Chapter 9. Rural Areas

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Executive Summary

There is a lack of clear definition of what constitutes rural areas, and definitions that do exist depend on definitions of the urban. [9.1.2] Across the world, the importance of peri-urban areas and new forms of rural-urban interactions are increasing. [9.1.3] Notwithstanding this, rural areas still account for almost half the world's population, about 75% of the developing world's poor people and 80% of the world's hungry. [9.1.1] Rural areas therefore are important for assessing the impacts of climate change and the prospects of adaptation in these areas, constituting a dynamic, spatial category. [9.1.1] A lack of focus on the rural sector in policy making increases its vulnerability to climate change. [9.2]

Climate change in rural areas in developing countries will take place in the context of many important economic, social and land-use trends. In different regions, rural populations have peaked or will peak in the next few decades. [9.3.1] The proportion of the rural population depending on agriculture is extremely varied across regions, but declining everywhere. Poverty rates in rural areas are falling more sharply than overall poverty rates, and proportions of the total poor accounted for by rural people are also falling: in both cases with the exception of sub-Saharan Africa, where these rates are rising. Hunger and malnutrition is prevalent among rural children in South Asia and Sub-Saharan Africa. Processes of commercialisation and diversification in developing countries, and inter linkages between land tenure and food policy are important drivers. Rural people are subject to multiple non-climate stressors, including under-investment in agriculture (though there are signs this is improving), problems with land policy, and processes of environmental degradation. In industrialized countries, there are important shifts towards multiple uses of rural areas, especially leisure uses, and new rural policies based on the collaboration of multiple stakeholders, the targeting of multiple sectors and a change from subsidy-based to investment-based policy. [9.3.1, Table 9-1]

Cases in the literature of observed impacts on rural areas often suffer from methodological problems of attribution [9.3.2], but evidence for observed impacts, both of extreme events [9.3.2.1] and other categories [9.3.2.2], is increasing. Heat waves and droughts can cause severe impacts while saline intrusion, storm surges, and other coastal climatic events can affect rural livelihood systems. [9.3.2.1] Climate volatility can increase poverty in developing countries. [9.3.2.1]

Future impacts of climate change on the rural economic base and livelihoods, land-use and regional interconnections are at the latter stages of complex causal chains that flow through changing patterns of extreme events and/or effects of climate change on biophysical processes in agriculture and less-managed ecosystems. This increases the uncertainty associated with any particular projected impact. [9.3.3]

Major impacts of climate change in rural areas will be felt through impacts on water supply, food security [9.3.3.1] and agricultural incomes. [9.3.4.1] Migration patterns will be driven by multiple factors of which climate change is only one, and projections of migration can only be tentative. [9.3.3.2.1] There will be secondary impacts of climate policy, such as policies to encourage cultivation of biofuels. [9.3.3.3] In certain countries shifts in agricultural production may be seen. [9.3.4.1] Price rises, which may be induced by climate shocks apart from other factors [9.3.3.2.2], have a disproportionate impact on the welfare of the poor in rural areas, such as female headed households and those with limited access to modern agricultural inputs, infrastructure and education. [9.3.3.1]

Valuation of climate impacts needs to draw upon both monetary and non-monetary indicators. Most studies on valuation highlight that climate change impacts will be significant especially for the developing regions, due to their economic dependence on agriculture and natural resources, low adaptive capacities, and geographical locations. [9.3.4] The valuation of non-marketed ecosystem services [9.3.4.6] and the limitations of economic valuation models which aggregate across multiple contexts [9.3.4] pose challenges for valuing impacts in rural areas.

There are low levels of agreement on some of the key factors associated with vulnerability or resilience in rural areas [9.3.5.2], including rainfed as opposed to irrigated agriculture [9.3.5.2.1], small-scale and family-managed farms [9.3.5.2.2], and integration into world markets. [9.3.5.2.4] There is greater agreement on the importance for resilience of access to land and natural resources [9.3.5.2.5], flexible local institutions [9.3.5.2.6], and knowledge and information [9.3.5.2.7], and the association of gender inequalities with vulnerability. [9.3.5.2.9]

There is a growing body of literature on successful adaptation in rural areas, including both documentation of practical experience [9.4.3], and discussion of preconditions. Prevailing development constraints, such as low levels of educational attainment, environmental degradation and armed conflict create additional vulnerabilities which undermine rural societies' ability to cope with climate risks. [9.4.4] The supply of information for decision-making, and the role of social capital in building resilience, are key issues. [9.4.1]

9.1. Introduction

9.1.1. Rationale for the Chapter

Rural areas, even after significant demographic shifts, still account for almost half the world's population (UN 2011). They also account for about 75% of the developing world's poor people (Ravaillon *et al.*, 2007) and 80% of the world's hungry (UNDP, 2005), important points given the association of climate vulnerability with poverty and food insecurity. At the same time, changes in land-use and livelihoods in rural areas make it less straightforward to associate rural areas with agriculture or food production.

The Fourth Assessment Report (AR4) of the IPCC contains no specific chapter on "rural areas". Material on rural areas and rural people is found throughout the AR4, but rural areas are approached from specific viewpoints and through specific disciplines. Agriculture and food production, the impacts of which are assessed by Easterling *et al.* (2007), clearly take place mainly in rural areas, but that chapter was not able to cover impacts on other human activities taking place in rural areas or of significance to rural people. Many rural people follow livelihoods directly dependent on unmanaged or less-managed ecosystems, such as forests. However, the AR4 chapter on ecosystems (Fischlin *et al.*, 2007) was not able to cover the indirect impacts of ecosystem change on such livelihoods. The chapter on industry, settlement and society (Wilbanks *et al.*, 2007) reaches important conclusions about specific vulnerabilities of both urban and rural systems to climate change, but much of the literature reviewed and the most important conclusions, on high-density settlements, industry and infrastructure, are implicitly concerned with urban areas.

This chapter, under the general heading of "Human Settlements, Industry, and Infrastructure" will assess the impacts of climate change on, and the prospects for adaptation in, rural areas, seen as diverse patterns of settlement, infrastructure and livelihoods, in complex relations of interdependence with urban areas. Some of the key considerations will be as follows.

- Rural areas are largely defined in contradistinction to urban areas, but that distinction is increasingly seen as problematic.
- Rural areas are a spatial category, associated with certain patterns of human activity, but with those associations being subject to continuous change.

- Rural populations have, and will have, a variety of income sources and occupations, within which agriculture and the exploitation of natural resources have privileged but not necessarily predominant positions.
- Rural areas suffer from specific vulnerabilities to climate change, both through their dependence on natural resources and weather-dependent activities, and through their relative lack of access to information, decision-making, investment and services.

The chapter will address issues also dealt with in Chapter 7 “Food Production Systems and Food Security” and Chapter 4 “Terrestrial and Inland Water Systems”, but will primarily look at how biophysical impacts of climate change on agriculture and on less-managed ecosystems translate into impacts on human systems. It will also address issues dealt with in Chapter 12 “Human Security” and Chapter 13 “Poverty and Livelihoods”, but primarily from the point of view of rural areas as spatial categories with particular characteristics.

9.1.2. Definitions of the Rural

“Rural” and “rural areas”, in both policy-oriented and scholarly literature are terms often taken for granted or left undefined. IFAD (2010) states that the definitions of rural and urban are fraught with difficulties. Hart *et al*. (2005) set out the multiple and sometimes contradictory official definitions used in the United States. Some definitions depend on the scale of the area or settlement being defined. They conclude that choice of a definition depends on purpose, data availability and its place within an appropriate taxonomy. Ultimately, however, in developing countries as well as developed countries, the rural is defined as the inverse or the residual of the urban (Lerner and Eakin, 2010).

The U.S. Bureau of the Census defines rural areas as consisting of all territory outside of Census Bureau-defined urbanized areas and urban clusters, that is open country and settlements with fewer than 2,500 residents. Such areas can in practice have population densities as high as 999 persons per square mile (386 persons/km^2) (Womach, 2005).

The UK Department for Environment, Food and Rural Affairs (Defra, 2011) uses two definitions of rural areas. In national statistics areas are defined as rural if they fall outside urban areas defined as having 10,000 or more inhabitants. Some urban areas of between 10,000 and 30,000 inhabitants, serving a wider rural hinterland and meeting certain service criteria are defined as Large Market Towns. These Towns and their populations are therefore classified as rural for the purposes of classifying local government areas. Districts with at least 50 per cent of their population living in rural settlements and larger market towns are defined as “predominantly rural”. These two examples demonstrate both the variation of definitions of the rural between countries and the dependence of those definitions on definitions of the urban.

In India urban areas are defined essentially as those with populations of 5,000 or more, or where least 75% of the male working population is non-agricultural, or having a density of population of at least 400 people per km^2 (GOI 2012)

Human settlements in fact exist along a continuum from ‘rural’ to ‘urban’, with ‘large villages’, ‘small towns’ and ‘small urban centres’ not clearly fitting into one or the other. The populations of these ambiguous settlements tends to range from a few hundred to approximately 20,000 inhabitants, with 20 to 40 percent of the population in many nations living in settlements in this category (Satterthwaite, 2006).

Definitions of the rural are therefore variable between countries, increasingly seen as problematic, and increasingly subject to various attempts at refinement and sub-classification. While remaining aware of these issues, this chapter will in general assess literature on current trends in rural areas, and on climate impacts, adaptation and vulnerability, using whatever definitions of the rural are used in that literature.

9.1.3. Between 'Rural' and 'Urban': the Peri-Urban Interface

Authors have increasingly recognized that the simple dichotomy between 'rural' and 'urban' has "long ceased to have much meaning in practice or for policy-making purposes in many parts of the global South" (Simon *et al.*, 2006:4; Simon, 2008). Because of this, attempts to refine rural-urban classifications have included the concept of "peri-urban areas", reviewed by Lerner and Eakin (2010). Webster (2002:5) writes of a process of peri-urbanisation as rural areas around cities "become more urban in character" but equally "households may be pursuing peri-urban incomes while still residing in what appears to be largely rural landscapes" (Lerner and Eakin 2010:1). Other conceptualisations stress that peri-urban areas should be seen as more than just the "urban periphery", but rather as locations in which rural and urban land uses coexist, whether in contiguous or fragmented units (Bowyer-Bower, 2006). Although assessments of "land degradation" and "sustainability" in peri-urban areas exist (e.g. Allen, 2006; Diaz-Chavez, 2006; Gough and Yankson, 2006; Binns and Maconachie, 2006), these have not yet focused on how these areas will be affected by climate change, or how the process of peri-urbanization will shape vulnerability or resilience.

The widening use in academic literature of the Bahasa Indonesian term *desakota* (starting with McGee, 1991) is intended to include more than the peri-urban (Moench and Gyawali, 2008). It recognizes that diversified economic systems exist across the urban-rural spectrum, and focuses on the closely interlinked, co-penetrating rural/urban livelihoods, communication, transport and economic systems (Desakota Study Team, 2008). Desakota areas are seen to be increasing in importance as "push" factors – including climate change (Desakota Study Team, 2008) – drive people out from both rural areas and urban centres. Ecosystem services are particularly important in these areas, and environmental degradation – again, including the impacts of climate change (Desakota Study Team, 2008) will influence ecosystems services and their role as a foundation for livelihood systems across developing countries in these systems, with particularly important consequences for the poor who are often the most directly dependent on water-dependent ecosystem services.

9.2. Findings of Recent Assessments

This section will review AR4 findings of relevance to rural areas (IPCC, 2007), as well as those findings of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2009) that are related both to climate change and rural areas. Easterling *et al.*, (2007) focus on productivity and production of crops, livestock and forests, which clearly have impacts in rural livelihoods, but are only one of many other aspects to be considered. Wilbanks *et al.*, (2007), on human settlements, focus strongly on urban areas. They also state that "research on vulnerabilities and adaptive potentials of human systems has lagged behind research on physical environmental systems, ecological impacts and mitigation (p.385)" and for that reason uncertainties are very prominent in their treatment of the topic. These include uncertainties associated with identifying impacts at small geographical scale, with secondary impacts on human systems of primary effects, with the potential for adaptation to reduce impact, and with the socio-economic and technical trends that will be the context for climate change.

Easterling *et al.*, (2007) state that any assessment of climate change impacts on agriculture has to be undertaken against a background of global demographic and economic trends in rural areas (p.280). These factors determine how rural populations can cope with changing climate conditions, and how climate will affect food security. Different development paths may increase or decrease vulnerabilities to climate-change impacts (Wilbanks *et al.*, 2007: 384). Global numbers of people at risk from hunger will be affected by climate change, but more by socioeconomic trends as captured in the difference between the SRES scenarios (Easterling *et al.*, 2007: 298-299). The significance of climate change needs to be considered in the multi-causal context of its interactions with other non-climate sources of change and stress (Wilbanks *et al.*, 2007: 364). That is, climate change is not the only stress on human settlements, other stresses, such as water scarcity, governance structures, institutional and jurisdictional fragmentation, limited revenue streams for public sector roles, or inflexible land use patterns, which are inadequate even in the absence of climate change, also need to be considered (Wilbanks *et al.*, 2007: 373).

In terms of rural livelihoods linked to agriculture, AR4 concludes that subsistence and smallholder livelihood systems suffer from a number of stressors apart from climate change. But these systems are also characterized for having certain resilience factors: efficiencies associated with the use of family labour, livelihood diversity to spread risks, and indigenous knowledge that facilitates coping with crises (Easterling *et al*., 2007: 281-282). Agricultural knowledge that favours an optimization of resources use to produce food can be of major relevance in this context. Traditional knowledge related to agriculture and natural resource management is assessed as a valuable individual and social asset (IAASTD, 2009). The combinations of stressors and resilience factors gives rise to complex positive and negative trends in livelihoods, that are very locally-specific (293-294) and resistant to aggregate modelling (Wilbanks et al., 2007: 359, 376).

Forestry is also assessed in AR4 from the viewpoint of timber production by Easterling *et al*. (2007), but forests are also important for millions of people in providing ecosystem services other than timber or the forestry industry, such as food, medicines or fuel. In many rural Sub-Saharan Africa communities, Non-Timber Forest Products (NTFPs) may supply over 50% of household cash income and provide the health needs for over 80% of the population (FAO, 2004a). Yet little is known about the possible impacts of climate change on NTFPs. Fires, disease outbreaks, general deforestation trends are all expected to affect the contribution of NTFPs to rural livelihoods. In general terms, Easterling *et al*., (2007: 291) suggest that the loss of forest resources may directly affect 90% of the 1.2 billion forest-dependent people who live in extreme poverty.

In terms of systems assessed, tourism, water supplies (demand and availability), insurance, sanitation, and infrastructure, including transport, power and communication, all affect rural settlement. It is recognised that neglect of the rural sector, and rural women in particular, by policy makers and service providers has favoured a lack of investment in infrastructure, water systems, education and health services, and the dismantling of public extension systems, which have all left their mark on rural areas and their inhabitants (IAASTD, 2009). In terms of climate change, these services in rural areas might be less affected than in urban areas precisely because of the lower provision of infrastructure, but the lack of services can limit rural peoples' ability to cope with extreme climate events. Specifically, water supply is important since most water in the world is used for agricultural purposes.

