced net emissions. Developing simple, cost-efficient methods that can be applied globally will facilitate comparisons and rapid implementation.
- *Financing and economic incentives* - Funding is required to achieve mitigation in agriculture. Public finance is needed to support capacity strengthening for implementing pilots and developing regionally relevant tools and methods for monitoring, reporting and verification. Private finance is important for carbon markets and corporate-driven programmes. Agri-businesses have a strong interest in investments that stabilize or enhance their supply chains while contributing to corporate mitigation targets. Consumer demand for low carbon products and increased use of carbon labelling on products can provide additional incentives.
- *Strengthening national capacities* - Low capacity exists in most developing countries for promoting climate change mitigation in agriculture, and accountability structures are typically weak. Few countries have the means for monitoring GHG emissions or to effectively develop technical options with farmers. Agriculture should build on the foundations created by REDD and seek additional funding for capacity strengthening in both government and nongovernmental sectors.
- *Ensuring co-benefits for the environment and poverty alleviation* - Co-benefits will be necessary for mitigation to be widely adopted and sustained. Some existing standards and certification programmes like the Climate, Community and Biodiversity Alliance, provide such opportunities, including poverty reduction, enhanced biodiversity and soil health. Mitigation initiatives should also include safeguards to reduce negative social or environmental impacts. Smallholders still remain largely uninformed about climate change policy and mitigation options, even in existing REDD and CDM projects. They must be informed about how mitigation mechanisms work, what benefits they can realistically expect and potential risks from engaging in offset contracts along with other impacts.

Source: Wollenberg, E. and Negra, C. 2011 forward mitigation in agriculture (see Box 3 below).

2.4 Sustainable intensification

The concept of sustainable intensification emerged from a growing recognition that as global food demand is increasing neither conventional *intensification* nor *extensification* provide viable options in the face of resource scarcity and the need to enhance a wide range of environmental services in agricultural, as well as non-agricultural landscapes. The 2007/08 food crisis, projected climate change impacts and renewed appreciation of the importance of agricultural in developing countries have all contributed to this emerging consensus.

Promoting sustainable intensification was one of the twelve key priorities for action for policy makers identified by the Foresight: The Future of Food and Farming (2011, p 35) report[vii] which states: *It follows that if (i) there is relatively little new land for agriculture, (ii) more food needs to be produced and (iii) achieving sustainability is critical, then sustainable intensification is a priority. Sustainable intensification means simultaneously raising yields, increasing the efficiency with which inputs are used and reducing the negative environmental effects of food production. It requires economic and social changes to recognise the multiple outputs required of land managers, farmers and other food producers, and a redirection of research to address a more complex set of goals than just increasing yield.*

Based on projected increases in population and real income per capita, Tilman et al (2011) forecast a 100–110% increase in global crop demand from 2005 to 2050. If current trends of greater agricultural intensification in richer nations and greater land clearing (extensification) in poorer nations were to continue, ~1 billion ha of land would be cleared globally by 2050, with CO2-C equivalent GHG emissions reaching ~3 Gt y−1 and N use ~250 Mt y−1 by then. In contrast, if 2050 crop demand was met by moderate intensification focused on existing croplands of "under yielding" nations, adaptation and transfer of high-yielding technologies to these croplands, and global technological improvements, Tilman et al forecast land clearing of only ~0.2 billion ha, GHG emissions of ~1 Gt y−1, and global N use of ~225 Mt y−1. Efficient management practices could substantially lower nitrogen use. Tilman et al conclude that attainment of high yields on existing croplands of "under yielding" nations, is of great importance if global crop demand is to be met with minimal environmental impacts. The Foresight (2011) report argues that since the 1980s there has been a slow down in the growth rate of yields and in recent years a slow down in public research and expenditure on agriculture, particularly relating to increasing productivity (Box 4).

Traditionally agricultural intensification has been defined in three different ways:

- increasing yields per hectare,
- increasing cropping intensity (i.e. two or more crops) per unit of land or other inputs (water), and
- changing land use from low value crops or commodities to those that receive higher market prices (Pretty et al 2011).

Pretty (2008) suggests *"intensification using natural, social and human capital assets, combined with the use of best available technologies and inputs (best genotypes and best ecological management) that minimize or eliminate harm to the environment, can be termed 'sustainable intensification'"*. In 2011, Pretty et al, further state that sustainable intensification is about *"producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services" (*Pretty et al, 2011).

Box 4: Is agricultural productivity growth increasing or decreasing?

From 1961–2008, growth rates of yields (output per hectare) for grains were on average 1.5% per annum in developed countries and 2.1% in developing countries. Since 1985, there has been a reduction in these average growth rates.

Growth in agricultural output can result from growth in either area planted or yields, or both. Yield growth can arise from intensification of inputs (more inputs used with the same amount of land) or from productivity growth (changes that yield more output for the same level of inputs). Total factor productivity (TFP) growth is a measure of increases in output per unit of all inputs, including land, and is used as a summary measure of increases in output that are not due to increases in inputs. While intensification (e.g. greater use of machinery, labour, or chemicals with the same amount of land) is an important source of growth in agriculture in low-income countries, productivity growth is generally more important. Identifying the nature and sources of productivity growth is crucial for informing what mix of policies should be emphasised to develop improved machinery, seeds, chemicals, farm management practices, and improvements in land and irrigation.

Research suggests that global TFP growth has improved in recent decades and accounts for an increasing share of the growth in agricultural output. There has been a slowdown in the growth of inputs for production, with variation across different regions.

Growth in TFP is important to the concept of sustainable intensification because it will ease constraints on land, labour and other resources: 1% growth in TFP means 1% fewer resources are needed to produce the same amount of output. Research and development is needed to increase productivity, but there may be long lead times before benefits are fully realised.

In summary, productivity growth has offset the deceleration of input growth to keep global agriculture growing at an average of 2% per annum since the 1960s. There has, however, been a slowdown in recent years in public research and development expenditure on agriculture, particularly on productivity-enhancing research.

Source: Foresight. The Future of Food and Farming (2011)

Similarly, The Royal Society (2009) states that *crop production methods will have to "sustain the environment, preserve natural resources and support livelihoods of farmers and rural populations around the world. There is a pressing need for the 'sustainable intensification' of global agriculture in which yields are increased without adverse environmental impact and without the cultivation of more land".*

The Royal society publication goes on to say "Science can potentially continue to provide dramatic improvements to crop production, but it must do so sustainably. Science and technology must therefore be understood in their broader social, economic and environmental contexts. Improvements to food crop production should aim to reduce rather than exacerbate global inequalities if they are to contribute to economic development".

A sustainable production system would exhibit most or all of the following attributes (Pretty et al 2011):

- utilizing crop varieties and livestock breeds with a high ratio of productivity to use of externally and internally derived inputs;
- avoiding the unnecessary use of external inputs;
- harnessing agro-ecological processes such as nutrient cycling, biological nitrogen fixation, allelopathy, predation and parasitism;
- minimizing the use of technologies or practices that have adverse impacts on the environment and human health;

- making productive use of human capital in the form of knowledge and capacity to adapt and innovate and social capital to resolve common landscape scale problems;

- quantifying and minimizing the impacts of system management on externalities such as greenhouse gas emissions, clean water availability, carbon sequestration, biodiversity and dispersal of pests, pathogens and weeds.