Wilbanks *et al*. (2007: 375) noted the difficulty of finding valuations of climate change for human settlements. It states that estimates based on aggregate macroeconomic costs of climate change at a global scale are not directly useful while other types of social and environmental costs are poorly captured by monetary metrics. The IAASTD confirmed this finding suggesting other forms of non-monetary valuations, such as energy-related valuations.

A general adaptation trend highlighted for rural communities is the diversification of livelihoods strategies, moving livestock, harvesting water, shifting crop mixes and migration (Easterling *et al*. 2007: 293). All these require adequate institutional support for longer-term livelihood sustainability. The IAASTD (2009) puts strong emphasis on adaptation and research strategies promoting participation, social learning and empowering rural people. Yet, prospects for adaptation depend on the magnitude and rate of climate change, adaptation strategies being inseparable from increasingly strong and complex global linkages. Adaptation actions can be effective in achieving their specific goals, but they may have other (positive or negative) effects as well. Special attention will have to be given to the access to resources in adaptation measures. As climate change exacerbates and adaptation becomes a common need, there is likely to be competition for resources, whether financial or physical resources, like water or land, exacerbating risks of conflict over resources and further increase inequity, particularly in developing countries (IAASTD, 2009).

AR4 suggests that mitigation and adaptation policies are in many cases, and certainly for agriculture, settlements and industry, closely linked (Klein *et al*., 2007; Easterling *et al*., 2007; 283, 284; Wilbanks *et al*., 2007: 359, 384). A growing body of literature confirms this statement.

9.3. Assessing Impacts, Vulnerabilities, and Risks

9.3.1. Current and Future Economic, Social, and Land-Use Trends in Rural Areas

Climate change in rural areas will take place against the background of the trends in demography, economics and governance which are shaping those areas. While there are major points of contact between the important trends in developing and industrialized countries, and the analytical approaches used to discuss them, it is easier to discuss trends separately for the two groups of countries.In particular there is a close association in developing countries between rural areas and poverty. Table 9-1 summarizes and compares the most important trends across the two groups of countries. Figure 9-1, Table 9-2, and Figure 9-2 focus on two specific trends in developing countries: demographic trends and trends in poverty indicators.

[INSERT TABLE 9-1 HERE
Table 9-1: Major demographic, poverty-related, economic, governance, and environmental trends in rural areas of developed and developing countries.]

[INSERT FIGURE 9-1 HERE
Figure 9-1: Key demographic indicators in rural areas of developing countries.]

[INSERT TABLE 9-2 HERE
Table 9-2: Poverty indicators for rural areas of developing countries.]

[INSERT FIGURE 9-2 HERE
Figure 9-2: Poverty indicators for rural areas of developing countries, by region.]

9.3.2. Observed Impacts

Documentation of observed impacts of climate change on rural areas involves major questions of detection and attribution. Much discussion of vulnerability and adaptive capacity in rural areas, especially work based on qualitative fieldwork at community level, reports local perceptions of climate change, or uses local meteorological data without systematic attempts to distinguish between decadal trends and manifestations of long-term global climate change (see for example chapters in Ensor and Berger, 2009, and Castro *et al.*, 2012). Similarly, impacts, vulnerability and adaptive capacity are frequently discussed in the context of extreme events, and perceived increases in their frequency, without systematic discussion of the difficulties of attributing extreme events to climate change (see Paavola, 2008 as an example), difficulties that have been further highlighted by the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC 2012, Seneviratne *et al.,* 2012). Implied equivalence between perceptions, local decadal trends and global change is not a problem in the context of detailed social-scientific analysis of vulnerability, adaptive capacity and their determinants, but creates problems if such work is used as evidence for observed impact.

The impacts of climate change on patterns of settlement, livelihoods and incomes in rural areas will be the result of multi-step causal chains of impact. Typically, those chains will be of two sorts. One sort will involve extreme events, such as floods and storms, as they impact on rural infrastructure. The other sort will involve impacts on agriculture or on ecosystems on which rural people depend. These impacts may themselves stem from extreme events, from changing patterns of extremes due to climate change, to changes in mean conditions. The detection and attribution of extreme events is discussed by IPCC (2012). The detection and attribution of impacts on ecosystems and on agriculture are dealt with in Chapters 4 and 7 of this report. Both exercises are complex.

With these provisos, observed impacts in the literature can be considered under the headings of impacts of extreme events and impacts of more incremental changes in climate parameters, though there is no clear divide between the two.

9.3.2.1. Impacts of Extreme Events

Seneviratne *et al*. (2012) give a detailed and critical assessment of the detection and attribution of observed patterns of extreme events, which shows greatly varying levels of confidence in the attribution to climate change of global and regional trends. For example they state that it is *likely* there has been a worldwide increase in extreme high water events, and it is *likely* that there has been an anthropogenic influence on this. They have *medium confidence* in detecting trends towards more intense and frequent droughts in some parts of the world (Southern Europe and West Africa) while noting that opposite trends exist, and that there is *low confidence* in any trend in dryness in, for example, East Africa. They assign *low confidence* to any observed long-term increases in tropical cyclone activity, or attribution of any changes in cyclone activity to anthropogenic influence. They state that “attribution of single extreme events to anthropogenic climate change is challenging” (2012:112).

These conclusions, and the evolving literature on attribution of extreme events must be taken into account when discussing the impacts of extreme events on human systems, which are clear. Handmer *et al*., (2012) summarize the evidence of such impacts. Although no specific analysis is given for rural areas, the main conclusions for human settlements are valid in our context. Extreme events can produce severe distress in societies. For example, Hurricane Stan in October 2005 affected nearly 600,000 people on the Chiapas coast as a consequence of flooding and sudden river overflows (Saldaña-Zorrilla, 2008). Natural disasters produce adverse impact on the macro-economy. Developing countries, and smaller economies, experience larger declines following a disaster of similar relative magnitude than do developed countries or bigger economies. Martine and Guzman (2002) analyze the consequences of Hurricane Mitch (the most powerful hurricane of the 1998 season) on the underlying vulnerability of Central America. They concluded that poverty can act as a magnifier of the threat of natural hazards.

Heat waves are one of the climate shocks that can substantially affect human comfort and even produce mortality. Although there are differences between urban and rural areas regarding the magnitude of extreme high temperatures, there is evidence pointing towards the fact that human populations seem to be equally vulnerable among urban and rural areas (Loughan *et al*., 2010).Despite the direct impacts on human systems, droughts produce severe economic distress on rural areas. Employment reduction as a consequence of lower agricultural productivity and ultimate migration are two of the most common responses (Gray and Muller, 2012). Other examples of climate related stressors that can produce major impacts on rural areas are sea level rise that can worsen saline intrusions, inundation, storm surges, erosion, and other coastal hazards in island communities, and glacier melt that affects major agricultural systems in Asia (Warner *et al*., 2009).

Extreme events have a strong influence on poverty levels. Ahmed *et al*. (2009) found that under the present climate, extreme events (referred to as climate volatility) increase poverty in developing countries with clear impacts in Bangladesh, Mexico, Indonesia, and Africa. Literacy rate, better institutions, higher per capita income, higher degree of openness to trade, and higher levels of government spending are conditions that reduce disaster shock and prevent further spillovers into the macro-economy (Noy, 2009).

Raleigh *et al*. (2008) present a comprehensive paper with regionally specific data and a break out of extreme events by type and frequency. Even though they recognize the influence of climate drivers on migration, their analysis differs from “environmental refugee” assessments as they emphasize the role of human reaction and adaptation Raleigh and Urdall (2007) also state that population growth and density are factors that increase risk and that socioeconomic and political factors have generally outweighed environmental stressors in the past.

Preliminary assessments often analyze the observed impacts of climate stressors such as droughts, floods, and heat waves to obtain response functions. These functions are then used to generate estimates of the impacts of climate change in rural areas.

9.3.2.2 Other Observed Impacts

Glacial retreat in Latin America (Orlove, 2009) is one of the least ambiguous current impacts on rural areas. In highland Peru there have been rapid observed declines since 1962 in glacier area and dry-season stream flow, on which local livelihoods, which accord well with local perceptions of changes that are necessitating adaptation. There is also a rich specialized literature on the impacts of shrinking sea-ice and changing seasonal patterns of ice formation and melt on Inuit in circumpolar regions (Ford, 2009).

Poverty indicators can be considered as a result of climate impacts as well as a key component of vulnerability. Migration is another relevant impact that can be observed and attributable directly to climate. Black *et al.* (2011), in work that seeks to understand how and why existing flows from and to specific locations may change in the future, recognizing the complexity of the phenomenon and exploring climate drivers that act on it, present two examples. In Ghana, rainfall variability increases seasonal migration in good years, and reduces migration in drought years. However, the growing variability and uncertainty associated with rainfall patterns have resulted in more anticipatory migration. When addressing migration, Reuveny (2007) uses the term "ecomigrant" to show how environmental change can trigger migration. The Dust Bowl is an example where drought was one (but not the only) cause of this disaster. It is argued that environmental degradation removed the basis for the agricultural-based lifestyle, setting the stage for ecomigration.

9.3.3 Future Impacts and Vulnerabilities

This section will examine the major impacts of climate change identified or projected for rural areas, under the headings of: economic base and livelihoods; landscape and regional interconnections, including migration, trade, investment and knowledge; and second-order impacts of climate policy. The following section, 9.3.4, assesses literature on impact through a different and specific lens, that of economic valuation, though there is some overlap. The biophysical impacts of climate change on food crops are dealt with primarily in Chapter 7; but also here and in section 9.3.4 insofar as they affect rural economies. Issues relating to biophysical impacts on non-food cash crops are illustrated in Box 9-1 with reference to coffee.

As with the observed impacts in section 9.3.2, the future impacts of climate change described here, and quantified in section 9.3.4, are at the latter stages of complex causal chains that flow through changing patterns of extreme events and/or effects of climate change on biophysical processes in agriculture and less-managed ecosystems. This increases the uncertainty associated with any particular impact on the economic base, on land-use or on regional interconnections.

9.3.3.1. Economic Base and Livelihoods

Climate change will affect rural livelihoods, or "the capabilities, assets (stores, resources, claims and access) and activities required for a means of living" (Chambers and Conway, 1992).This is because many rural livelihoods are dependent on natural resources (e.g. agriculture, fishing and forestry), and their availability will vary in a changing climate. This may have effects on human security and wellbeing (Kumssa and Jones, 2010).

Morton (2007), adapting findings from AR4, suggests that the impacts of climate change on smallholder and subsistence farmers can be conceptualized as a combination of: biological processes affecting crops and animals at organism or field level; environmental and physical processes affecting production at a landscape, watershed or community level; and other impacts, including those on human health and on non-agricultural livelihoods. This schema is developed by Anderson *et al.* (2010), with a cross-cutting dimension of extreme events, increased variability and shifts in average temperature and rainfall, as well as introducing indirect impacts, for example through trade and food prices, and through climate mitigation policies.

An additional dimension is effects of climate change on water supply which in turn affect rural livelihood bases, whether through a decrease or increase. In South Africa, for example, most of the climate change models predict a reduction in freshwater availability by 2050, and a computable general equilibrium approach shows that this will adversely affect household welfare (Juana *et al.*, 2008). In the Mount Kenya region, in contrast, the NRM3 Streamflow Model under the TGICA climate change projection will result in an increase of annual runoff by 26%, with a severe increase in flood flows, and a reduction of the lowest flows to about a tenth of the current value

(Notter *et al*., 2007). Changing rainfall levels will also affect groundwater levels, which play a role in rural livelihoods. At the continental level in Africa, analysis of existing rainfall and recharge studies suggests that climate change is unlikely to lead to widespread catastrophic failure of improved rural groundwater supplies (Macdonald *et al*., 2009). However, at higher resolution groundwater resources are threatened (e.g. in South Africa, Knüppe, 2011), and water crises are expected to multiple resulting from the increasing demand, and this will further affect the people in rural areas who fetch water (Nkem *et al*., 2011).

Water availability plays a key role in the viability of agricultural livelihoods, alongside changes in temperature. Climate change is expected to impact water resources in the Asian region in a major way. A study by the World Bank (2010a) argues that diminishing Himalayan glaciers would impact water requirement and food security of more than one billion people in Asia. There are some regional and country studies, which support this view. Likewise, Immerzeel *et al*. (2010) in a study of major river basins of the region viz. Indus, Ganges, Brahmaputra, Yangtze and Yellow rivers conclude that different river basins would have different impacts on water availability and food security due to climate change. They further argue that the Brahmaputra and Indus basins would be more susceptible to water availability affecting food security of 60 million people (ibid). ADB (2009a) argues that climate change would increase water stress in four south East Asian countries of Indonesia, Philippines, Thailand and Vietnam.

In assessing the impacts of climate change on water resources in rural areas of Europe, it is predicted that Mediterranean climates will experience more pressure on water resources from reduced rainfall and melt water from glacial ice and snow. Schroter *et al*. (2005) predict that in the Mediterranean region summer water supply could fall by 20 to 30% following global warming of 2ºC and 40 -50% for 4ºC . These declines would increase the costs of production and living in the South (Falloon and Betts, 2010). Drought could threaten biodiversity and traditional ecosystems particularly in Southern Europe with problems exacerbated by declining water quality. Decline in economic activity is likely to increase rural depopulation and harm the development of rural communities in Southern Europe (Westhoek *et al*., 2006). According to MacDonald *et al*. (2009) climate change will not lead to a widespread failure of improved rural groundwater supply in Africa, but it could affect a population of up to 90 million people, as they live in rural areas where annual rainfall is between 200 and 500mm per year, and where decreases in annual rainfall, changes in intensity or seasonal variations may cause problems for groundwater supply.

Various studies conclude a decline in crop yield and water availability of agriculture due to climate change over the next three to four decades in different parts of the world (Section 7.2.1, Chapter 7, AR5). For the Asia –Pacific region several studies have concentrated on impacts emanating from the agricultural sector (ADB & IFPRI, 2009; ADB, 2009a; Srivastava *et al*., 2010; De Silva *et al*., 2007; Xiong *et al*., 2009, 2010; Ramirez-Villegas *et al*., 2011) *S*imilarly, studies on the adverse impacts of climatic changes on yields in different parts of North America, Australia and Europe have been conducted (Warren *et al.,* 2006; Olesena *et al*., 2011; Anwar *et al.,* 2007; COPA COGECA, 2003; Schlenker and Roberts, 2009; Roberts and Schlenker, 2010; Niemi *et al*. 2009; Wolfe *et al*. 2008). The impacts of climate change on the smallholder and rain-fed dominated (96% of all agricultural land is rain-fed) agricultural sector are considered to be very significant to the economies and livelihoods in Africa (Müller *et al*., 2011; Kotir, 2011; Collier *et al*., 2008; Hassan, 2010). These results emerge across a range of scenarios. Several other studies also map declines in net revenues from crops and the associated links with food security and poverty (Molua, 2009; Thurlow *et al*., 2009; Reid *et al*., 2008; World Bank, 2010a; Thurlow and Wobst, 2003. Yield patterns are expected to present spatial differences in South America, as projected by various studies with some losing such as bean growers in Central America and some gaining such as sugarcane cultivators in Brazil. Such country case studies are based on climate projections for SRES A2 and B2 scenarios derived by Hadley Center HadRM3P model (Pinto and Assad, 2008; ECLAC, 2009; ECLAC, 2010a). Adverse impacts on yield derived on the basis of simulations of the above mentioned scenarios imply that since bean growers in Central America are small, low-income farmers, climate change may have large repercussion throughout the region, endangering the food security of large segments of the population (ECLAC, 2010b).

There will also be impacts on non-food cash crops, on which many rural people depend. The case of tropical beverage crops, in particular coffee, is discussed in Box 9-1, and projected changes in area suitable for all three tropical beverage crops are set out in Table 9-3.

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Box 9-1. Impacts of Climate Change on Tropical Beverage Crops

The major traded beverage crops coffee, tea and cocoa support the livelihoods of several million small-scale producers. Coffee production has long been recognized as sensitive to climate variability with global production and prices sensitive to occasional frosts in Brazil – the world's largest producer. Likewise the livelihoods of millions of small producers are dependent both on stability of production and stability in world prices. During the last crash in coffee prices from 2000-2003 poverty levels in the coffee growing regions of Nicaragua increased, while they fell in the rest of the country (World Bank, 2003); subsequently during the drought associated with El Nino in 2005 coffee productivity fell to between a third and half of normal similarly leading to severely reduced income for small producers (Haggar, 2009).

Analysis of the effects of recent climate change on coffee producing areas in Mexico by Gay *et al*. (2006) show that in Veracruz between 1969 and 1998 rainfall has decreased by 40mm per year and temperatures have increased by 0.02^{o}C per year. Extrapolating these changes to 2020 they find that coffee production could decline by 34%, but most importantly this decline in production takes producers from making net profits of on average around US$200 per acre, to less than $20 per acre. This has led to a series of studies projecting the effects of climate change on the distribution of Arabica coffee growing areas of the coming decades.

For Brazil, Pinto *et al*., (2004) have mapped the changes in area suitable for coffee production in the four main coffee producing states. Major changes in the distribution of coffee producing zones are foreseen in Minas Gerais and Sao Paulo with the potential area for production declining from 70-75% of the state to 20-25%, production in Gioas being eliminated but only a 10% reduction in area in Parana. New areas suitable for production in Santa Catarina and Rio Grande do Sul will only partially compensate the loss of area in other states (Pinto and Assad, 2008). The economic impacts of a rise in temperature of 3^{o}C would cause a 60% decline coffee production in the state of Sao Paulo equal to nearly 300 million dollars income (Pinto *et al*., 2007).

Models developed by CIAT predict the distribution of coffee under climate scenarios averaged from 21 different models by parameterising current distribution using 19 climatic variables and mapping where those conditions may occur in the future. This method has been applied to coffee distribution in Kenya (CIAT 2010), Central America and Mexico (Laderach *et al*., 2010), tea production in Kenya (CIAT, 2011b) and Uganda (CIAT, 2011b), and cocoa production in Ghana and Ivory Coast (CIAT, 2011c) (Table 9-3). Only one similar study appears to have been done for Robusta coffee (Simonett, 2002) in Uganda, which appears to show similarly drastic changes in both distribution and total area suitable for coffee production. At minimum climate change will cause considerable changes in the distribution of these crops disrupting the livelihoods of millions of small-holder producers, in many cases the total area suitable for production would decrease considerably with increases of temperature of only 2-2.5^{o}C.

____ END BOX 9-1 HERE ____

[INSERT TABLE 9-3 HERE
Table 9-3: Projected changes in areas suitable for production of tropical beverage crops by 2050.]

Food security is now known to reflect a broader range of factors than merely food production (Sen, 1992), and in three countries in African which suffered mass mortality food crises since 2000 – Ethiopia, Malawi and Niger - these crises were triggered by a moderate decline in crop and/or livestock production, exacerbated by "exchange entitlement failures" – food price spikes and asset price collapses (Devereux, 2009).). For example, the food crisis of 2007-2008 exposed the vulnerability of rural livelihoods to external price shocks. Review of the evidence shows that price rises have a disproportionate impact on the welfare of the poorest of the poor in rural areas - female-headed households (which tend to be poorer than male-headed households) and those who have limited access to land, modern agricultural inputs, infrastructure and education (Ruel *et al*., 2009: 3). This has illustrated that the vulnerability of rural livelihoods is affected by not only ecological, but also social and economic factors that mediate or hinder people's access to different assets and capacities to adapt (Ericksen, 2008a, b; Ellis, 2000: 290-91).

However, changes in production will play a role in affecting food security and resultant increases in malnutrition (Ringler, 2010).

Agricultural livelihoods are not restricted to crops, but also involve livestock. On the African continent, pastoralists have developing strategies for responding to climate variability, for example in the Afar region of Ethiopia (Davies and Bennett, 2007). Data from over 9000 African livestock farmers in 10 countries shows that farmers are more likely to have livestock as temperatures increase and as precipitation decreases, based on logit analysis to estimate whether farmers adopt livestock, followed by three econometric models (a primary choice multinomial logit, an optimal portfolio multinomial logit and a demand system multivariate probit) to determine species choice. The climate scenarios predict a decrease in the probability of beef cattle and an increase in the probability of sheep and goats, and more heat-tolerant animals will dominate the future in Africa (Seo and Mendelsohn, 2007a). A development of the Ricardian method shows that these choices relate to the net income of different animal species. On this basis, large-scale commercial beef cattle farmers are most vulnerable to climate change in Africa, particularly since they are less likely to have diversified (Seo and Mendelsohn, 2007b). Six SRES scenarios generated by six GCMs were used by Hein *et al* .(2009) for the Ferlo Region in Northern Senegal, where livestock keeping is the main economic activity of the rural population. A modest reduction in rainfall of 15% in combination with a 20% increase in rainfall variability could have considerable effects on livestock stocking density and profits, reducing the optimal stocking density by 30%. Livestock is also important to the livelihoods of many citizens of Kenya (Kabubo-Mariara, 2009), a country where more than 77% of its people live in rural areas (UN, 2010). A recent study shows that livestock production is highly sensitive to climate change, whereby increased mean precipitation of 1% could reduce revenues by 6% (Kabubo-Mariara, 2009).

Livelihoods dependent on fisheries will also experience vulnerability to climate change. Impacts of climate change on aquatic ecosystems will have adverse consequences for the world's 36 million fisherfolk as well as the nearly 1.5 billion consumers who rely on fish for more than 20% of their dietary animal protein (Badjeck *et al*., 2010). The linkage between various fish populations, such as black hake, and climate dynamics has been shown using correlations with indices such as the North Atlantic Oscillation (Meiners *et al*., 2010). Climate change will cause increasing sea surface temperatures, ocean acidification, sea level rise, increasing storm intensity and altered ocean circulation, and rainfall patterns. All of these will affect target species through a range of direct and indirect mechanisms. The sensitivity of fish stocks to these changes will determine the range of potential impacts to life cycles, species distributions, community structure, productivity, connectivity, organism performance, recruitment dynamics, prevalence of invasive species, and access to marine resources by fishers (Johnson and Welch, 2010). An indicator approach showed that economies with the highest vulnerability of capture fisheries to climate change were in Central and Western Africa (e.g. Malawi, Guinea, Senegal, and Uganda), Peru and Colombia in north-western South America, and four tropical Asian countries (Bangladesh, Cambodia, Pakistan, and Yemen)(Allison *et al*., 2009). This vulnerability arises from the combined effect of predicted climate change on fish stocks, the relatively high share of fisheries as a source of income (including export earnings) and diets, and limited societal capacity to adapt due to the prominence of poverty in these societies (Allison *et al*., 2009). In another study of changes in climate and social systems in north eastern Asia on fisheries development, Kim (2010) argues that in countries like China, Japan and South Korea these changes could have a negative impact on fisheries adversely affecting livelihoods and food security of the region.

Climate change may in different regions accelerate or retard the processes of livelihood diversification away from agriculture. Although it is also determined by other factors such as poverty, income distribution, farm output, gender, labour and credit markets, diversification into non-farm incomes might accelerate if climate-related risks of farm income failure increase as a result of climate change (Ellis, 2000:294). Such diversification would help households achieve low risk correlations between their livelihood components (Ellis, 2000:294)

The livelihoods framework allows analysis of livelihoods outcomes as embedded within an external context of multiple stresses and dynamics, all of which change over time (Kepe, 2008; Morton, 2007). Climate variability and change interacts with, and sometimes compounds, existing livelihood pressures in rural areas, such as economic policy, globalization, environmental degradation and HIV/AIDS, as has been shown in Tanzania (Hamisi *et al*., 2012), Ghana (Westerhoff and Smit, 2009), South Africa (O'Brien *et al*., 2009; Ziervogel and Taylor, 2008; Reid and Vogel, 2006), Malawi (Casale *et al*., 2010), Kenya, (Oluoko-Odingoa, 2011), Senegal (Mbow *et al*., 2008) and

India (O'Brien et al, 2004). In the Kenya example, analytical techniques such as multiple correlation and regression analysis, principal components analysis, factor analysis and cluster analysis showed that poverty was the main contributor to food insecurity, although climate complicated the issue (Oluoko-Odingoa, 2011). In other examples, climate change is deemed the most critical stress, for example in the Ruaha Valley of Tanzania, where about 42% of variation in cereal production is described by the rainfall amount variability, in addition to changes in wildlife diversity and hydroelectric power generation (Malley *et al*., 2007). Vulnerability to climate change is often exacerbated by factors such as poverty, poor health, unemployment and inadequate village infrastructure in rural areas (Jones and Thornton, 2009; Tschakert, 2007).

Especially for agriculture and other traditional livelihoods in developing countries, the concept of the "centrality of the social" (Fairhead and Leach, 2006) is important: social relations within households (particularly gender relations) and between households, profoundly affecting production decisions, management of knowledge, and marketing (Morton, 2007). Similarly access to diversification as adaptations to climate extremes depends on gender, age, governance institutions based on studies in South Africa, Tanzania and Uganda (Goulden *et al*., 2009). Vulnerability within rural areas is gendered. Women's water security relative to men already places them at a disadvantage in a context of changing availability (Tandon, 2007). Gendered and unequal patterns of participation in decision-making and politics, labour, resource access and control, and possession of knowledge and skills. shape the ability of men and women to adapt to climate risks (Rossi and Lambrou 2008).

9.3.3.2. Landscape and Regional Interconnections

As well as economic livelihoods, climate change will have implications for landuse and landscape in rural areas. Around one-sixth of the world's population is living in arid and semi-arid regions, which are mostly formed by rural areas. More than 250 million people are directly affected by desertification, while another one billion are at risk. The world's major arid regions are in the developing world, where the population growth rate is high, and socio-development levels are low (Jiang and Hardee, 2011). Some of the agricultural shifts described above can also be viewed as landscape changes which may, in turn, feed back into local changes to the climate system. Olson *et al*. (2008) suggested that the seemingly subtle land use change from savannas to cropping in East Africa may have a significant regional climate impact. Spatial pattern is also important, for instance, different socioeconomic scenarios can have the same urbanisation trend, but the spatial pattern may differs, reflecting alternative development processes, e.g. periurbanisation versus counter urbanisation (Rounsevell *et al*., 2007).

In both developing and developed countries, rural areas have been increasingly integrated with the rest of world. The main channels through which this rapid integration process takes place are migration (permanent and cyclical), commuting, transfer of public and private remittances, regional and international trade, inflow of investment and diffusion of knowledge through new information and communication technologies (IFAD, 2010). In this context, changes in the occurrence of some types of extreme events due to climate change, increased variability, and changing mean climate parameters are likely to have significant implications for regional and global integration trends in rural areas.

Desakota systems represent a change in the type of relationships between human society and ecosystems, and therefore create shifts in the geographical and social distribution of risk and vulnerability (Pelling and Mustafa, 2010: 3). Because of this, the characteristics of desakota regions can both increase and decrease disaster and climate risk, and can pose both opportunities and challenges for disaster response and reconstruction (Pelling and Mustafa, 2010). For example, increased transport connectivity in desakota regions can reduce disaster risk by providing a greater diversity of livelihood options and improving access to education, but can also encourage land expropriation to enable commercial development (hence increasing vulnerability of those who are made landless). Similarly, the expansion of local labour markets and wage labour in these areas can reduce disaster risk and improve disaster response through providing new livelihood opportunities and more effective risk management through the management and financial capacity of the formal sector but can simultaneously increase disaster risk as reliance on wage labour can increase dependence on the external economy and exposure to systemic shocks (Pelling and Mustafa, 2010: 7, Figure 2).

9.3.3.2.1. Migration

One of the consequences of changing economic livelihoods and landscapes in rural areas due to climate change is an impact on migration. Typically out-migration to urban areas by the semi-skilled and low-skilled has been the predominant migration flow out of rural areas, particularly in developing countries, although the rates vary from country to country (IFAD, 2010). Other countries show greater trends of rural-rural migration (e.g. India).

Growing efforts are researching environmental migration, building on the AR4 conclusion that extreme events will lead to changed patterns of migration (Boko *et al*., 2007). Though the impacts of climate change are likely to affect population distribution and mobility, it is difficult to establish a causal relationship between environmental degradation and migration, which is still termed "complex and unpredictable" (Brown, 2008). The link between internal migration in response to environmental stresses is contested. One school of thought shows internal (and particularly rural out-migration increasing during times of environmental stresses (e.g. Afifi, 2011; Gray and Mueller, 2012), with projections that these trends will continue under climate change (Kniveton et al, 2011). Growing vulnerability to environmental change may also lead to an increase in abandonment of settlements (McLeman, 2011). Another body of literature shows that migration rates are no higher under conditions of environmental or climate stress (Black, 2011; van der Geest, 2011; van der Geest and de Jeu, 2008; Tacoli, 2009). Whilst rural-urban migration was once the dominant flow, there is now also a trend for migration to small and medium-sized towns (Sall et al, 2010). Increased migration due to climate change may also affect human security (Brown and Crawford, 2008).

9.3.3.2.2. Trade

The volume of global agricultural trade has substantially increased over recent decades. Between 2000-2008, the value of global agricultural exports rose from US$ 551 billion to US$ 1 342 billion, representing an average annual growth of 5 percent (WTO, 2009). In addition to trade in primary crops, trade in processed food, fish and forest products has also been expanding (WTO, 2009). Growing volumes of international trade indicate that an increasing number of producers and consumers of agricultural goods are connected to global markets (IFAD, 2010). However, the fundamentals of agricultural trade have changed significantly in the late 2000s. There was a major agricultural price spike, and historically high degree of price volatility towards the end of the period. Some cyclical and structural factors – such as droughts in Australia and Ukraine creating shortage of cereals in international markets, the expansion of bio-fuels at the expense of food crop production, export controls, and growing demand by emerging economies for secondary agricultural products such as meat, energy and feed crops – have led to a volatile and unpredictable trading environment (FAO, 2008; Timmer, 2010; Schmidhuber and Matuschke, 2010; Karapinar and Haberli, 2010).