Pretty et al (2011) analysed 40 projects and programmes in 20 African countries where activities that are described as sustainable intensification has been developed during the 1990s–2000s (Table 2). These cases included crop improvements, agroforestry and soil conservation, conservation agriculture, integrated pest management, horticulture, livestock and fodder crops, aquaculture and novel policies and partnerships. By early 2010, these projects had documented benefits for 10.39 million farmers and their families and improvements on approximately 12.75 million ha. Food outputs by sustainable intensification had changed through a) yields per hectare increasing by combining the use of new and improved varieties and new agronomic–agroecological management (crop yields rose on average by 2.13-fold), and b) diversification, with a range of new crops, livestock or fish that added to the existing staples or vegetables already being cultivated. The timescale for the agronomic-agroecological improvements varied from 3 to 10 years.

Table 2 Summary of productivity outcomes from African sustainable intensification case studies

Thematic focus	Area improved (ha)	Mean yield increase (ratio)	Net multiplicative annual increase in food production (thousand tonnes yr^{-1})
Crop variety and system improvements	391,060	2.18	292
Agroforestry and soil conservation	3,385,000	1.96	747
Conservation agriculture	26,057	2.20	11
Integrated pest management	3,327,000	2.24	1,418
Horticulture and very small scale agriculture	510	nd	nd
Livestock and fodder crops	303,025	nd	nd
Novel regional and national partnerships and policies	5,319,840	2.05	3,318
Aquaculture	523	nd	nd
Total	12,753,000	2.13	5786

Source: Pretty et al 2011

Pretty et al (2011) argue that the challenge is to spread effective sustainable intensification processes and lessons to many more millions of generally small scale farmers and pastoralists across Africa[viii].

Sustainable intensification retains a relatively flexible definition allowing room for diverse interpretations. Reed (2012) suggests there are two distinct views about the concept based on the perceived causes of food insecurity and hence different appropriate solutions. There are those who view the situation as the product of the pressures stemming from the success of development and resulting environmental stresses and those who view it as a product of the globalised market in food. Both groups share concerns about the finite limits of the planet, demographic pressures, the threat of climate change, the need for conservation of resources and the importance of biological processes. It is over questions of participation, the forms of technology to be deployed, the role of markets and national autonomy that they diverge.

2.5 Agroecology

The science of agroecology may be defined as the application of ecological concepts and principles to the design and management of sustainable agroecosystems and it provides a framework to assess the complexity of agroecosystems (Altieri, 1995 in Altieri and Nicholis 2005 p 30).The term can be traced back to the 1930s. Though agroecology initially dealt primarily with crop production and protection aspects, in recent decades new dimensions such as environmental, social, economic, ethical and development issues are becoming relevant. Today, the term ‘agroecology’ means either a scientific discipline, agricultural practice, or political or social movement (Wezell et al 2009).

Altieri (2004) argues a key challenge for agroecologists is to translate general ecological principles and natural resource management concepts into practical advice directly relevant to the needs and circumstances of smallholders. The strategy must be applicable under the highly heterogeneous and diverse conditions in which smallholders live, it must be environmentally sustainable and based on the use of local resources and indigenous knowledge. The emphasis should be on improving whole farming systems at the field or watershed level rather than the yields of specific commodities. However, without appropriate policy support, they are likely to remain localized in extent. Necessary institutional and policy changes include land reform, appropriate and equitable market opportunities, and equitable partnerships between local governments, NGOs and farmers replacing top-down transfer of technology models with participatory technology development and farmer to farmer research and extension replacing top-down transfer of technology models.

De Schutter (2011) links agroecology and the right to food, arguing that as states must reinvest in agriculture (triggered by the 2008 food price crisis) they should also reorient their agricultural systems towards modes of production that are *"highly productive, highly sustainable and contribute to the progressive realization of the human right to adequate food*'. As well as strong connections to the 'right to food', there are proven results for 'fast progress in the concretization of this human right for many vulnerable groups in various countries and environments' (De Schutter, 2011). However, scaling up is the key challenge and requires the following policies: prioritizing the procurement of public goods in public spending rather than solely providing input subsidies; investing in knowledge by reinvesting in agricultural research and extension services; investing in forms of social organization that encourage partnerships, including farmer field schools and farmers' movements innovation networks; investing in agricultural research and extension systems; empowering women; and creating a macro-economic enabling environment, including connecting sustainable farms to fair markets (De Schutter, 2011).

Box 5 Definition of agroecology

Agroecology is both a science and a set of practices. It was created by the convergence of two scientific disciplines: agronomy and ecology. As a science, agroecology is the "application of ecological science to the study, design and management of sustainable agroecosystems." As a set of agricultural practices, agroecology seeks ways to enhance agricultural systems by mimicking natural processes, thus creating beneficial biological interactions and synergies among the components of the agroecosystem. It provides the most favourable soil conditions for plant growth, particularly by managing organic matter and by raising soil biotic activity. The core principles of agroecology include recycling nutrients and energy on the farm, rather than introducing external inputs; integrating crops and livestock; diversifying species and genetic resources in agroecosystems over time and space; and focusing on interactions and productivity across the agricultural system, rather than focusing on individual species. Agroecology is highly knowledge-intensive, based on techniques that are not delivered top-down but developed on the basis of farmers' knowledge and experimentation.

Source: De Schutter 2011

2.6 Sustainable value chains and corporate responsibility

Climate change opportunities and challenges in relation to agricultural value chains and corporate practices are beginning to be more widely explored. There has been a gradual build up of pressure and interest amongst companies themselves on how to respond to sustainability issues in a more substantial way. Hamilton et al (2010 p11) suggests that: *'In food and agriculture over the past five years sustainability has shifted from the periphery to core strategy for most brand manufacturers and retail companies in Europe and the United States. Much of the rest of the world is trailing, but the growth in social responsibility is clear. The reasons are diverse: risk to supply, customer interests, public expectations and the "license to operate."* Specifically, in agri-business, companies are at the forefront of this process: "*Virtually every major food company is now piloting healthier value chain practices"* (Hamilton et al, 2010 p 21), because agriculture as an industry has '*perhaps the largest global environmental and social footprint of any human activity'.*[ix]

The Sustainable Food Lab is a consortium of business, non-profit and public organizations working together to accelerate the shift toward sustainability. According to its website, the consortium facilitates market-based solutions to the key issues—including climate, soil, poverty, and water—that are necessary for a healthy and sustainable food system to feed a growing world. The Sustainable Food Lab uses collaborative learning to incubate innovation at every stage along the supply chain from producing to distributing and selling food. Figure 4 shows the leverage points they identify for shifting the global food system towards a more sustainable basis.

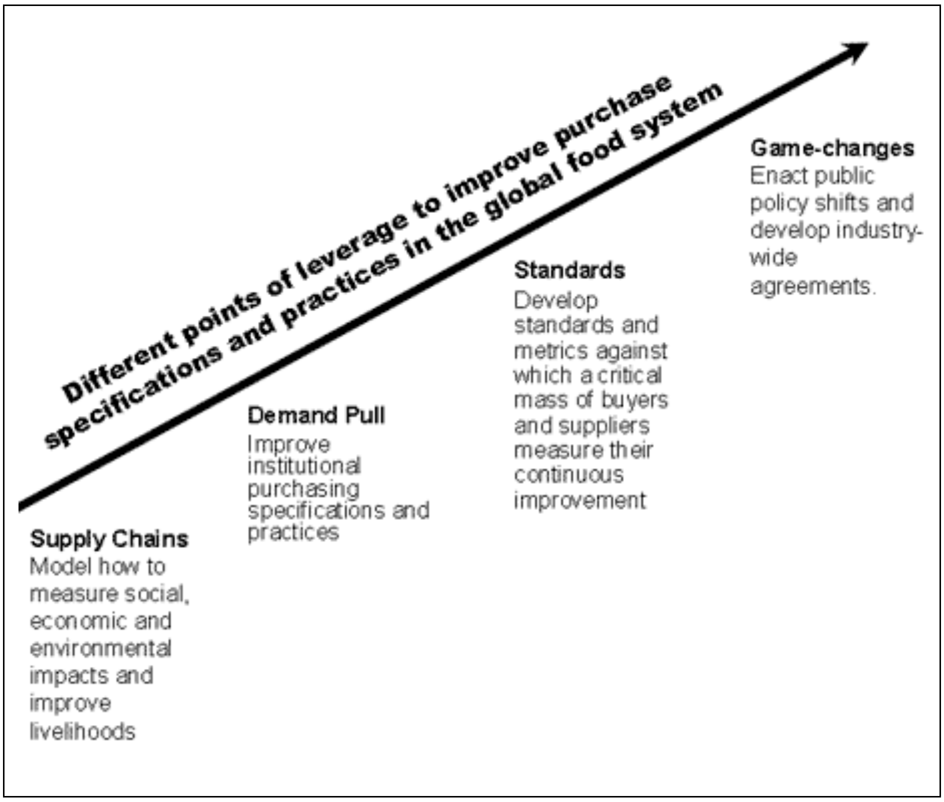

Figure 4: Leverage points to tip the balance in global food systems.