Against this backdrop, climate change is expected to affect the pattern and volume of international trade flows. At the sectoral and product levels, it may alter the comparative advantage of countries and regions through its potential impacts on their agricultural supply capacities. These effects will be reflected on agricultural prices – which are the signals of economic scarcity or abundance. Based on a limited number of studies that were available at the time, AR4 concluded that the effects of moderate increases in global mean temperatures (GMTs) (between 2-3°C) on food prices might lead to a small rise or decline (10-15 percent) in food (cereals) prices, while GMT increases in the range of 5.5°C or more might result in an increase in food prices of, on average, 30 percent. However, more recent studies produce more pessimistic projections which are differentiated at the crop level. For example, simulations results of two climate models —the National Centre for Atmospheric Research, US (NCAR) and the Commonwealth Scientific and Industrial Research Organization, Australia (CSIRO) —based on A2 scenario inputs — suggested that climate change might result in additional price increases in 2050, ranging from 30-37 percent for rice, 52-55 percent for maize to 94-111 percent for wheat (Nelson *et al*., 2009). If CO2 fertilization is taken into account, the 2050 price increases are expected to be smaller (for example, by 15-17 percent for rice relative to no CO2 fertilization). It is important to note that these price increases are projected in addition to the price increases (62 percent in rice, 63 percent maize, and 40 percent in wheat) that are expected under no-climate-change scenario, which are largely driven by population and income growth projected to be greater than productivity and area growth (Nelson *et al*., 2009).

The prices of beef, pork and poultry are also projected to increase significantly under A2 inputs simulated in CSIRO and NCAR models. Accordingly, in addition to the projected price increases, under no-climate-change scenario, of 33, 36, 35 percent for beef, pork and poultry respectively, 20, 18, 21 percent increases are projected under climate change scenario for these three commodities respectively, without taking into account CO2 fertilization ((Nelson *et al*., 2009).

Other studies, using different models and scenario combinations, produce significantly different results in relation to price projections. For example, a study undertaken by IFPRI using another model (called IMPACT) estimates additional price increases (relative to no-climate change) of 32- 34 percent for maize (with baseline and pessimistic socioeconomic scenarios), 18-20 percent for rice (with optimistic and pessimistic socioeconomic scenario) and 23-24 percent for wheat (with baseline and pessimistic socioeconomic scenarios) ((Nelson *et al*., 2010).

The projected production and price changes across regions will affect trade flows substantially. Without climate change, net developed-country exports (of rice, wheat, maize, millet, sorghum, and other grains) to developing countries are expected to increase by 22.4 million mt, from 83.4 million mt to 105.8 million mt between 2000 and 2050, representing a growth of 27 percent (Nelson *et al*., 2009). Climate change might lead to an additional export volume of 0.9 million mt (with wetter NCAR scenario) to 39.9 million mt (with drier CSIRO scenario) (Nelson *et al*., 2009). Developed-country exports are projected to increase by an additional 12 to 18 percent relative to no climate change if CO2 fertilization is taken into account (Nelson *et al*., 2009). Regions such as South Asia, East Asia and Pacific are projected to increase their imports substantially over this period. For example, South Asia which exported around 15 million mt in 2000 is expected to import up to 54 million mt (with drier CSIRO scenario) (Nelson *et al*., 2009). By 2050, the Middle East and North Africa region and Sub-Saharan Africa which are already net importers of cereals are estimated to increase the volumes of cereals imports by 29 and 30 percent, respectively (Nelson *et al*., 2009). In addition, due to climate impacts on prices, trade flow values will increase even at higher rates than trade volumes.

However, there are other models producing substantially different projections for developed country cereals exports. For example, MIROC scenario (produced by the Center for Climate System Research, University of Tokyo) with A1B-induced production effects on U.S. maize production project a radical decline in net maize exports by up to 70 percent by 2050 (Nelson *et al*., 2010). This is in sharp contrast to the projection that U.S. exports would double under no-climate change scenario (Nelson *et al*., 2010). These different projections underline the high degree of uncertainty in the climate scenarios and the potential role of international trade in mitigating the effects of climate change on agricultural productivity.

It is projected that additional food deficits caused by climate change will be supplied, fully or partly, through trade and food aid from surplus regions (Nelson *et al*., 2009; Huang, et al., 2011:12; Jankowska, et al 2012) This would place additional pressure on food aid agencies, which have already been struggling to deliver aid in an environment of growing scale of poverty and malnutrition due to the recent price hikes and of historical volatility in food aid supplies (Barrett and Maxwell, 2006; Harvey, et al. 2010)

The potential role that trade could play in mitigating the impacts of climate change will also be affected by countries' trade policies. In the period of the 1980s and 1990s, global agricultural trade was largely shaped by market distortions caused by border protection measures (in the form of tariff barriers) imposed by both developing and developed countries, and by export subsidies and domestic support measures of OECD countries (OECD,2010; Aksoy and Ng, 2010). However, with the recent price hikes, agricultural trade regulation has entered a new era of lower domestic price support, lower applied tariffs, and increasingly frequent export restrictions (Anderson and Martin 2011; Huang, et al., 2011; Karapinar 2010). For example, during the 'food crisis' of 2007–2008, dozens of countries imposed various forms of export restrictions on food staples, in order to maintain domestic availability of supplies, which created additional volatility in global markets (FAO, 2008; Anderson and Nelgen, 2012; Headey, 2011; Karapinar, 2011, 2012). The emerging literature on the subjects illustrates that deepening agricultural markets through trade reform and improved market access as well as by investing in additional supply capacity of small-scale farms in developing countries could help reduce market volatility and mitigate supply shortages which might be caused by climate change (UNEP, 2009; WTO, 2009).

9.3.3.2.3. Investment

Climate change may also affect investment patterns in rural areas. On the one hand, countries, regions and sectors that are expected to be affected adversely by climate change may have difficulty attracting investment. On the other hand, ecological zones that will become favourable due to climate change are expected to see increasing inflow of investment. For example the recent price hikes in agricultural commodities have led to new initiatives of foreign direct investment (FDI) in the form of large-scale crop production in poor countries (Anseeuw *et al*., 2012; World Bank, 2010). This type of FDI seems to follow a new pattern whereby capital-endowed countries with high imports of food or feed crops are preparing to invest in large production projects in low-income countries endowed with low-cost labour force, land and water resources. Climate change may lead to similar investment patterns. However, there is a risk that these new investments might not be integrated into local structures and the local populations becoming increasingly vulnerable as they might lose access to vital assets such as land and water (Anseeuw *et al*., 2012). On the other hand, if FDI comes with a basket of new technology, business connections, infrastructure and human capital, and if such investments lead to local business development and employment generation, they could bring substantial benefits to the host country (World Bank, 2010).

Climate change will also lead to investment in clean energy technologies. Investments in renewable energy sources, such as wind and solar, are often located in rural areas which may create employment opportunities for rural areas (second order impact) (del Río and Burguillo, 2008).

9.3.3.2.4. Knowledge

Rural areas, as never before, are exposed to diffusion of knowledge through migration, trade and investment flows, technology transfers, and improved communication and transport facilities (IFAD, 2010). Future impacts of climate change on these channels of integration will affect the pace and intensity of knowledge transfers. For example, increased transport and communication connectivity can reduce disaster risk by providing a greater diversity of livelihood options and improving access to education (Pelling and Mustafa 2010). Similarly, if trade, migration and investment flows will be intensified as a result of climate change, this will inevitably have a positive impact on knowledge transfer to rural areas.

9.3.3.3. Second-Order Impacts of Climate Policy

Climate policies, both for mitigation and adaptation, will have secondary and often unforeseen impacts on rural people.

One example is the possibility of use of GMOs as an adaptive strategy in agriculture. Where GMOs are considered as a plausible strategy for rural areas, choices about biotechnology will play a defining role in shaping the future of rural places. This future might be characterised by increased diferentiation among commodity sectors and between large and small farms, spatial differentiation between GM and non-GM areas, increased economic vulnerability of producers if consumer resistance to GMOs continues, and increasing social tensions between GM and non-GM producers (Cocklin *et al*., 2008). All this will impact rural spaces.

The promotion of biofuel crops as a source of energy in substitution of fossil fuels will also have impacts on rural areas (land-use change) and agriculture. Calls for future policies to support a switch to biofuel production indicate how current concern about climate change will manifest as future landscape change (Dockerty *et al*., 2006). Concerns already expressed about the impact of biofuel production on food security due to increase in food prices, increasing land concentration (and land grabs), and competition for water (Eide, 2008; also Müller *et al*., 2008). Model potential production and implications of a global biofuels industry: estimate production at the end of the century will reach 220-270 exajoules in a reference scenario, and 320-370 exajoules under a global effort to mitigate greenhouse gas emissions. They recognise the need for a high land conversion rate to achieve this (Gurgel *et al.*, 2007). The need to work towards increasing energy supply from renewable resources as responses to climate change,will in time manifest themselves in landscape changes, whether it be through the granting of planning consents for wind farms, the creation of a market for energy crops, structural changes in coastal defences, etc. (Dockerty *et al.*, 2006).

9.3.4. Valuation of Climate Impacts

This section assesses literature on climate change impacts through studies that have adopted various economic methods for valuation of impact. The impacts of climate change are expected to be unequally distributed across the globe, with developing countries at a disadvantage, given their geographical position, low adaptive capacities (Stern, 2007; World Bank, 2010a) and the significance of agriculture and natural resources to the economies and people (World Bank, 2010b; Collier *et al.*, 2008). Both direct and indirect impacts have been projected , such as lower agricultural productivity, increase in prices for major crops and rise in poverty (Hertel *et al.,*2010), which have implications for rural areas and rural communities. This section discusses literature on the valuation of impacts as relevant for rural areas and arising from climate change, with reference to agriculture, fisheries and livestock, water resources, GDP and rural economy, extreme weather events and sea level rise and health. There are various channels through which changes in economic values may occur in rural areas, such as through changes in profitability, crop and land values and loss of livelihoods of specific communities through changes in fisheries and tourism values. Losses and gains in health status and nutrition, and wider economy-wide impacts such as changes in job availability and urbanization also impact economic values that accrue to rural communities, the opportunities and the constraints that rural communities experience and changes that rural landscapes undergo. The impact on availability of fresh water resources is another major area of concern for the developing regions in particular. Climate change can adversely impact poverty through multiple channels (Section 10.9, chapter 10, AR5).

Viewing impacts regionally, despite the ongoing debates around the uncertainty and limitations of valuation studies, scholars generally agree that African countries could experience relatively high losses compared to countries in other regions (World Bank, 2010b; Watkiss *et al.*, 2010; Collier *et al.,* 2008). These conclusions emerge across a range of climate scenarios and models used by researchers. For instance, Watkiss *et al.* (2010) use the FUND model for a business as usual scenario and a mitigation 450ppm 2 degrees scenario as generated by using the PAGE2002 model, while the World Bank uses a range of country specific models for calculating costs. Overall negative consequences are seen for Africa and Asia, due to changes in rainfall patterns and increases in temperature (Müller *et al.*, 2011). Though climate change would impact a range of sectors, water and agriculture are expected to be the two most sensitive to climatic changes in Asia (Cruz *et al.*, 2007, Chapter 3 AR5). In South American countries, higher temperatures and changes in precipitation patterns associated with climate change affect the process of land degradation, compromising extensive agricultural areas in LAC countries. Research on climate change impacts in rural North America has largely focused on the effects on agricultural production and on indigenous population, many of whom rely directly on natural resources. Developed countries in Europe will be less affected than the developing world (Tol *et al.,* 2004), with most of the climate sensitive sectors located in rural areas.

Valuation and costing of climate impacts, draws upon both monetary and non-monetary metrics. Most studies use models that estimate aggregated costs or benefits from impacts to entire economies, or to a few sectors, expressed in relation to a country's gross domestic product (GDP) (Stage, 2010; Watkiss, 2011). Values which are aggregated across sectors generalise across multiple contexts and could mask particular circumstances that could be significant to specific locations, while expressing outcomes in aggregated GDP terms. This is a matter of concern for economies in Africa and Asia, where subsistence production continues to play a key role in rural livelihoods. Valuation of non marketed ecosystem services poses further methodological and empirical concerns (Dasgupta, 2008; Dasgupta et.al, 2009; Watkiss, 2011; Stage, 2010).

Illustrative regional and sub-regional estimates for the value of impacts of climate change are presented here. Estimates for agriculture in most cases relate directly to rural lives. A range of other impacts on which available information exists is also considered, since these values and costs concern significant proportions of livelihoods and assets in rural areas. It is also to be noted that available literature concentrates on certain sectors and a few countries. For instance, research on specific rural populations is less developed than for particular sectors that are largely located in rural spaces such as agriculture. Limited information is available on West Asia and Pacific islands, on health impacts for both Africa and Asia, small and poor communities of the Arctic (Furgal and Seguin 2006, Furgal and Prowse, 2008; Ford and Pearce, 2010).

9.3.4.1. Agriculture

Changes in agricultural production will have corresponding impacts on incomes and wellbeing of rural peoples. The largest known economic impact of climate change is upon agriculture because of the size and sensitivity of the sector, particularly in the developing world. A large number of studies to evaluate the impacts on the agricultural sector and its ramifications for communities have been conducted at various scales, ranging from micro level farm models to large scale regional and country level climate cum socio- economic scenario modeling exercises. Some of these also report values for associated economic losses. Since models are simplifications of complex real world phenomena, different models tend to highlight different aspects of impacts and their consequent economic values. For instance, in estimating economic losses the Ricardian method has been used widely to study climate change impacts in agriculture and inbuilt adaptation. However, often such analysis does not incorporate features like technological progress, relative price changes, agricultural policy and other dynamic characteristics. Similarly on the bio-physical impacts side, changes in the El Niño/Southern Oscillation (ENSO) statistics may also have serious economic implications for the agricultural sector in certain countries such as in Latin America. However, ENSO responses differ strongly across climate models, and at the current stage of understanding do not allow conclusions to be drawn on how global warming will affect the Tropical Pacific climate system (Latif and Keenlyside, 2009). A sample of the available studies is provided in Table 9-4, since it is beyond the scope of the chapter to present the entire literature.

[INSERT TABLE 9-4 HERE
Table 9-4: Illustrative sample of studies on economic value and changes in value from climate change.]

9.3.4.2. Fisheries, Livestock, Mining

Fisheries are significant ecosystems that are vulnerable to climate change impacts and have implications for rural livelihoods and food security (Section 7.3.2.5, Chapter 7, AR5, Allison *et al*., 2009, Section 9.3.3.1 current chapter). Climate change can also have significant impacts on livestock keeping (Section 9.3.3.1 current chapter).

Some relatively less researched areas which may impact the livelihoods of rural communities include mining and ranching. Pearce *et al*. (2011) highlight the current and ongoing vulnerability of mining and mining communities in Canada, often rural and with few other economic activities, to climate change. Current and past infrastructure for mines was built under a no-climate change presumption and economic and ecological vulnerabilities as a result are substantial, and industry actors are unprepared to deal with this. Findings (Franco *et al.,* 2011) reveal significant declines in forage for ranching under all climate scenarios (B1 and A2) considered for California. The dairy sector in California is predicted to lose $287-902 million annually to climate impacts by the end of the century (Lal *et al.,* 2011).

9.3.4.3. Water Resources

The changes in valuation of water resources due to climate change arise from expected impacts on populations dependent on these water resources and these will be felt in several parts of the world (Sections 3.4.9, 3.5 and 3.8, Chapter 3, AR5). While monetary estimates of the losses are few and not generalisable, estimates are available on the number of people that are expected to be adversely impacted in terms of direct access to water resources by communities and also indirectly on food security (Section 9.3.3.1, current chapter).

9.3.4.4. GDP and Economy-Wide Impacts

All the sub regions of Asia-Pacific are expected to become warmer due to climate change. Incidence of extreme weather events is also expected to increase which would reduce the agricultural GDP of all countries in the region especially in South and Southeast Asia (ADB and IFPRI, 2009). In a regional review of economics of climate change in four south East Asian countries of Indonesia, Philippines, Thailand and Vietnam, ADB suggests that climate change would result in a mean annual loss of 2.2% of GDP by 2100 if only market related impact is accounted. If non market impacts related to health and ecosystems are also accounted for, then it would result in 5.7% annual loss of GDP for the same period (ADB, 2009a). Bigano *et al*. (2008) suggest that the predicted 25cm rise in sea level alone would result in a GDP loss of 0.1% in southeast Asia by 2050. Another estimate suggests that four Asian countries of Bangladesh, India, Philippines and Vietnam had a cumulative loss of $20billion due to natural disasters in the last decade, which makes them quite sensitive to climate risks (ADB, 2009 b). In case of Bangladesh, which is extremely vulnerable to climate change because of a large area less than 5 metres above sea level, a single severe cyclone could result in damages worth $9 billion by 2050 accounting for 0.6% of the country's GDP (ibid).) Most of the impacted regions are rural, and coastal. Thus the implied losses in GDP become relevant for the rural communities in these countries.

Coastal and island rural communities throughout North America are less able to afford major infrastructure improvements and will thus be more vulnerable to the effects of sea level rise, including waterborne and food borne diseases, water table salinity, and diminished storm protection from affected reefs and wetlands, but detailed costs are very site-specific (Hess *et al.,* 2008). Cordalis *et al*. (2007) discuss the climate vulnerabilities and policy complexities facing Native American tribes and note that moving villages where needed could cost billions of dollars.

In Arctic Canada and Alaska, infrastructure built for very cold weather will deteriorate as the air and ground warm. Larsen *et al*. (2008) estimate increases in public infrastructure costs of 10-20 percent through 2030 and 10% through 2080 for Alaska, amounting to several billion dollars, much of it to be spent outside of urban centers. The climate models used were part of the IPCC's coordinated AOGCM model inter-comparison project and the underlying model assumptions are based on a middle-of-the-road ''A1B'' emissions and growth scenario defined by the IPCC. Lemmen *et al*. (2007) reports that foundation fixes alone in the largely rural Northwest Territories could cost up to CAN$420 million, and that nearly all of Northern Canada's extensive winter road network, which supplies rural communities and supports extractive industries which bring billions of dollars to the Canadian economy annually, is at risk. Replacing it with all-weather roadways is estimated to cost CAN$85,000/km.

9.3.4.5. Extreme Weather Events, Sea-Level Rise

The main climate change related extreme events that can cause changes in economic values in rural areas include heat waves and droughts, storms, inundation and flooding (Stern 2007; Handmer *et al*., 2012; Section 3.4.9, Chapter 3, AR5). A detailed discussion on the costs of climate extremes and disasters is set out by Handmer *et al*., 2012. Costs can be of two kinds: losses or damage costs and costs of adaptation. While some of the costs lend themselves to monetary valuation (such as infrastructure costs) others cannot be easily estimated such as the value of lives lost and the value of eco system services lost (for discussion on the methodologies for valuing costs refer to Handmer *et al*., 2012: Section 4.5.3).

Damage costs of floods and droughts (Section 10.3.1, chapter 10, AR5) and from rise in water levels in Europe (Swiss Re, 2009a) demonstrate the cost implications for rural communities in the developed regions of the world. Studies mapping the adverse impacts in UK and Europe show a range of sectors that are impacted in rural areas particularly due to drought in Europe and flooding in UK. For instance, major impacts hit farming and forestry with an estimated $15 billion production lost through drought, heat stress and fire (Munich Re 2004), the worst effect being on summer crops in Mediterranean regions (Giannakoupoulos *et al*., 2009). Longer term adaptation could reduce the severity of losses but could include displacement of agricultural and forestry production from Southern Europe to the North. The UK Government's Foresight Programme (2004) estimates that global warming of 3 to 4 ºC could increase flood damage from 0.1% up to 0.4% of GDP. In Europe costs could rise from $10 billion today to $120-150 billion by 2100. With strengthened flood defences these costs may only double. Much of the investment in flood defences and coastal protection would be in rural coastal areas.

Several studies from the developing countries provide evidence on the substantial costs rural communities in particular face in these countries. Salinity and salt water intrusion have implications for rural livelihoods as they impact both fisheries and agriculture (Section 5.5.3, Chapter 5, AR5). Sea level rise also leads to wetland loss and coastal erosion. A few illustrations of the range of impacts of relevance for the rural economy are provided here. Loss of agricultural land and changes in the saline-freshwater interface is estimated to impact the economies of Africa adversely (SEI, 2009, S. Dasgupta *et al.,* 2007). Ahmed *et al*., (2009) suggest that for households, characterized as agricultural self-employed (95% or more income from farm income), climate volatility increases poverty rate in some African countries. They also find that on simulating the effect of climate extremes on poverty in Mexico using the SRES A2 scenario as generated by CMIP3 multi-model dataset, rural poverty increases by 43-52% following a single climate shock. Kronik and Verner (2010) note that some 12% of Mexico's population is indigenous and that these rural subsistence communities are more vulnerable to extreme weather events and often depend on climate-sensitive crops like coffee. Studying extreme events Boyd and Ibarrarán (2009) use a CGE model to simulate the effects of a long drought on the Mexican economy and find declines in production of 10-20% across a variety of agricultural sectors.

9.3.4.6. Recreation and Tourism; Forestry

Studies assessing the changes in economic value of recreation and tourism due to climate change are relatively fewer in number (Coastal tourism is discussed in Section 5.4.4.2, Chapter 5, AR5). While some studies locate an increase in values for certain regions others estimate shifts in tourism and losses (Bigano *et al*., 2007; Hamilton *et al*., 2005; Beniston, 2010), methodological challenges and contrasting findings for the short and long run pose problems in generalizing findings (economic values for recreation and tourism are discussed in Section 10.6, Chapter 10, AR5). Change in economic values will impact rural communities (Lal *et al*., 2011), with the linkages between biodiversity, tourism and rural livelihoods and rural landscapes being an established one both for developing and developed countries (Nyaupane and Poulde 2011, Scott *et al*., 2007, Hein *et al*., 2009).

It has been argued that climate change would have adverse impacts on various ecosystems, including forests and biodiversity in many regions of the world (AR4; Stern, 2007; Eliasch, 2008; Ogawa-Onishi *et al.,* 2010; ADB, 2009a; Tran *et al.,* 2010; Preston *et al*., 2006) and these will have implications for rural livelihoods and economies (Chopra and Dasgupta, 2008; Safranyik and Wilson, 2006; Kurz *et al*., 2008; Walton, 2010). However, monetary valuation of changes in non-marketed ecosystem services due to climate change continue to pose a challenge to researchers.

9.3.4.7. Health

Some studies have looked at the health impacts in various regions of the world, however for the most part these do not by and large distinguish the rural from the urban sector . Studies have examined the linkages between health and climate change terms of the implications for vector-borne and waterborne diseases for Asia and Africa. No comprehensive assessment of climate change effects on health in Africa or Asia has been conducted so far, and there remain considerable gaps in knowledge (Costello *et al*., 2009; Byass, 2009). In general it appears that the region of Africa could be seriously affected if counter measures are not put in place (Byass, 2009; Costello *et al*., 2009; Ebi, 2008; SEI, 2009) and that most climate change related health impacts are in children of rural areas in Sub-Saharan Africa and Asia. As there is a lack of studies which consider rural areas specifically, the interested reader is referred to chapter 11 for current sources of vulnerability (Section 11.3.1, Chapter 11, AR5) and major climate sensitive health outcomes (section 11.2, Chapter 11, AR5). A discussion on the additional costs of treatment due to climate related health outcomes is available in Section 10.8.2, chapter 10, AR5.

9.3.5. Key Vulnerabilities

9.3.5.1. Competing Definitions of Vulnerability

Discussions on climate vulnerability in rural areas is necessarily related to discussion on competing conceptualizations and terminologies of vulnerability, much of which arises from research based on case-studies located in rural areas. Different conceptualizations are important, because the policy prescriptions for rural areas derived from each are different (O'Brien *et al.*, 2007), if not contradictory. Two main type of vulnerability analysis/concepts/approaches exist (O'Brien *et al.*, 2007; Nelson *et al.*, 2010; Füssel, 2007):

- Vulnerability viewed as a combination of exposure to hazards, sensitivity and adaptive capacity (as in the AR4 Glossary), also called end-point or outcome vulnerability. The resulting policy options derived strongly emphasise new technologies as options to reduce vulnerability and enhance adaptive capacity. One important constraint of this approach is that vulnerabilities related to factors such as gender (Nelson *et al*,. 2002) or the status of indigenous people, tend to remain hidden (O'Brien *et al.*, 2009)
- Vulnerability viewed as pre-existing socio-economic factors that make populations vulnerable to extreme events (or climate change more broadly), also called starting-point interpretation or contextual vulnerability, emphasizing climate change interactions with multiple processes of change and thus widening the boundaries of the research. It is assumed that vulnerability arise less from physical sensitivities of the resource base that supports the human system than from the social, economic and political facts that affect how the human system interacts with the resource base. The resulting policy options have a strong focus on diversity and local knowledges (Brondizio and Moran, 2008). This type of assessment has grown in the last few years.

In line with these interpretations, to measure vulnerability both inductive and deductive methods exist (Nelson et al. 2010) and approaches vary from what is called a vulnerability variable, unicriterial or econometric assessment, e.g. centered on examining changes in agricultural yield; or a vulnerability indicator or multicriterial approach, (Gbetibouo *et al.*, 2010). The selection of the type of indicators is also affected by these two approaches, since a number of judgments have to be made when translating the concepts into estimates of vulnerability (Heltberg and Bonch-Osmolovskiy, 2011). For instance, wealth has been widely used to define human vulnerability, but an indicator of equity in income distribution has recently been suggested as a more important factor (Lioubimtseva and Henebry, 2009).

9.3.5.1.1. Vulnerability or resilience

Recent discussions in this field relate to whether studies should be centered in the analysis of vulnerability or resilience. Here again the focus is different, since vulnerability implies a key role for targeted international development assistance in helping the rural poor while resilience research enhances more bottom-up forms of assistance that allow adaptive capacities and flexible governance structures. Resilience research considers that conventional development assistance can exacerbate vulnerability before and after shocks (McSweeney and Coomes, 2011). In that manner, sources of vulnerability at one point in time can be sources of resilience in another.

9.3.5.2. Vulnerability in Rural Areas: Debates

The stresses that climate change hazards will create for rural livelihoods will have two major aspects: reduction of existing livelihood options, and greater volatility and unpredictability in streams of livelihoods benefits, especially in semi arid, mountainous, polar, and coastal ecological environments (Agrawal and Perrin, 2008). It is widely agreed that rural areas are among the most vulnerable to climate changes since two thirds of the world's poor live in rural areas, they lack access to important goods, services (including health (Horton *et al.*, 2010) and education) and information (Casillas and Kammen, 2010), a big proportion of their livelihoods derive from nature-dependent activities. On the other hand, because rural communities have always been exposed to climate risk they are often highly adapted to it (R. Nelson *et al.*, 2010). For instance, *Ruel et al.*, (2009) suggest that the urban poor are disproportionally more vulnerable to recent food, fuel and financial crises, of which climate change is an exacerbating factor.

Vulnerability in rural areas can be aggravated by non-climate factors, such as:

- physical geography, e.g. desert or semi-desert conditions (Lioubimtseva and Henebry, 2009), remoteness (Horton, *et al*., 2010), level of dependence on climate conditions (Brondizio and Moran, 2008));
- economic constraints and poverty (Ahmed *et al*., 2011; Macdonald *et al*., 2009; Mertz *et al*., 2009; Mertz *et al*., 2009);
- gender inequalities (V. Nelson *et al*., 2002);
- social, economic and institutional instability and changes (e.g. urbanization, industrialization, female-headed households, landlessness, short-time policy horizons, low literacy, high share of agriculture in GDP), demographic changes, HIV/AIDS, access and availability of food, density of social networks, memories of past climate variations, knowledge and long-term residence in the region (Macdonald *et al*., 2009; Mougou *et al*., 2011; Ruel *et al*., 2010; Sallu *et al*., 2010; Simelton *et al*., 2009; Mertz *et al*., 2009; Parks and Roberts, 2006; Gbetibouo *et al*., 2010; Ahmed *et al*., 2011; Cooper *et al*., 2008; Brondizio and Moran, 2008)).

These factors can operate at both individual and community levels (Eakin and Wehbe, 2009).

However, the adoption of different approaches in the analysis of vulnerability and the acknowledgment that vulnerability is in many cases an extremely local circumstance, results in contradictory findings with regard to vulnerability in rural areas. For instance, although poverty has always been considered a clear factor increasing vulnerability to climate change, McSweeney and Coomes (2011) found that climate-related disasters can change the structural factors, fostering local capacities for endogenous institutional changes that enhance community resilience, increasing intergenerational equity and long-term ecological sustainability. Also Brouwer *et al*. (2007) found that vulnerability to flooding in Bangladesh in terms of damage suffered was lower for households that fully depended on natural resources than those who did not fully depend on natural resources. Osbahr *et al*. (2008) found that diversification in rural areas does not always reduce vulnerability and can increase inequity in one community if they are not accompanied by reciprocity.

In general, there are low levels of agreement on some of the key factors associated with vulnerability or resilience in rural areas, including rainfed as opposed to irrigated agriculture, small-scale and family-managed farms, and integration into world markets. There is greater agreement on the importance for resilience of access to land and natural resources, flexible local institutions, and knowledge and information, and the association of gender inequalities with vulnerability.