Source: Sustainable Food Laboratory
http://www.sustainablefood.org/index.php?option=com_content&view=article&id=42:food-lab-theory-of-change&catid=8

A similar initiative is a UK university programme, which reports the views of ten major companies on their visions of the fundamental changes in retail and manufacturing value chains which are required to achieve resilience. Companies face increasing insecurity of supply and reduced access to natural capital are becoming major risks for them. As the risks become clearer, businesses are likely to pressure policy makers to ensure other sectors do not undermine the ecosystems upon which they rely, and this is already occurring in the timber industry (Cambridge Natural Capital Programme, undated). The programme has a vision of *'a global economy that operates within the finite limits of its natural resource base, with value chains that are resilient over the long-term and that provide goods and services which deliver quality and sustainable lifestyles*' (CNCP, ibid). Essentially, these senior people in these major corporations are saying that they are seeking greater resilience – not specifically to climate change, but in linking purchasing decisions to resource use and incorporating the costs of externalities. There must be a shift from a demand-led approach to consumption to one that is 'supply-constrained', with natural capital forming a core part of the business model'.

Resilience, according to the views of company decision makers reported by the Cambridge programme, *'describes the ability of value chain systems to function effectively within the finite limits of one planet, while handling dynamic changes around natural capital availability and use. Resilience is not a finite attribute. It involves flexibility and adaptability over time'* (CNCP, undated). Box 6 below outlines the principles of resilient value chains according to CNCP.

Many of these principles for resilience outlined by the Cambridge programme will be necessary to tackle climate change imperatives. Some might critique this type of industry led approach as paying insufficient attention to the trade-offs involved in these decisions, and might be sceptical that financial short term imperatives will be overlooked for longer-term objectives without significant regulation and government intervention.

Further, there is a great deal of work to be done looking at local and regional markets in Africa and the drivers for sustainability and corporate responsibility within those nations beyond the export led value chains.

Box 6 Principles for building resilient value chains and the next steps for business

1. Operate within the finite limits of supply. Ensure that all those involved with supply networks understand the critical importance of operating within the limits of the Earth's natural capital. Put in place strategies and procedures to make this happen, collaborate to find new solutions and create a critical mass that can deliver these solutions to scale. Identify the ecosystems on which specific products rely, and only take from these ecosystems what they can produce sustainably, sharing this natural capital equitably between stakeholders including local communities. Lead the debate on how consumption can fit within environmental limits, and reach a consensus on the key elements of a sustainable lifestyle.

2. Reflect the right value for externalities in the product price. Advocate bold policy measures by governments to value natural capital and sustain it long-term. Establish how to price externalities, what this would mean for product prices, and the policy measures needed from government to support this move.

3. Change the way we view value chains. Look beyond a single product sector to take a supply-constrained approach that encourages collaboration among those that rely on the same ecosystem for their products and services. Use language that positions natural capital more centrally within the supply network to encourage a better understanding of the flows and dependencies between the natural systems on which these networks depend.

4.Build a portfolio of effective interventions. Share evidence of interventions that most effectively build resilient supply networks, and particularly those that create changes in practice for a wide spectrum of producers. Recommend how to simplify and coordinate value chain interventions. Take a proactive approach in advocating the policy measures and institutional infrastructure needed to deliver a consistent improvement in product standards and the management of resilient supply networks.

5. Edit consumer choice. Design and manufacture sustainable products that consumers can use in a sustainable way, and phase out unsustainable products with determination and rigour. Be vocal in calling for public procurement to drive significant change in the sustainability of products and their supply network.

6. Draft and implement operating principles. Draft a set of operating principles for value chains in relation to natural capital and establish a process for getting these principles widely accepted.

7. Ensure the best use of land. Play a leadership role in supporting government to take a transparent, inclusive approach to land use decisions. Understand the balance between the role of local governments in deciding the best use of land and the role of procurement standards in assisting public policies to become a reality. Identify, measure and manage the land use footprints of business in order to reduce exposure to land-related risk and risks to the sustainability of supply networks.

Source: The Cambridge Natural Capital Programme Building resilient value chains within the limits of natural capital http://www.cpsl.cam.ac.uk/Leaders-Groups/Natural-Capital-Leaders-Platform/Resilient-Value-Chains.aspx

2.7 Climate Smart Agriculture

Climate Smart Agriculture as a concept appears to have originated from the FAO (FAO 2010), but is now being supported by other development agencies, such as the World Bank (World Bank, undated a) and the Rockefeller Foundation, including several high profile events in 2011. Climate Smart Agriculture (CSA) is defined by the FAO as: "*agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals*" (FAO 2010, pii) CSA, according to the World Bank and Wageningen statement, 2011) comprises: i) *proven practical techniques* (e.g. mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agroforestry, improved grazing, and improved water management and ii) *innovative practices,* (e.g. better weather forecasting, early warning systems and risk insurance.

In Africa, most Comprehensive Africa Agricultural Development Programme (CAADP) Country Investment Plans (CIPs) have identified land and water management as priorities, with significant budgets allocated to them. However, many CIPs fail to explicitly address climate change and, where it is covered, it is not adequately integrated. In an attempt to start addressing this, programme design workshops on climate-smart agriculture which supported the United Nations Framework Convention on Climate Change (UNFCCC's) goals and African Union Commission-New Partnership for Africa's Development (AUC-NEPAD's) goals were implemented in Nairobi and Senegal in the lead up to COP17 in Durban in December 2011[x] . An African Ministerial Conference on CSA was held prior to the Durban COP. CSA was at the centre of the third Agriculture and Rural Development Day in Durban, in December 2011.

Over 160 participants from 38 countries from scientific organizations, universities, governments, international organizations, farmers' organizations, private sector and civil society organizations convened at the Global Science Conference on CSA in Wageningen, Netherlands in October 2011, to identify scientific priorities that will lead to CSA. The participants took stock of the current state of global knowledge of the science and best practices concerning climate smart agriculture worldwide; identified key priorities for further knowledge development as well as efficient and effective ways to implement possible interventions. The Wageningen Statement on CSA called for various actions to take CSA forward[xi].

The Meridian Report (2011) suggests that CSA maximizes benefits and minimizes negative trade offs across food security, development, and climate change adaptation and mitigation goals. Early action measures could build confidence, capacity, knowledge and experience, including data collection, policy development and the support of demonstration activities. ‗Pursuing early action activities will result in country-specific data and knowledge as well as experience with agricultural practices and policies that could inform long- term national strategies' (Meridian Report, 2011, p. xii). Further, ‗a strategy that brings together prioritized action, financial incentives, investment policies, institutional arrangements, tenure security, and aggregating mechanisms constitutes an important step in the transition to climate-smart agriculture' (Meridian Report, 2011, p. xii).

Figure 5 focuses largely on technological innovations and to some extent land use change. Institutional innovation will be equally important (e.g. climate index insurance, climate-based social protection programmes, climate farmer field schools). The term 'adaptation' here refers to approaches and capabilities within agriculture, and does not include more radical shifts such as 'getting out of farming', which may be the most effective adaptation to climate change for farmers in particularly vulnerable contexts (Meridian 2011). Implementation of different options will have varying outcomes at different scales. There will also be trade offs in decision making and outcomes for different social groups now and in the future.

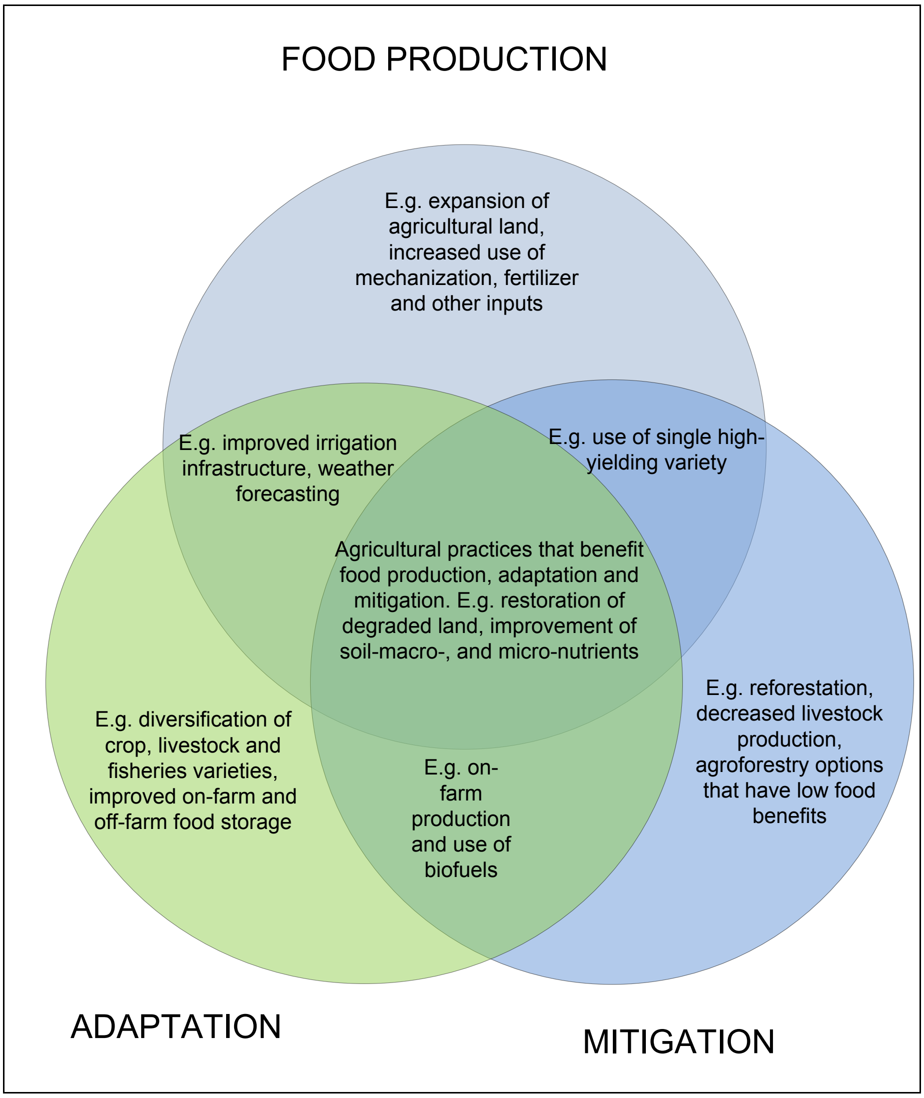

Figure 5 Potential synergies and trade-offs among food production, adaptation and mitigation (Meridian Institute 2011: 16)

The concept of CSA is gaining increasing popularity as a potential unifying concept for policy, institutional arrangements, and funding channels for responding to climate change, food security, and other development goals. However, considerable challenges remain. For some, CSA represents an attempt to promote industrial agriculture. For example, civil society groups at the Durban Cop in December 2011 expressed concerns that the CSA vision for African agriculture will lead to land grabs, farmer poverty and food insecurity, and only worsen global climate change Simon Mwamba of the East African Small Scale Farmers' Federation explains: '*Climate Smart Agriculture is being presented as sustainable agriculture – but the term is so broad that we fear it is a front for promoting industrial, 'green revolution' agriculture too, which traps farmers into cycles of debt and poverty'.*[xii]" For others, CSA is perceived as a threat to the modernisation of agricultural and achieving food security. There are concerns with the emphasis on mitigation - the technical mitigation potentials and whether carbon markets will actually deliver payments for carbon services to farmers. CSA presents potentially new funding opportunities, but implementation will also require strong political leadership, supportive government policies and institutional arrangements that make investments worthwhile and bring about poverty reduction. These are challenges already central to debates on agricultural development.

2.8 Green Economy and Agriculture

There are diverse interpretations of Green Economy (GE), amongst both supporters and opponents of GE.

- One view emphasizes the *Greening of the Existing Economy*, where growth remains the prime goal of economic policy, but there is an acknowledgement of environmental constraints to growth, especially climate change and the need for low-carbon development. In this view technological changes are thought to be the key route to achieving green production and consumption and ultimately to sustainability.
- A different interpretation is more radical: *Green Development* is an approach to GE that involves adjustments to existing economic structures and the creation of a new model of production and consumption, diverging from the model that underpins Western development pathways. In this latter thinking, changes are needed across an innovation system in institutions, culture and welfare concepts – not only in technologies.
- A third view places *GE within the existing Sustainable Development framework* and emphasises social development, especially international equality and poverty reduction. This view acknowledges potential conflicts between development and the environment and emphasises that many developing countries are not yet a stage of development to reduce their resource and energy intensity.

Agriculture is thought to be central in a green economy because it accounts for: 70% of water use; 17-30% of GHG emissions and 37% of global labour force (Farming First undated). Key organisations promoting a green economy in recent years include: UNEP, OECD and FAO and we summarize their approaches below.

OECD: OECD (2011b) promotes green growth, and in a recent OECD publication it states that: *"business as usual will lead to a future in which economic growth will be constrained by natural resource limits, putting the security of food supplies at risk.*

Implementing policies that will move food and agriculture on to a green-growth pathway, and developing the means to measure progress are all important". Further, *"a green-growth strategy aims to ensure that enough food is provided, efficiently and sustainably, for a growing population. This means increasing output while managing scarce natural resources; reducing the carbon intensity and adverse environmental impacts throughout the food chain; enhancing the provision of environmental services such as carbon sequestration, flood and drought control; and conserving biodiversity"* (OECD, 2011b, p 8). A strategy is needed to: a) increase productivity in a sustainable manner; b) ensure that well-functioning markets provide the right signals: and c) establish and enforce well defined property rights (OECD 2011b).