9.3.5.2.1. Irrigation

Past research has tended to agree that rain-fed agriculture is more vulnerable to climate change (Bellon et al. 2011) and that irrigation is needed to decrease that vulnerability (Gbetibouo *et al*., 2010). More recent findings suggest that this is context-dependent and irrigation has been found to increase vulnerability in certain cases (Lioubimtseva and Henebry, 2009; Eakin, 2005). Cooper *et al*. (2008) concluded that in rainfed Sub-Saharan Africa the focus should be on improving productivity of rain-fed agriculture instead of irrigation as irrigation schemes are also being threatened by drought, and Ahmed *et al*. (2011) emphasise the role of drought-tolerant crops.

9.3.5.2.2. Scale of farming systems

Some authors suggest that high reliance on small-scale farming increases the vulnerability of communities in rural areas (Bellon *et al*., 2011; Gbetibouo *et al*., 2010) although it is suggested that their resilience capacity (stemming from factors such as indigenous knowledge, family labour, livelihood diversification) should not be underestimated. On the contrary, Brondizio and Moran (2008) indicate that small farmers are less vulnerable than large, monocropping farmers when climatic variations make an area inappropriate for a particular crop, because they tend to cultivate multiple crops. However, they recognize that small farmers tend to suffer from technological limitations, low access to extension services, and market disadvantages. Mertz *et al.* (2009) suggest that small farmers are highly resilient as they have shown along history facing numerous changes and suggest that the value of local knowledge in climate change studies has received little attention. To Eakin (2005), the shift in support agriculture from subsistence to commercial agriculture suffered in Mexico reduced smallholders resilience for climatic variations.

9.3.5.2.3. Livestock and pastoralism

Although the intersection of climate change with livestock systems and pastoralism has been a relatively neglected research area (Thornton *et al.*, 2009), it is widely recognized that pastoralists face specific constraints that make them particularly vulnerable (Macdonald *et al.*, 2009; Cooper *et al.*, 2008). On one hand, mobility is claimed to be an excellent strategy to reduce vulnerability to certain climate stressors. Jones and Thornton (2009) suggest that in marginal areas of Africa where agriculture is becoming increasingly difficult, livestock may become a future alternative, and to Sallu *et al.* (2010) investment in and accumulation of physical assets, including land and livestock, is a form to decrease vulnerability. Brooks *et al.* (2009) suggest that in semi-arid environments mobile pastoralism could be rehabilitated. According to Lioubimtseva and Henebry (2009) and Fraser *et al.*, (2011) the decline of livestock and traditional practices such as mobility increases vulnerability of people in arid and semiarid regions. On the other hand, a range of social, economic, environmental and political changes threaten the activity or makes it more vulnerable. For instance, the lack of recognition of grazing rights, land privatization (and grabbing) processes, increased rainfall variability, drought and flooding or the perception that pastoralists are backward, are important barriers to this activity (Dougill *et al.*, 2010). Furthermore, the lack of other alternatives in certain marginal areas where animals are the only secure assets can lead to overstocking and overgrazing, and thus, to increase the vulnerability of the pastoral activity (Cooper *et al.*, 2008).

9.3.5.2.4. Development strategies, trade, external market integration

Another point of discussion is the linkages between development trends, market integration and climate change and how they impact vulnerability. In terms of trade, some authors argue that opening markets to international trade increases vulnerabilities of small farmers and poor people. Market integration reduced the capacity of indigenous systems for dealing with climate risk in Bolivia (Valdivia *et al.*, 2010) and Mozambique (Eriksen and Silva, 2009), and shifting towards cash-cropping a narrow range of commodities has favoured dryland degradation in the Sahel (Fraser *et al.*, 2011) and Honduras (McSweeney and Coomes, 2011), by accelerating socioeconomic stratification or focusing incomes in a single crop. Ruel *et al.* (2010) suggest that excessive dependence of cash income increases vulnerability of the urban poor compared with the rural poor, who can have access to other type of assets. On the other hand, Jones and Thorton (2009) estimated that rainfed mix crop/livestock areas in sub-Saharan Africa which are far from large markets have higher poverty rates and thus, conclude they are more vulnerable to climate change. Also Gbetibou *et al.* (2010) proposed increased market participation as a valid measure to reduce vulnerability of vulnerable regions in South Africa as calculated by a vulnerability index.

According to Brooks *et al.* (2009) the dominant development paradigm favoring transitions from tradition to modernization, economic growth and globalization, does not favor action under uncertainty, a point also relevant in agricultural activities (Rivera-Ferre and Ortega-Cerdà, 2011). Climate change is mostly seen as something that *affects* development, tackling environmental considerations onto policies. Brooks *et al.* (2009) suggest the need of new models of development built *around* environmental constraints and opportunities which search for a balance between productivity and resilience. McSweeny and Coomers (2011) suggest development priority should aim at ensuring a favorable context for the emergence of informal networks and endogenous solutions. Enhancement of social networks is also an important element to tackle vulnerability.

Also relevant is the discussion about famine relief as a controversial strategy that increases vulnerability of poor people. Food relief favors sedentarization, which constrains mobile livelihoods and also makes it more difficult for women access resources such as fuelwood and water (V. Nelson *et al.*, 2002). Also, MacDonald *et al.* (2009) state that "the 'food-first' culture that dominates vulnerability assessments and emergency response in most African countries ignores the impact of water insecurity on livelihoods, and the role that water interventions can play in reducing immediate and longer-term vulnerability".

9.3.5.2.5. Access to resources

Lack of access to assets, among which land is an important one, is accepted to be an important factor increasing vulnerability in rural people. The breakdown of traditional land tenure systems increases vulnerability (Fraser *et al.* 2011). Dougill *et al.* (2010) suggest that although land privatization in Bostwana has increased vulnerability of poorer communal pastoralist, it has helped the wealthier farmers, remaining a route to enhance resilience as this private land-owning group has become less vulnerable.

9.3.5.2.6. Vulnerability and institutions

Vulnerability and livelihood security are closely linked to the institutional environment. Institutions can increase (Eakin, 2005) or reduce vulnerability to climate change. For that reason it is important to foster research on the role of local institutions in vulnerability and the way in which local and external institutions can be articulated (Agrawal and Perrin, 2008; Berman *et al.*, 2012). Anderson *et al.* (2010) associate flexible local institutions in dryland societies, primarily for resource management, with resilience to climate change.

9.3.5.2.7. Knowledge and information

Lack of information and knowledge of rural people is suggested as a factor that increases vulnerability, mostly among poor people. What is not so much agreed in the literature is what type of knowledge is best to reduce vulnerability. Valdivia *et al.,* (2010) suggest the need for local responses and indigenous knowledge to reduce vulnerability, while Bellon *et al.*, (2011) state that local knowledge and traditional institutions are too local, and in some contexts gathering information from further away is important. They find that to face the forecasted climatic changes, the geographical area of exchange of seeds should be larger than the one covered by the traditional systems of seed exchange. Access to information is not always a guarantee of success either. Coles and Scott (2009) found that in Arizona, despite ample access to weather forecasting, ranchers did not rely on such information, implying that changes are required to make more attractive information to users.

9.3.5.2.8. Migration

The issue of migration relates to vulnerability in two ways, depending on the context and situations. Vulnerable people tend to migrate, and this is both a coping and adapting strategy, depending on the temporal scale of that migration. The places they leave can reduce the vulnerability if migrants send remittances, or can increase it if the burden of work, usually for women, also increases. Social networks, essential to reduce vulnerability, are also affected reducing the transmission of traditional knowledge (Valdivia *et al.*, 2010). Furthermore, those places receiving migrants change their population pattern which in some cases can also affect their vulnerability, or experience an excessive demographic growth, which increases pressure over scarce resources, as it is being experienced in the semiarid tropics (Cooper *et al.*, 2008). Brondizio and Moran (2008) found that in-migration in the Amazon brought people with knowledge that is ill-adapted to the local environment.

9.3.5.2.9. Gender

Gender issues were a "latecomer" to the climate debate (Denton, 2004), but vulnerability reflects gender-related inequalities that pervade in the developing world (Denton, 2002; Vincent *et al.,* 2010; Nelson and Stathers, 2009). Gender differences in roles, responsibilities and capabilities mean that climate change may actually reinforce disparities between men and women (Vincent *et al.*, 2010). These points are demonstrated by cases from rural

Africa. In the context of climate change-induced conflicts among the Turkana pastoralists of Kenya, women are likely to be more adversely affected than men (Omolo, 2011). Female-headed households in drought-prone rural Zimbabwe are disadvantaged in terms of access to land, access to markets, and access to productive labour (given women's time sharing with reproductive labour), hence more vulnerable than their male-headed counterparts (Huisman, 2005). African women farmers have typically not benefited from government interventions to increase production, such as support for cash cropping and non-farm enterprises – since cash income is seen as a male activity – hence reinforcing their vulnerability (Gladwin *et al*., 2001). Climate change increases vulnerability through male out-migration that increases the work to women; cropping and livestock changes that affect gender division of labor; increased difficulty in accessing resources (fuelwood and water) and increased conflicts over natural resources. Also health impacts increase work for women as carers (V. Nelson *et al*., 2002).

9.4. Adaptation and Managing Risks

9.4.1. Framing Adaptation

Adaptation is required where vulnerabilities are high and projected impacts severe. As the previous sections outlined, rural areas in both developed and developing countries need to adapt to climate change. This process of adaptation, and building capacity to adapt, is a dynamic process and should be linked to other development initiatives aiming for poverty reduction or improvement of rural areas (Nielsen *et al*., 2012; Hassan, 2010; Eriksen and O'Brien, 2007). An analysis in Mali showed that policy support now for agriculture in a changing climate would yield an annual gain of $252million in economic benefits, as opposed to a $161million loss without policy adjustment (Tanveer *et al*., 2006). Likewise in Ethiopia "low regrets" measures to respond to current variability are important to shift the trajectory from disaster-focused to longer-term vulnerability reduction (Conway and Schipper, 2011). Economic and institutional development, improvements in health, education and infrastructure, growing interconnectedness and technology transfers help rural societies develop their human and social capital which allows them to deal with a range of risks including climate change.

Many adaptations build on examples of responses to past variability in resource availability, and it has been suggested that the ability to cope with current climate variability is a prerequisite for adapting to future change (Cooper *et al*., 2008). At the same time, however, it cannot be assumed that past response strategies will be sufficient to deal with the range of projected climate change. In some cases, existing coping strategies may increase vulnerability to future climate change, by prioritising short–term resource availability (O'Brien *et al*., 2008; Adepetu and Berthe, 2007). Evidence of adaptation is found in agriculture, water, biodiversity and fisheries.

Agricultural societies have a history of responding to the impacts of change in exogenous factors, including (but not limited to) weather and climate (Mertz *et al*., 2009). They undertake a range of adjustment measures relating to their farming practices (e.g. planting, harvesting and watering), crop and livestock varieties that they use, investment decisions in relation to infrastructure, technologies and livelihoods, and such examples have been observed in Nigeria and Mali (Adepetu and Berthe, 2007), Burkina Faso (Barbier *et al*., 2009), Ghana (Gyampoh *et al*., 2008), Botswana (Dube and Sekhela, 2007), Ethiopia and South Africa (Bryan *et al*., 2009; Baiphethi *et al*., 2008; Thomas *et al*., 2007). Adaptations are also evident among livestock farmers, who use new varieties of fodder crops suited to the changing conditions (Salema *et al*., 2010), choose their animals based on the prevailing conditions (Kabubo-Mariara, 2009, 2008), or modify grazing patterns, as has been observed in East Africa (Eriksen and Lind, 2009) and southern Africa (O'Farrell *et al*., 2009). Conservation agriculture shows promising results and can be used as an adaptation (Nyala *et al*., 2011) and for sustainable intensification of production (Pretty *et al*., 2011), with significant yield productions observed in South Asia and southern Africa (Erenstein *et al*., 2012). In other cases, the potential effectiveness of adaptation under future climate scenarios has been modeled, for example in Cameroon (Tingem and Rivington, 2009), and for the African continent (Seo, 2011a). Water management for agriculture is also critical in rural areas under climate change, for example the use of rainwater harvesting (Biacin *et al*., 2011; Kahinda *et al*., 2010, Vohland and Barry, 2009), and more efficient irrigation, particularly in rural drylands (Thomas, 2008). Diversified farms are more resilient than specialized ones (Seo, 2010); but rural societies also diversify their income sources beyond agriculture, which allows them to reduce their risk exposure. Examples include the exploitation of gums and resins in Kenya (Gachathi and Eriksen, 2011).There may be some rural areas, however, where limits to agricultural adaptation are reached, and thus the only option that remains is to migrate or diversify away from farming (Mertz *et al*., 2011).

As well as being an important input to agriculture, adaptation in water resources in general is critical in rural areas. Given projected reductions in water availability, improved management is required. This can include demand- and supply-side measures, for example through the use of dams, as has been proposed in the Volta River in Ghana (van de Giesen *et al*., 2010). The extent to which such adaptation measures have been implemented to date varies: in a study from Europe, Africa and Asia, the Elbe and Rhine basins had the highest level of water resource management measures in place, followed by the Orange and Guadiana, with lower levels in the Amu Darya and Nile Equatorial Lakes (Krysanova *et al*., 2010). In the Middle East and North Africa, whilst supply-side measures are advanced, little attention has been paid to the demand-side measures that will be critical in a changing climate (Sowers *et al*., 2010). In the cases of transboundary basins additional barriers exist to adaptive management measures, particularly in Africa (Goulden *et al*., 2009a), although examination of potential institutional designs has been undertaken (Huntjens *et al*., 2012). Where appropriate water management institutions exist and are effective, their role in improving rural livelihoods has been demonstrated, for example in Tanzania’s Great Ruaha basin (Kashaigili *et al*., 2009). The need for effective water management for adaptation therefore exists not only at the basin level, but at a higher resolution, for example in human settlements and towns (Mukheibir, 2008). Some potential for recharge of groundwater as an adaptation measure has also been shown, for example in India (Sukhija, 2008).

Effective management is also essential for adaptation of forests and biodiversity to climate change. As with water resources, forests can adapt through management of forest fires, silvicultural practices, and the conservation of forest genetic resources. In Africa, the systematic analysis of current policies and practices in order to understand the nature and extent of intervention required is often lacking (Fobissie *et al*., 2009). Forest resources can play a role in enabling adaptation during extreme events in Zambia, Mali and Tanzania, although should take place within a managed context to ensure sustainability (Robledo *et al*., 2011). As the climate changes, part of adaptive management may entail modification of existing biodiversity management practices. In addition to land and water management and law and policy, direct species management is important (Mawdsley *et al*., 2009). In terms of managing protected areas, to maintain appropriate habitats a network approach may be effective (Hole *et al*., 2011).

Adaptation in marine ecosystems is also of relevance to rural areas. Bleaching of coral reefs through rising temperatures causes habitat loss which, in turn, affects fisheries. Management through selective use of gear is a recommended management measure, based on 15 global sites (Cinner *et al*., 2009). As with other ecosystems, the extent to which adaptation is required will depend on existing capacity. Of 5 countries in the southwestern Indian Ocean, the environmental sensitivity in Mauritius is offset by the higher adaptive capacity, although the more environmentally-sensitive parts of Madagascar will be priorities for intervention assistance (McClanahan *et al*., 2009).