UNEP: A green economy is defined as *"as one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities"* (UNEP 2011a, p 2). UNEP's Green Economy report states that "*the greening of economies has the potential to be a new engine of growth, a net generator of decent jobs and a vital strategy to eliminate persistent poverty*" UNEP (2011c, p 16). Further, it is suggested that the greening of agriculture refers to the increasing use of farming practices and technologies that simultaneously: (i) maintain and increase farm productivity and profitability while ensuring the provision of food on a sustainable basis, (ii) reduce negative externalities and gradually lead to positive ones, and (iii) rebuild ecological resources (i.e. soil, water, air and biodiversity "natural capital" assets) by reducing pollution and using resources more efficiently. A diverse, locally adaptable set of agricultural techniques, practices and market branding certifications such as Good Agricultural Practices (GAP), Organic/Biodynamic Agriculture, Fair Trade, Ecological Agriculture, Conservation Agriculture and related techniques and food-supply protocols are provided as examples of varying shades of "green" agriculture. Farming practices and technologies that are instrumental in greening agriculture include (UNEP 2011b):

- restoring and enhancing soil fertility through the increased use of naturally and sustainably produced nutrient inputs; diversified crop rotations; and livestock and crop integration;
- reducing soil erosion and improving the efficiency of water use by applying minimum tillage and cover crop cultivation techniques;
- reducing chemical pesticide and herbicide use by implementing integrated biological pest and weed management practices; and

- reducing food spoilage and loss by expanding the use of post-harvest storage and processing facilities.

A number of potential action and outcome indicators for measuring progress towards green agriculture are shown in Table 3.

Table 3 Potential indicators for measuring progress towards green agriculture

Action indicators	Outcome indicators
1. Number of enacted and implemented policy measures and officially approved plans that promote sustainable agriculture (eg trade and export policy measures, payment for ecosystem services through agriculture)	1. Percentage and amount of land under different forms of green agriculture (organic, GAP-good agriculture practices, conservation, etc).
2. Level of governmental support to encourage farmers to invest in conversion to green agriculture and get the farm and the product certified	2. Decline in use of agro-chemicals as a result of conversion to green agriculture; and the number and percentage of farmers converting to green agriculture
3. Percentage of agricultural budget that is earmarked for environmental objectives	3. Increasing proportion of Payments for Ecosysteml Services as a percentage of total farm income
4. Proportion of available producer support utilized for environmental objectives as a percentage of total agricultural producer support	4. Number of agriculture extension officers trained in green agriculture practices
5. Approved measures that reduce or eliminate barriers to trade in technologies and services needed for a transition to a green agriculture.	5. Number of enterprises set up in rural areas, especially those that produce local organic agricultural inputs, to offer off-farm employment opportunities.

Source UNEP 2011b

FAO: A recent FAO document refers to the process of Greening the Economy with Agriculture (GEA) and tentatively suggest this means "*increasing food security (in terms of food availability, access, stability and utilization) while using less natural resources, through improved efficiency, resilience and equity throughout the food value chain*" (Muller 2011).

GEA entails the following:

- Availability: Food and natural resources availability in a green economy
- Access: Decent rural livelihoods and rights in a green economy environment
- Stability: Stability of food systems in a green economy environment
- Utilization: Sustainable diets and low carbon food systems (Muller 2011)

Reasons for supporting GEA are as follows:

- there can not be a green economy without agriculture, because it occupies 30% of land area and 2.4 billion people;
- agriculture, forestry and fisheries are key drivers in the transition towards a green economy and poverty reduction;
- a well-managed agri-food sector is a response to the imperatives of climate change, depletion of natural resources and alarming nutrition-related diseases;
- under the right circumstances, the agri-food sector generates innumerable global goods and services, including decent livelihoods and ecosystem services (Muller 2011).

The OECD perspective is perhaps more orientated towards its 34 more advanced and emerging economy members and the need '*to foster and support new sources of growth through innovation, environmentally friendly 'green growth' strategies*' (OECD.com). UNEP starting from an environmental care perspective[xiii], states '*the concept of a green economy does not replace sustainable development; but there is a growing recognition that achieving sustainability rests almost entirely on getting the economy right*' (UNEP 2011c). FAO, with a mission of '*helping to build a food-secure world for present and future generations*' is inevitably concerned with food and agriculture, which ties in with its CSA approach. The GE perspective possibly puts more emphasis on the whole food and agriculture value chain.

Most African countries' economic, poverty reduction and food security strategies are based on increasing agricultural production through conventional high input intensification and /or expansion into uncultivated land. A GE approach potentially offers a more sustainable way forward. At this stage GE means very different things to different interested parties and this has raised concerns amongst G77[xiv] countries in relation to sustainable development (SD) and poverty eradication goals and with regard to the potential misuse of GE for "green protectionism" and as a means of introducing new conditionalities in financing for developing countries. What GE could mean for African agriculture and different social groups thus remains an open question.

2.9 Climate Resilience

Climate resilience can be described in broad terms as the ability of households and communities to recover from shocks and stresses. Alongside adaptive capacity, resilience indicates a more positive attribute than vulnerability – which has been critiqued as casting those at risk as victims and therefore as powerless, rather than as active agents. However, resilience is also used much more specifically, in a *systems* sense: referring to the 'regenerative abilities of a system and its capacity to maintain desired functions in the face of shocks and stresses' (Pelling, 2011). Walker and Salt (2006) identify a number of dimensions or indicators of socio-ecological system resilience, including diversity, social networks, innovation, redundancy, ecosystem services, tight feedbacks, modularity, overlapping governance, and acknowledging slow variables. Resilience and diversity is discussed in Box 7 below.

Box 7: Resilience and Diversity

One of the key indicators of resilience is diversity. Ecologists recognise both effect and response diversity (species have traits which shape their effects on ecosystem processes and traits that govern the response of species to environmental variation). The biodiversity effects on ecosystem services can be divided into functional composition, numbers of species, and landscape structure and diversity. Increasing diversity can generally speaking increase resilience:

- Agriobiodiversity and planting on different terrains has long been recognized in agro-ecology as a critical strategy employed by small-scale farmers, drawing upon their local and indigenous knowledge, to spread risk. Mono-crop farm systems are more susceptible to plant diseases which will increase with climate change.

- Diversity of assets and livelihood strategies help farmers and urban dwellers to spread risk. However, at some point spreading of assets may reach a limit and accumulation of assets, such as savings, may be more important to help a household cope.

- Involvement of multiple stakeholders in decision-making may help to reduce potentially damaging policy developments.

- Social protection by government and international organizations is also important to compensate for a lack of diversity and to back-stop specialization. A whole range of interventions exist, many of which have already proved effective and which could become increasingly relevant as climate change occurs, including cash and asset transfers, seed fairs etc, although these need to be adaptive.

Source Nelson et al, 2010

Resilience thinking has informed adaptation debates in a number of ways. For example, the nature of the shocks and stresses, that farmers face, has perhaps been more closely analysed and in a more integrated fashion. The types of actual or potential disturbances may be ecological (e.g. drought, fire, disease, hurricanes and floods); economic disturbances (e.g. recessions, market volatility); or social (e.g. revolutions, new connections, new values, technological developments). Key questions include: How *frequent* are these disturbances (frequency, duration, severity, predictability)? Pulse disturbances occur and then cease before recurring, (e.g. application of new fertilizer, hurricanes, disease outbreaks) and press disturbances are unremitting (e.g. grazing land that is stocked year round). Do the disturbances compound each others' effects or *vice versa*? It is worth noting that management strategies which attempt to control disturbances (e.g. by reducing vulnerability) can erode the resilience of a managed system, making it susceptible even to small disturbances (Resilience Alliance, 2007)

According to Folke (2006), there are three key dimensions of SES thinking that have informed work on climate change responses (functional persistence, self-organisation and adaptation from social learning). Functional persistence is an ecological concept, referring to the ability to maintain function in the face of shocks and stresses. Flexibility in the face of *unexpected* as well as *predicted* hazards, vulnerabilities and impacts is an important dimension of adaptive capacity (Pelling, 2011). However, resilience in situations of social inequality is not desirable from a development perspective – because highly unequal or discriminatory social relations and structures may persist to the detriment of the less powerful. But functional persistence may not be desirable from a socio-political perspective.

Resilience thinking emerged from work by systems theorists and ecologists. In resilience thinking, the maximising of diversity and maintaining redundancy in a socio-ecological system contributes to resilience – by ensuring that risk is spread and that there are breaks between components of a system preventing system-wide collapse (Walker and Salt 2006). But Nelson, Adger and Brown (2007) suggest there needs to be a more actor-oriented interpretation– one that explores the desired state of a system, rather than taking for granted the fact that a systems' continuance is preferable, and that focuses on the agency of different actors to create or stifle change. They also raise questions about inter-generational equity – for example, is it better to protect vulnerable communities now, if such actions foreclose on other options that might protect future generations more effectively.

A resilience check is suggested by Ifejika Speranza (2010) to review new adaptation proposals and options. This check is important to ensure that although an adaptation option might improve farmer wellbeing in the short-term, it could also leave farmers and communities more vulnerable to shocks and stresses in the future and thus would be mal-adaptation. Solely focusing on cash cropping at the expense of food crops or on using expensive pesticides could decrease farmer resilience, even though they may achieve greater short term income security. Although smallholder farming is inherently risky and complex (Morton, 2007) and farmers face a multiplicity of pressures in many developing countries, climate change is increasing the shocks and stresses. Building up resilience reduces vulnerability to a range of hazards which helps farmers and communities prepare for the uncertainties ahead.

Resilience has encouraged adaptation thinking to consider the importance of *scale*. Resilience and adaptation achieved at one level could be undermined by processes at a different, inter-linked scale, because each system is nested within another.

Box 8: Inter-acting dimensions of resilience

- **Social Resilience**: Tackling inequality is a key part of building *social resilience*, including supporting participation of disadvantaged groups in decision-making.
- **Ecological resilience** is also important - ecosystems provide key services for rural livelihoods and a healthy environment acts as a buffer to shocks and stresses, whereas localised processes of environmental degradation increase local people's vulnerability to climate related hazards. Environmentally-friendly farming and promoting agro-biodiversity may help to increase resilience to climate shocks and stresses.
- **Economic resilience**: diversifying the income sources and livelihood activities and access to assets. This could mean diversifying the crops grown, but could also involve more non-farm activities which are playing an increasingly important role in rural household budgets (e.g. working locally or at a distance when less work is required on farm). It is necessary to strike a balance between diversifying and building up assets (e.g. stocks and savings) as the latter also increases a household's ability to cope with shocks or stresses.

Source: Nelson et al, 2010

Climate resilience forms a major plank in more integrated approaches such as 'Climate Smart Agriculture' and Climate Compatible Development, although these integrative conceptual frameworks seek to move beyond resilience, adaptation, and mitigation, to make linkages and identify potential synergies, and in the case of CCD perhaps to profile development pathways, economic policy-making and visions more clearly.

2.10 Climate Compatible Development (CCD) and Agriculture

Essentially Climate Compatible Development (CCD) represents a *'new generation of development processes that safeguard development from climate impacts (climate resilient development) and reduce or keep emissions low without compromising development goals (low emissions development)'.* 'Triple win' strategies are sought that result in low emissions, build resilience and promote development simultaneously (Mitchell and Maxwell, ibid). Similarly (although not termed CCD), Boyd et al, (2010) suggest that current development planning timescales are likely to have to be extended by climate change considerations, with more investments made in foresight thinking, analysis of the implications for 'lock in' to particular unsustainable development pathways by decisions taken now (e.g. in infrastructure investments) and greater policy coherence across adaptation, mitigation and development planning.

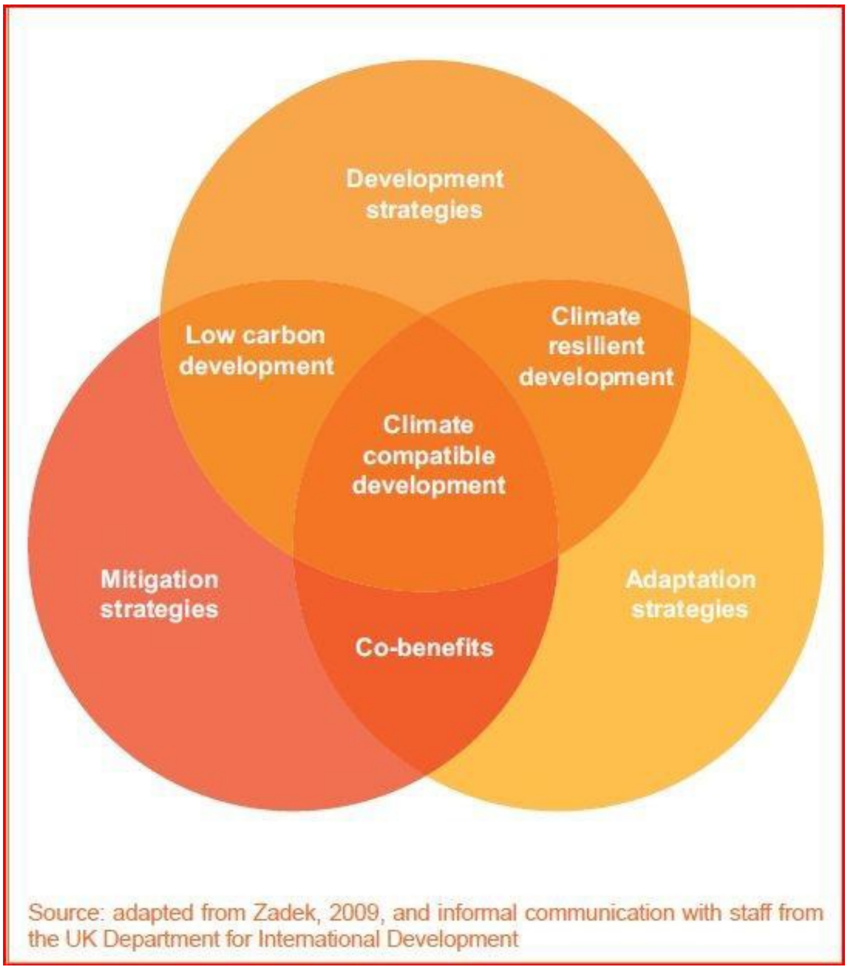

Figure 6 Climate Compatible Development (Source: Mitchell and Maxwell 2010)

A Meridien Institute Scoping Report (2011) outlines the relationship between agriculture and climate change in a detailed, but broad-based way. Thus while it has a section on early opportunities in relation to climate change, it is also probably the nearest document to Climate Compatible Agricultural Development we have come across to date, because it has a whole section dedicated to the synergies and trade offs that may occur between food production, adaptation and mitigation goals, and addresses some of the economic and social development processes and issues, which previous, separate work streams on climate adaptation and mitigation have neglected.

On climate change and food production, for example, the Meridien report (2011) finds that:

- *Agriculture has multiple functions* within climate change (as source and sink, in adaptation and mitigation), and more broadly (as food production, but also including incomes, revenues, environmental services and cultural value). In the international negotiations agriculture therefore requires a unified approach rather than separate treatment in different negotiating streams;

- *Production, adaptation and mitigation synergies:* Myriad technical and institutional opportunities exist to deliver simultaneously on food production, adaptation, and mitigation, while benefiting wider environmental services and farming incomes, and hence food security. Many practices, technologies, and systems are already available and affordable, but interactions are complex, may involve trade-offs, and need to be tailored to specific contexts.