It is often the case that adaptation measures are implemented to address climate conditions as part of risk management strategies of individuals, societies or governments. Government-provided safety nets lead to adaptive social protection and can be used to scale up to meet unanticipated circumstances, such as those caused by climate hazards (Alderman and Haque, 2006). There are possibilities of using social protection (cash transfers, asset transfers and conditional cash transfers) to manage and reduce the risks of forced displacement resulting from climate change by increasing the threshold for distress migration, as opposed to economic migration that is voluntary (Johnson and Krishnamurthy, forthcoming). According to data from Suriname and French Guiana, when shocks are extreme, irreversible, cumulative and co-variate, as in climate change, public welfare systems complement informal risk-sharing arrangements. Government-provided safety nets reduce climate risks by alleviating poverty, enabling new risk management strategies, and promoting human capital development (Heemskerk *et al*., 2004).

Integration across various types of schemes, such as for drought insurance, microfinance and social protection programmes can prove effective as risk management strategies (Osgood and Warren, 2007; Conway and Schipper, 2011). Index based insurances are largely characterized by pilot schemes of limited areal extent, yet spatial pooling of micro-insurance schemes reduce capital requirements and encourage micro-insurers to cover drought-related losses (Meze-Hausken *et al*., 2009). Index insurance has been trialled in a number of rural locations, including in

Malawi (Hochrainer *et al*., 2009; Osgood *et al*., 2008) and Ghana (Molini *et al*., 2010). Microfinance can improve delivery of adaptation financing to the grassroots, as in the case of Bangladesh and Nepal (Agrawala and Carraro, 2010).

In rural areas worldwide, with agriculture still playing an important role as the main source of livelihood, adaptation and mitigation strategies are often inter-linked, and managing climate change related risks can simultaneously lead to adaptation and mitigation (bearing in mind the greenhouse gas emissions from rural dwellers). Some authors emphasize the role of new energy technologies as mitigation and adaptation strategies within agriculture and forestry, with special relevance in rural areas (Povellato *et al*. 2007). For example, in western Kenya small-scale experiments on agricultural production practices and domestic energy efficiency (the "smokeless kitchen") can mitigate climate change while increasing energy efficiency, health standards, food security, and community-based adaptive capacity (Olsson and Jerneck, 2010).

Social capital, meaning the various networks and links that connect people, have been shown to play a major role in resilience to climate change (as well as other idiosyncratic and covariate risks). In KwaZulu Natal, South Africa, social capital-related failures, such as a breakdown in two-parent families, divergences between religious groups, ambiguous leadership characterised by conflict, and changes in cultural norms have been linked to food insecurity (Misselhorn, 2009). In Mexico, Guatemala and Honduras the existence and development of local networks among farmers, service providers and information sources facilitates adaptation, particularly in the context of economic liberalisation (Eakin *et al*., 2006). That said, there are limits to the role of social capital in bringing about resilience, particularly in the case of covariate shocks which affect a large proportion of the population. The scale of the 2000 Mozambique floods, for example, surpassed the response capacity in Limpopo basin communities not helped by external aid – although supporting local support mechanisms was identified as appropriate to assist recovery (Brouwer and Nhassengo, 2006).

Social capital has also been identified as critical to facilitate adaptation. Farmers' decisions to adopt new crops relates to the adoption choices of farmers in their social network, particularly within a religious network (Bandiera and Rasul, 2006). However, the importance of social capital in facilitating adaptation varies among different groups within the population, depending on their education levels and gender. A study of sunflower adoption in northern Mozambique showed that adoption decisions of farmers with better information are less sensitive to the adoption choices of others (Bandiera and Rasul, 2006). Women typically amass more social capital, and use this to manage livelihood risks, including those from climate, and sometimes are successful in empowering themselves economically (Goulden *et al*., 2009; Vincent *et al*., 2010).

Whilst social capital can be useful in supporting adaptation, it does not provide a panacea, and several cautionary notes have arisen regarding its social differentiation. The sustainability of social capital-related adaptation actions is scale-dependent. Research in Mozambique and South Africa showed that collective action adaptation options can enhance livelihood resilience to climate change but others have negative spillover effects to other scales of analysis – meaning that defining whether or not adaptation is successful is scale-dependent (Osbahr *et al*., 2010). At the same time there is evidence that the political dimensions of social capital are important in influencing adaptation. In Kenya, for example, livelihood adjustments and adaptations are influenced through forming social relations and political alliances to influence collective decision-making. In the face of drought and conflict, rural pastoralists form relations aimed at retaining or strengthening their power, and adaptations tend to mirror existing power relations, hence can reinforce inequality (Eriksen and Lind, 2009).

There are important gender dimensions to adaptation. Social institutions — laws, norms, traditions and codes of conduct - have not only a direct impact on the economic role of women but also an indirect one through women's access to resources like education and health care (Morrison and Juetting, 2004), and are thus essential in promoting adaptation. Computable general equilibrium (CGE) model evidence from Mozambique shows that agricultural technology improvements benefit both men and women within rural households, and technological change in cassava appears to be a particularly strong lever for increasing female and overall household welfare, especially when risk is considered (Arndt and Tarp, 2000). Gender differences in the ability to adapt are also noted in other sectors. Adaptation options such as rainwater harvesting and conservation are not gender-neutral, as they require additional labour which women may not have (Baiphethi et al, 2008). Addressing this requires gender-sensitive analysis of adaptation support, as has been done with water management in the Sister Watersheds project (with Brazilian and Canadian partners), and in Kenya, Mozambique and South Africa (Figueiredo and Perkins, 2012). In Tanzania, public investment in rural infrastructure, in the availability and technically efficient use of inputs, in a good, gender-equal, education system and in the strengthening of social capital, agricultural extension and microcredit services are the best means of improving the adaptation of farmers (Below *et al.*, 2012).

9.4.2. Decision-making for Adaptation

Decision-making for adaptation takes place at a variety of levels, and can be public or private or public. At the national and local levels, law and policies can enable planned adaptation (Stuart-Hill and Schulze, 2010). Proposed adaptation strategies in the water, biodiversity and fisheries sectors above fall within the realm of policies and governance. To improve the robustness of such adaptations, understanding decision-making of rural people is essential (Bryan *et al.*, 2009). For example, in Canada's North, communities use resources from "land and sea" for their nutrition, livelihoods, and cultures (Van Oostdam *et al.*, 2005). Climate change has had a negative impact on health and safety by warming ice in the winter and making it less stable for hunting, fishing, and traveling. Inuit Tapiriit Kantami, Canada's national Inuit organization, has initiated a program with regional Inuit groups and research groups in Canada to document changes in communities and means of adaptation. Similarly the role of indigenous knowledge has been observed in the Sahel (Nyong *et al.*, 2007).

At the local level, many of the agricultural adaptations outlined above are examples of private decisions for adaptation. These agricultural adaptation decisions are embedded in the inter-relationship of a variety of social factors in which climate drivers are only one consideration (Crane *et al.*, 2011). An example of where public policy can support private adaptation is in index-based insurance schemes. In Africa where understanding of insurance is low, participation rates can be improved by using simulation games, as trialed in Ethiopia and Malawi, or by more conventional training methods (Patt *et al.*, 2010). Data from India, Africa and South America shows that the trust that people have in the insurance product and the organisations involved in selling and managing it may be more important than economic factors, such as the size and timing of the premium and potential payouts (Patt *et al.*, 2009). Public policy also has a role to play in supporting gender-sensitive adaptation (Molua, 2009). However, private decisions often take place in the context of national policies and laws, which are not always mutually-supportive (Stringer *et al.*, 2009), especially in the agropastoral sector where settlement is encouraged (Awuor *et al.*, 2011).

One major difference between public and private decision-making is that that latter is typically more responsive. An analysis of agricultural water schemes in South America, for example, found that private irrigation schemes increase in response to a warmer climate, whereas public ones do not, and that they are taken gradually (Seo, 2011b). Participatory stakeholder processes to inform public policy and law can take time. A case study of a resettlement programme in Mozambique showed that farmers and policymakers disagreed about the seriousness of the climate risks, and the potential negative consequences of proposed adaptive measures (Patt and Schroeter, 2008). In Bangladesh, the ambitious national Flood Action Plan (FAP) did not receive support from NGOs, who embarked upon an anti-FAP movement and attained what they perceived to be a more people-oriented national water policy, (Mallick *et al.*, 2005).

9.4.3. Practical Experiences of Adaptation in Rural Areas

There have been a range of measures that facilitate adaption to climate change in rural areas around the world. These include actual and planned adaptation measures to observed and expected changes in mean climate conditions, variability and extreme events.

In Northern China, the negative effects of climate change such as "drought and ecological degradation," are very serious. As an adaptive measure, China moved "winter wheat northwards" and expanded rice crops to increase yields and the quality of wheat-flower. In order to sustain 'Northeast Rice' with limited water availability, policy efforts have been focused on better irrigation systems, water-management, multiple-cropping systems, and watersaving techniques. This case has shown that the combined efforts of "individual farmers, extension staff, technology institutes and governments," in conjunction with financial support, may help farmers in efficiently adapting to climate change (Lin *et al.*, 2005).

In the Mekong Delta in Vietnam, Columbia University's Center for International Earth Science Information Network has projected that a "one-meter sea-level rise could result in the displacement of more than seven million residents in the delta, and a two-meter rise would double to 14 million- or 50 percent of the delta residents." An increase in flood frequency and magnitude has threatened residents' lives and created instability in crop fields. As rapid industrialization has placed stresses on the environment and Vietnam's natural resources, many people in Mekong have adapted by moving east to cities with rapid economic growth. The government's "living with floods" program has encouraged rice farmers to shift to aquaculture, while the planned relocation of 20,000 "landless and poor households" has altered social networks and livelihoods (De Sherbinin *et al.*, 2011).

In Kenya, the dryland areas have experienced over 15 severe droughts since 1950, leading to major losses of crops and livestock. El Nino flooding has "destroyed infrastructure, crops and property," led to "increased animal and plant diseases," and killed many people. Government and development partners view assisting Kenya with both food and seed provision to be a superior approach to simply providing food to households affected by climate change, because it could lead to long-term improvements in resilience and agriculture. The seed fairs successfully provided quality seeds and information to farmers at a lower cost than commercial seeds, and the system is now "used in many areas to provide emergency seed relief in response to both climate-related and social disasters" – in Uganda and Sudan as well as Kenya (Orindi and Ochleng, 2005).

In the highlands of Ethiopia, land management has been unable to meet growing demands for "food, feed, and fiber," as land degradation and soil infertility have negatively impacted yields. An increasing population and exploitative land use have contributed to this problem. Farmers believed that soil erosion in outfields and soil compaction due to livestock trampling were the most significant causes of low crop yield. Researchers tested the effect of zai, or "small water harvesting pits," on crop yield and water retention in the Sahel dryland regions, over the course of three years. Both enlarged zai pits and increased inputs increased yields, water retention, and incomes drastically. Contrary to the conventional belief that nutrient deficiencies are limiting plant growth in this area, this study showed that "low soil water holding capacity" was the major factor preventing plant utilization of nutrients and growth. The zai pits helped make this condition more favorable (Amede *et al.*, 2011).

Over the course of the past decade, floods in Mozambique have displaced hundreds of thousands of people from their homes to temporary shelters, depriving them of their livelihoods, homes, and access to medicine, drinking water, and sanitation. Climate models predict that the north will likely experience increased levels of rainfall while the south will likely experience less, leading to simultaneous drought and floods in Mozambique and leaving the country at the "mercy of increasingly unpredictable weather patterns". After the 2001 floods, the government created an incentive program to permanently resettle, away from areas prone to dangerous flooding, providing construction materials and assistance in return for brick-making. The government resettlement program has led to dependency on the government due to a lack of infrastructure for a self-sustaining economy and the problem of frequent crop-failure. Additionally, experts suggest that even with outside humanitarian assistance, people in Mozambique may need to migrate further and further to the capital of the country or to neighboring countries (De Sherbinin *et al.*, 2011). Another case study in Mozambique showed that informal institutions, forms of livelihood diversification and collective land-use systems that allow reciprocity, flexibility and the ability to buffer shocks help facilitate adaptation in rural areas (Osbahr *et al.*, 2008).

An environmental factor that has often been neglected is wind, which erodes soils and thus leads to a decline in agricultural productivity. In Sebikotane, Senegal, "brutal sea winds" hinder vegetation and erode soil. Hence a new, "third-generation agricultural system," intended to "produce" an environment rather than merely protect or conserve it, was adopted to help adapt to climate change, increase yields, maintain biodiversity, and "improve the lives of women and girls". The system included natural intensification techniques such as diversification, contour cropping, sprinklers, ploughed furrows, and drop irrigation, "producing the right environment" for optimal production and ecosystem health, targeting local markets and export markets with agricultural production, and training the farmers in future generations. The Sebikotane farms have received substantial international funding and have promoted similar farms throughout Senegal (Seck *et al.*, 2005).

Adaptation can also occur on a de-centralized level. In Gutu district in Zimbabwe, 405 individuals addressed the community's problem with water shortages, and with the dryness and degradation of their primary water source, the Mutubuki wetland. The objectives of the project were to better protect and manage the wetland. This goal was pursued by seeking donations and funds from UNDP funding for the National Action programme (NAP) in 1999 to form the Mutubuki Chitenderano Development Association (MCDA) and act to prevent damage from livestock through demarcation and fencing. The MCDA established management, advisory, garden, and electrification committees, built dams for harvesting water to be used for gardening in 2000, attained electricity in the village, and promote "income-generating activities for livelihoods provision" that reflected the livelihood priorities of the community, including well construction, rearing small livestock, millet and sorghum seed (Chigwada, 2005). The central governments also help local communities to develop their local adaptation measures. For example, Zimbabwe "Future Change Agents" are being trained by government institutions to support smallholder communities in adapting their agricultural practices to current climate variability, which is also a step in building adaptive capacity to cope with future climate change at the local level (Twomlow *et al.*, 2008).

Individual farmers also take effective adaptation measures. For example, there is a documented case of a farmer in Burkina Faso, who over the course of 20 years has engaged in the process of adapting to a hotter and drier climate by innovating from existing farming practices. He augmented the practice of "zai," creating shallow pits to collect and concentrate rainfall onto crop roots, by increasing the size of the pits and adding manure to them during the dry season. This led to higher yields and growth of new trees amid his crop rows, which further increased "yields of millet and sorghum [and restored] the degraded soil's vitality," thus providing his family with food security (Hertsgaard, 2011). Scientists refer to the mixture of crops and trees as "farmer-managed natural regeneration," or agro-forestry. The practice of farmer managed natural regeneration or agro forestry benefits agricultural production by providing shade and bulk, which helps mitigate the effects of heat and wind and drastically reduces the amount of sowing required by farmers. Additionally, leaf litter acts as mulch, which increases the fertility of soil, and fodder may be used to feed livestock and, in emergencies, people. This technology and other simple technologies have "enabled more water to infiltrate the soil" and likely contributed to the recharging of once rapidly falling water tables. Additionally, the farmer has sold wood from his trees for cooking, furniture, and construction to diversify his income and used trees as a source for natural medicine. Farmer-managed natural regeneration has since spread throughout the region, mostly through word-of-mouth.