- *Coordination of agriculture and forestry land uses:* Agriculture is the primary driver of conversion of forests, grasslands and wetlands, but land use change is not counted as GHG emissions from agriculture. While intensification can free up land for carbon storage, perverse incentives and externalities can arise requiring policy coordination.

- *Joining up climate change and food security:* Opportunities exist for adaptation in the food system to improve links between food production and security. Climate change actions should assure availability, accessibility and utilization of food, and food security interventions should take full account of climate change impacts and options.

- *Need for appropriate incentives, governance and institutions to deliver on* these multiple objectives. Options are locally specific. There are financial, cultural, knowledge and policy issues deterring even immediate win-win-win options. A mix of instruments and governance arrangements that include both positive incentives on the one hand and safeguards, regulations, and sanctions on the other will be needed. Internationally, negotiations on trade, measurement, finance, technology transfer, and capacity development will be important (Box 9).

The Meridien (2011) report is also detailed on trade and climate change linkages and on the challenges and requirements in finance, technology transfer and capacity building.[xv]

A development lens requires consideration of who benefits and who pays the costs of any policy or practice changes and this question is relevant to climate change. Equity is a critical issue brought to the fore in the Climate Compatible Development concept that requires attention across climate change responses. Social protection measures may be required according to Mitchell and Maxwell (2010) and other authors suggest that social protection measures should become adaptive – i.e. take into account climate science and thinking (Davies et al, 2008)[xvi].

Box 9: Finance, technology transfer and capacity building

- *Changes needed to create enabling conditions:* Current incentive frameworks for agricultural mitigation and adaptation to not take account of the special characteristics of agriculture and fail to provide appropriate support and incentives for large-scale emission reductions or adaptation actions.

- *International mechanisms can facilitate action:* New mechanisms such as an expanded Climate Development Mechanism (CDM) and funding for NAPAs and NAMAs, may help countries in the short term to act, but needs assessments and funding proposals in agriculture require support as there is competition for limited funds.

- *Technology transfer can support a change in agricultural practices toward more sustainable activities:* The process of transferring agricultural innovation across agro-ecological zones is often subject to agronomic constraints and slow adaption rates. Technology transfer can support a change in agricultural practices toward more sustainable activities.

- *Capacity building and institutional strengthening is needed to support implementation:* Farmers and their supporting agencies, especially extension and research, need greater capacity to apply new farming approaches effectively and efficiently. Building farmer capacity could be part of a larger effort to build the capacity of local governmental institutions and local R&D and in finding ways to make capacities mutually reinforcing. Financing dedicated capacity-building programmes as well as improving coordination between existing and emerging programs can help address gaps in skills, knowledge, staffing, and management systems.

The Meridien Report (2011)

3. Discussion

Agriculture is one of the most important causes of global warming, as well as a critical sector that will be affected by climate change. Multiple demands are being placed upon on agriculture (including food security, importance to livelihoods and economies in most developing countries and provision of other ecosystem services) in the context of finite limits of natural resources , demographic pressures, the threat of climate change, the need for conservation of resources and the importance of ecological processes and tipping points.

While adaptation or mitigation projects can be important sources of learning, more programmatic and mainstream planning responses are needed. Attention needs to be paid not only to productivity issues, but also to how climate change may change value chains and global trade flows. Some commentators suggest that climate change uncertainties require a revisiting of prevailing economic models and assumptions – to avoid lock-in to unsustainable pathways.

There is also a need to understand climate change within broader development processes (e.g. de-agrarianisation, urbanisation, migration, globalisation, changing balance of economic and political power, volatility in global financial markets etc), because these may compound or significantly outweigh climate related challenges and add to the uncertainties that lie ahead.

More integrated or holistic conceptual frameworks have been developed and presented of late, in an attempt to combine climate change responses and shorter and longer term development objectives. For example, proponents of existing concepts such as sustainable agriculture increasingly recognize climate change issues. The green economy concept suggests that securing future economic development and protecting or enhancing environmental services are intertwined processes. Some organisations are promoting concepts such as Climate Smart Agriculture, which bring together responses to climate change (e.g. adaptation, mitigation, resilience) alongside broader development goals. However, as a result of merging multiple objectives these concepts can appear somewhat ambitious in terms of implementation. Figure 5 shows how food production, adaptation and mitigation goals overlap and gives examples of the component practices, but also practices which could in theory represent win-win-win solutions.

There is thus a crowded field of climate change and related concepts jostling for attention. Each concept has its own promoters and opponents – some more powerful than others. The competition between concepts is probably unavoidable, but it can create confusion, especially for those trying to implement change in practice – whether policy-makers or practitioners. Integrated approaches such as Climate Smart Agriculture and Climate Compatible Development highlight the importance of *trade-offs and synergies* in decision making related to agriculture. Although the Climate Smart Agriculture approach is already broad and explicitly mentions sustainable agricultural production, adaptation and mitigation, there is relatively little emphasis on other aspects of food/agriculture value chains, economic models, trade, and broader institutional issues in adaptation. Climate Compatible Development brings into focus questions pertaining to economic policy, longer-term horizons in development planning, and issues of (inter-generational) equity, by focusing not only on production, but also trade, social protection, economic policy, investment, migration etc. Green Economy is a concept that also raises questions about central economic policy and in some interpretations has similarities with Climate Compatible Development.

The broad nature of the concepts allows for varied interpretations in implementation. This conceptual flexibility is advantageous in that contexts differ it can encourage more inclusive processes and can spark productive debate. Conversely broad definitions risk masking real differences in development visions[xvii] including questions of participation, the forms of technology to be used, the role of markets and national autonomy. Thus, too open a definition could prevent recognition of the need for more radical, game changing action.

Considerations in making these concepts operational include building consensus amongst relevant stakeholders for change at the appropriate spatial scale (e.g. farm, community, water catchment, value chain, local government area, national, global) and time scale (immediate to long term). Finding appropriate ways to measure progress in responding to climate change adaptation is particularly challenging, but urgently needed to make progress visible and to enhance learning..

The climate change and agriculture challenges are many, and the incentives and enabling conditions are complex and often tantalizingly difficult to bring about. Climate change may only be adding to the challenges facing agriculture or more optimistically, it may also act as a catalyst, alongside other global concerns, to create fresh opportunities for sustainable agricultural development.

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Appendix 1: Changing the decision environment

Avenues for changing management behaviour in the light of climate change	
Convince managers of the reality of climate change	Policies which maintain climate monitoring and effective communication of this information (incl. targeted support of surveillance of pests, diseases etc)
Convince managers that projected changes will impact upon their enterprise	Policies that support the research, systems analysis, extension capacity, industry, and regional networks that provide this information could thus be strengthened. This includes modelling techniques that allow scaling up knowledge from gene to cell to organisms and eventually to the management systems and national policy scales.
Support increased access to technical and other innovations	Where existing technical options are inadequate, investment in new technical or management strategies may be required (e.g., improved crop, forage, livestock, forest, and fisheries germplasm), including biotechnology. In some cases, old approaches can be revived that may be suited to new climate challenges
Effectively plan for and manage climate-induced transitions in land use	Transitions of land use may include migration, resettlement and industry re-location. Provide direct financial and material support, creating alternative livelihood options with reduced dependence on agriculture, supporting community partnerships in developing food and forage banks, enhancing capacity to develop social capital and share information, retraining, providing food aid and employment to the more vulnerable, and developing contingency plans. Effective planning and management may result in less habitat loss, less risk of carbon loss and also lower environmental costs compared with unmanaged reactive transitions
Support new management and land use arrangements	Enable new management and land use arrangements via investment in new infrastructure, policies, and institutions. Addressing climate change in development programs; Enhancing investment in irrigation infrastructure and efficient water use technologies; Ensuring appropriate transport and storage infrastructure; Revising land tenure arrangements, including attention to property rights; Establishing accessible, efficient markets for products and inputs (seed, fertilizer, labour, etc.) and for financial services, including insurance.

Source: Nelson et al, 2010 based on Howden, 2007

[i] AFAAS (African Forum for Agricultural Advisory Services), FARA (Forum for Agricultural Research in Africa), NRI (Natural Resources Institute), CDKN (Climate and Development Knowledge Network)

[ii] : Underlying assumptions include: "a) nature is a competitor to be overcome; b) progress requires
[ii] : Underlying assumptions include: "a) nature is a competitor to be overcome; b) progress requires
unending evolution of larger farms and depopulation of farm communities; c) progress is measured primarily by increased material consumption; d) efficiency is measured by looking at the bottom line; and e) science is an unbiased enterprise driven by natural forces to produce social good" (Stauber et al, cited by Gold, 2007). The concerns that have led to the concepts and practices of sustainable agriculture are also worth noting (Gold, 2007):

[iii] *The New American Farmer: Profiles of Agricultural Innovation*, 2nd ed. (SARE, 2005). Available at SARE Website: http://www.sare.org/publications/naf.htm (8/23/07

[iv] The Adaptation Partnership (involving 23 countries, including founders the US, Costa Rica and Spain) recently released an inventory providing a wealth of information on climate adaptation activities in different regions of the world.
http://www.adaptationpartnership.org/index.php?option=com_content&view=article&id=4&Itemid=6

[v] Climate change is also expected to impact infrastructure and transport routes. Countries where climate change creates scarcity may meet their needs by importing and, in the case of food, this is likely to be from mid-high latitude areas (eg parts of N. America, N. Europe) to lower latitudes (eg much of Africa) (Huang *et al.* 2010).

[vi] UNFCCC divides countries into three main groups according to differing commitments: Annex I Parties include the industrialised countries that were members of the OECD (Organisation for Economic Co-operation and Development) in 1992, plus countries with economies in transition (EIT Parties), including the Russian Federation, Baltic states, and several central and eastern European states. Annex II Parties consist of the OECD members of Annex I, but not the EIT Parties. They are required to provide financial resources to enable developing countries to undertake emissions-reduction activities under the Convention and to help them adapt to adverse effects of climate change. In addition, they have to 'take all practicable steps' to promote the development and transfer of environmentally friendly technologies to EIT Parties and developing countries. Funding provided by Annex II Parties is channelled mostly through the Convention's financial mechanism.

Non-Annex I Parties are mostly developing countries. Certain groups of developing countries are recognised by the Convention as being especially vulnerable to the adverse impacts of climate change, including countries with low lying coastal areas and those prone to desertification and drought. Others (such as countries that rely heavily on income from fossil-fuel production and commerce) feel more vulnerable to the potential economic impacts of climate change response measures. The Convention emphasises activities that promise to answer the special needs and concerns of these vulnerable countries, such as investment, insurance and technology transfer. The 49 Parties classified as least-developed countries (LDCs) by the United Nations are given special consideration under the Convention on account of their limited capacity to respond to climate change and adapt to its adverse effects. Parties are urged to take full account of the special situation of LDCs when considering funding and technology-transfer activities.

[vii] The report presents the findings of a project aiming to explore the pressures on the global food system between now and 2050 and identify the decisions that policy makers need to take today, and in the years ahead, to ensure that a global population rising to nine billion or more can be fed

sustainably and equitably. The principle of sustainability implies the use of resources at rates that do not exceed the capacity of the earth to replace them.

[viii] Lessons for scaling up and spreading were: (i) science and farmer inputs into technologies and practices that combine crops–animals with agroecological and agronomic management; (ii) creation of novel social infrastructure that builds trust among individuals and agencies; (iii) improvement of farmer knowledge and capacity through the use of farmer field schools and modern information and communication technologies; (iv) engagement with the private sector for supply of goods and services; (v) a focus on women's educational, microfinance and agricultural technology needs; (vi) ensuring the availability of microfinance and rural banking; and (vii) ensuring public sector support for agriculture.

[ix] In June 2007 business leaders of the Sustainable Food Lab articulated the following Call to Action: *"We recognize that we influence the way one quarter of the world's population earns a living, half the world's habitable land is cared for, and two-thirds of the world's fresh water is used. With such influence comes opportunity and responsibility. We commit ourselves to establish standards of excellence in social, economic and environmental responsibility.*"Hamilton et al (2010 p 21)

[x] See http://www.caadp.net/pdf/1.%20CAADP%20Workshop%20Context.pdf.

[xi] 1.Urge increased farm and landscape level research, education, extension and innovation in CSA;2. Call on all stakeholders to contribute to platforms and capacity enhancement that improve dialogue &learning about proven policies, technologies and practices for CSA; 3. Call on implementing agencies from national governments and civil society, and the private sector, to provide the impetus for, and support to, proven climate-smart technologies and practices; 4. Urge all stakeholders to put in place the needed policies, strategies and frameworks to build CSA, and the associated research and development; 5. Urge national governments, regional organisations and private sector to allocate adequate financing to climate-smart agriculture and rural development, and the associated research and development; 6. Call on all countries to finance "early action" on proven technologies, practices and incentive systems to drive change in agricultural production systems to adapt to climate change and weather variability, while contributing to climate change mitigation.

[xii] http://www.climate-justice-now.org/climate-smart-agriculture-and-carbon-markets-will-be-a-disaster-for-africa-groups-warn-against-zuma%e2%80%99s-agriculture-prize-at-cop17/

[xiii] UNEP's mission is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations

[xiv] The Group of 77 is the largest intergovernmental organization of developing countries in the UN, which provides the means for countries of the South to articulate and promote their collective economic interests and enhance their joint negotiating capacity on major international economic issues within the UN system, and promote South-South cooperation for development.

[xv] Comparative advantages in agriculture will be affected, with variations in yields and prices, leading to changes in trade patterns. Food prices are likely to rise also due to climate change impacts, which might alter global trade flows. Further, trade and increased investment in agriculture production could help to rectify supply and demand imbalances in certain regions, and help to make food available in world markets by offsetting decreases in production resulting from climate change impacts. Some promote an open and undistorted trading system at regional and international levels to help ensure food remains available, especially in climate change badly affected regions. However, others suggest that appropriate flexibilities in liberalization agreements combined with productivity-

enhancing measures are needed to deal with market failures and imperfect institutions in countries where livelihoods are intricately related to farming. Agricultural mitigation could affect agricultural exporters and thus global food availability. Existing trade agreements may be challenged by some measures depending on design and implementation (e.g., subsidies for mitigation, border tax adjustments), but most climate-change policies will not breach existing multilateral trade rules because they would not be discriminatory or are covered by general exceptions of WTO's General Agreement on Tariffs and Trade (GATT) Article XX.

[xvi] Social protection measures may be needed to protect the most vulnerable to climate change, and there are examples of new initiatives, such as asset and cash transfers, that have proved successful on the ground (Davies et al, 2008). Social protection measures, however, need to take into account climate change science and thinking – i.e. it should become *adaptive.* Forward thinking planning may be required to assess which communities and areas may fall into poverty or fall into deeper poverty as a result of climate change impacts, for example. The types of social protection being developed may also be influenced by climate change considerations, with climate index insurance for herders and farmers being piloted.

[xvii] Murphy S. 2011. ' Changing perspectives: small-scale farmers, markets and globalisation'. Working Paper. Hivos Knowledge Programme. Hivos, The Hague, Netherlands and International Institute for Environment and Development, London, UK.

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