Improvement of the poor's ability to cope with climate change can be independent from institutional intervention or subsidies- it may be endogenous and occur without strong, targeted institutional action. Before Hurricane Mitch, in Honduras, "beans were grown on the terraced meander opposite the community, often in agroforestry systems including cacao, peach palm, and other fruit and timber trees." Almost 40% of each household's average income was from agriculture. After the 1998 hurricane, indigenous and poor communities were hit most severely with flooding and subsequent tropical storms, which caused over 5,000 deaths, and economic distress. The "subsistence base was crippled" and most of the rice, banana and manioc crops were destroyed, leading to hunger and illness. Hurricane Mitch taught cultivators to "avoid the first floodplain terrace," so no agro forests were lost in severe storms that occurred after Mitch. Additionally, the diversification of sources for income that occurred after Mitch ensured that many households still had the resources to cope with crop losses from later storms. Additionally, the new landholding system "removed incentives for speculative clearing of primary forest," thus improving social equity in Honduras (McSweeney, 2002; McSweeney and Coomes, 2011).

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Box 9-2. Drought Adaptation in Rajasthan

Rajasthan in India is located in an arid ecological zone and experiences severe droughts, a condition that communities have learned to cope with through conservative use of natural resources. Ways in which communities have adapted to drought include ending production of crops such as wheat and cotton that require a large amount of water, storing fodder for times of drought and scarcity, using savings or borrowing "from cooperatives and banks" for drinking water well construction, bunding fields, digging and deepening ponds and wells to retain water, growing medicinal plants to contribute to revenue, making compost using earthworms for environmentally friendly fertilizer. With the help of a local NGO, women have also formed a self-help group (SHG) to collect money to lend to the needy during emergencies. Additionally, a government Food-for-Work Programme helps provide communities with wheat, cash, and subsidized fodder (Chatterjee *et al*., 2005).

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Box 9-3. Adaptation to Extreme Events in Jamaica

Extreme weather events and severe droughts have badly affected Jamaica's households, communities, and agriculture since the mid 1990's. These changes will likely contribute to poverty and stunt Jamaica's growth and productivity. The adaptation methods that have already been used by farmers in St. Elizabeth, which is considered the breadbasket of Jamaica, include planting methods such as "quick crops and the scaling down of production during the dry season," when they will mature and be ready for the market during the tourist season. This also enables farmers to generate enough income to invest more during the rainy season to grow primary crops. Thus, farmers try to minimize risk because they are especially vulnerable to the dry season- their success during the rainy season is dependent on production during the dry season. Another adaptive strategy is to plant crops with multiple uses and crops that will be more tolerant to dry spells. In southern St. Elizabeth, a dry area, successful crop production depends on moisture retention, which is increase with practices such as "mulching, edging or perimeter planting, drip irrigation and managing the application of water to plants". During droughts, some farmers will "sacrifice a portion of the crops under cultivation," apply thicker mulching, borrow or share money for water, and using fertilizer on leaves. To recover from drought, farmers "scale down" so that their crops are more manageable and can grow successfully (Campbell, *et al*., 2011).

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Box 9-4. Adaptation Initiatives in the Beverage Crop Sector

One of the leading initiatives to prepare small holder producers of beverage crops for adaptation to climate change is the AdapCC project which worked with coffee and tea producers in Latin America and East Africa (Schepp, 2010). This process used risk and opportunity analysis and participatory capacity building (CafeDirect/GTZ, 2010) to help farmers identify changes in management practices to both mitigate their contribution to climate change and adapt to the changes in climate they perceived to be occurring. In general the actions for adaptation were a reinforcement of principles of sustainable production, such as using tree shade.

The Coffee Under Pressure project of CIAT and Green Mountain Coffee has complemented the models of changes in coffee distribution with models of changes in distribution of 20 other potential crops that may have potential to replace coffee where it will cease to be viable in the future. This has been complemented with detailed studies of the vulnerability of producers in terms of exposition, sensitivity and capacity to adapt to climate change (Baca *et al*., 2010). This indicates that there is a considerable variability in the overall vulnerability to climate change between different communities in the same region and even families within the same community. Facilitating processes of adaptation in this context will be a challenge, but supports the need for participatory community adaptation processes that would enable families to implement strategies appropriate to their own circumstances and capacity.

Policy recommendations to support adaptation in these sectors (Eakin *et al*., 2011; Laderach *et al*., 2011; Schepp, 2010; Schroth *et al*., 2010) have prioritized the follows interventions to support adaptation:

- Community-based analysis of climate risks and opportunities as a basis for community adaptation strategies
- Improved recording and access to climate information including medium and long-term predictions

- Sustainable production techniques including soil and water conservation, shaded production systems, diversification of production systems
- Development of new varieties with broader adaptability to climate variation, higher temperatures and increased drought tolerance
- Financial support to invest in adaptation and reduce risks through climate insurance
- Organization of small producers to improve access to knowledge, financial support and coordinate implementation
- Environmental service payments and access to carbon markets to support sustainable practices
- Development of value chain strategies across all actors to support adaptation and increase resilience across the sectors.

There are possibilities for synergy between adaptation and mitigation. The sustainability standards Rainforest Alliance and Common Code for the Coffee Community are piloting climate-friendly standards for producers that aim to reduce the GHG emissions from agricultural practices, increase sequestration of carbon in soils and trees, but also prepare producers for adapting to climate change (SAN, 2011; Linne, 2010). The later consists of improved understanding of climate impacts and promoting sustainable production practices to increase resilience in the production systems.

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9.4.4. Limits and Constraints to Rural Adaptation

In highly fragile ecologies and vulnerable rural societies that are highly exposed to severe impacts of climate change, adaptation measures may face significant physical, financial, social and cultural barriers and limitations to adaptation. Lack of access to credit and water are two major factors inhibiting adaptation for farmers in Africa and Asia. A multinomial logit analysis of climate adaptation responses suggested that access to water, credit, extension services and off-farm income and employment opportunities, tenure security, farmers' asset base and farming experience are key to enhancing farmers' adaptive capacity (Gbetibouo *et al.*, 2010). A multinomial choice model fitted to data from a cross-sectional survey of over 8000 farms from 11 African countries showed that better access to markets, extension and credit services, technology and farm assets (labour, land and capital) are critical for helping African farmers adapt to climate change. Hence government policies and investment strategies must support education, markets, credit and information about adaptation to climate change, including technological and institutional methods (Hassan and Nhemachena, 2008). Systematic assessment of rural risk and vulnerability and participatory identification of possible solutions can enable the rural poor to get better access to assets and the services they require to overcome the prevailing barriers to adaptation.

Rural households’ lack of access to technologies and markets is also a major barrier to adaptation. According to a study of adoption of improved, high yield maize in Zambia, production and price risks could render input use unprofitable and prevent rural households from benefiting from technological change which is crucial for adaptation (Langyintuo and Mungoma, 2008). The severe 1997 drought in the Central Plateau of Burkina Faso highlighted that household with a larger resources base took the advantage of distress sales and high prices of agricultural commodities (Roncoli *et al.*, 2001). A nationally representative rural household survey in Mozambique from 2005 shows that, overall, using an improved technology (improved maize seeds, improved granaries, tractor mechanization, and animal traction) did not have a statistically significant impact on household income. However when distinguishing between households using improved technologies, especially improved maize seeds and tractors, and those who do not, households who had better market access had significantly higher income (Cunguara and Darnhofer, forthcoming). Social characteristics of households heads and culture both affect access to adaptation options, based on modeled data from the Nile basin of Ethiopia (Deressa *et al.*, 2009) and evidence from Burkina Faso (Nielsen and Reenberg, 2010), respectively.

Although access to credit, water, technologies and markets are barriers, more fundamental is access to information – in terms of projected changes in climate (and weather conditions). Since adaptation strategies involve dealing with uncertainty, whether stakeholders have access to information for decision making and how they perceive and utilize this information affects their adaptation choices (Sheate *et al.*, 2008; Patt and Schröter, 2008; Dockerty *et al.*, 2006). So far the uptake of information has been suboptimal (Vogel and O'Brien, 2006), but the potential for improved prediction and effective timely dissemination has been noted in South Africa (Archer et al, 2007; Klopper et al, 2006) and also in Ethiopia (Bryan et al, 2009). There have been attempts to assess factors influencing uptake and utility of climate forecasts. Agent-based social simulation models show that to be effective in reducing climate risk, trust in forecasts has to be high, and they have be right 60-70% of the time to benefit smallholder farmers (Ziervogel *et al.*, 2005). As well as trust, the effects of user wealth, risk aversion, and presentational parameters, such as the position of forecast parameter categories, and the size of probability categories, on perceived value of seasonal forecasts have been investigated (Millner and Washington, 2011). An assessment of the extent to which climate change scenarios are currently used in developing adaptation strategies within the agricultural development sector in Africa shows that annual climate information (such as seasonal climate forecasts) is used to a certain extent to inform and support some decisions, yet climate change scenarios are rarely used at present in agricultural development (Ziervogel and Zermoglio, 2009). Although, there is a large and growing literature on the role of seasonal forecasts, in particular on the needs of rural end-user groups, e.g. smallholder farmers in a mountainous village in southern Lesotho (Ziervogel, 2004), the optimal use of seasonal forecasts in risk management by smallholder farmers is largely limited by constraints related to legitimacy, salience, access, understanding, capacity to respond and data scarcity (Hansen *et al.*, 2011).

The socio-cultural context of participatory processes in the dissemination and use of seasonal forecasts is important and affects who participates and what they gain (Peterson *et al.*, 2010). Rural producers in three ecological zones of Burkina Faso were statistically more likely to understand the probabilistic aspect of the forecasts and their limitations, to use the information in making management decisions and through a wider range of responses than those who had not been part of the participatory processes (Roncoli *et al.*, 2009). Evidence from Malawi shows that forests can be important in reactive coping by providing food during shortages and a source of cash for coping with weather-related crop failure – but households most reliant on forests have low income per person, are located close to the forest, and are headed by individuals who are older, more risk averse, and less educated than their cohorts (Fisher *et al.*, 2010). Gender differences have been observed in preferred dissemination channels in Limpopo province, South Africa, which highlighted that women preferred to hear the forecast from an extension worker, whilst men preferred to hear it on the radio (Archer, 2003). Debates over forecast skill and farmer skill are also common to other parts of the world such as the USA, where interviews with farmers in Georgia showed that the social nature of information processing and risk management bears upon the ways farmers may integrate climate predictions into their agricultural management practices (Crane *et al.*, 2010).

Stakeholder networks have been used to map forecast dissemination in Lesotho, and are useful for identifying obstacles (Ziervogel and Downing, 2004). There are promising signs for the integration of scientific-based seasonal forecasts with indigenous knowledge systems (Ziervogel *et al.*, 2010). Ensuring improved validity and utility of seasonal forecasts will require collaboration of researchers, data providers, policy developers and extension workers (Coe and Stern, 2011), as well as with end users. Additional opportunities to benefit rural communities come from expanding the use of seasonal forecast information for coordinating input and credit supply, food crisis management, trade and agricultural insurance (Hansen *et al.*, 2011). Attempts to use longer term crop forecasting options based on large-area seasonal crop yield forecasting and, genotypic adaptation based on long-term climate change projections have also been examined (Challinor, 2009). Climate forecasting has also been applied to ecosystem models for use in livestock farming (Boone *et al.*, 2004).

9.5. Key Conclusions and Research Gaps

9.5.1. Key Conclusions

There is a lack of clear definition of what constitutes rural areas, and definitions that do exist depend on definitions of the urban. Across the world, the importance of peri-urban areas and new forms of rural-urban interactions are increasing. Notwithstanding this, rural areas still account for almost half the world's population, about 75% of the developing world's poor people and 80% of the world's hungry. Rural areas therefore are important for assessing the impacts of climate change and the prospects of adaptation in these areas, constituting a dynamic, spatial category. A lack of focus on the rural sector in policy making increases its vulnerability to climate change.

Climate change in rural areas in developing countries will take place in the context of many important economic, social and land-use trends. In different regions, rural populations have peaked or will peak in the next few decades. The proportion of the rural population depending on agriculture is extremely varied across regions, but declining everywhere. Poverty rates in rural areas are falling more sharply than overall poverty rates, and proportions of the total poor accounted for by rural people are also falling: in both cases with the exception of sub-Saharan Africa, where these rates are rising. Hunger and malnutrition is prevalent among rural children in South Asia and Sub-Saharan Africa. Processes of commercialisation and diversification in developing countries, and inter linkages between land tenure and food policy are important drivers. Rural people are subject to multiple non-climate stressors, including under-investment in agriculture (though there are signs this is improving), problems with land policy, and processes of environmental degradation. In industrialized countries, there are important shifts towards multiple uses of rural areas, especially leisure uses, and new rural policies based on the collaboration of multiple stakeholders, the targeting of multiple sectors and a change from subsidy-based to investment-based policy.

Cases in the literature of observed impacts on rural areas often suffer from methodological problems of attribution, but evidence for observed impacts, both of extreme events and other categories, is increasing. Heat waves and droughts can cause severe impacts while saline intrusion, storm surges, and other coastal climatic events can affect rural livelihood systems. Climate volatility can increase poverty in developing countries.

Future impacts of climate change on the rural economic base and livelihoods, land-use and regional interconnections are at the latter stages of complex causal chains that flow through changing patterns of extreme events and/or effects of climate change on biophysical processes in agriculture and less-managed ecosystems. This increases the uncertainty associated with any particular projected impact.

Major impacts of climate change in rural areas will be felt through impacts on water supply, food security and agricultural incomes. Migration patterns will be driven by multiple factors of which climate change is only one, and projections of migration can only be tentative. There will be secondary impacts of climate policy, such as policies to encourage cultivation of biofuels. In certain countries shifts in agricultural production may be seen. Price rises, which may be induced by climate shocks apart from other factors, have a disproportionate impact on the welfare of the poor in rural areas, such as female headed households and those with limited access to modern agricultural inputs, infrastructure and education.

Valuation of climate impacts needs to draw upon both monetary and non-monetary indicators. Most studies on valuation highlight that climate change impacts will be significant especially for the developing regions, due to their economic dependence on agriculture and natural resources, low adaptive capacities, and geographical locations. The valuation of non-marketed ecosystem services and the limitations of economic valuation models which aggregate across multiple contexts pose challenges for valuing impacts in rural areas.

There are low levels of agreement on some of the key factors associated with vulnerability or resilience in rural areas, including rainfed as opposed to irrigated agriculture, small-scale and family-managed farms, and integration into world markets. There is greater agreement on the importance for resilience of access to land and natural resources, flexible local institutions, and knowledge and information, and the association of gender inequalities with vulnerability.

There is a growing body of literature on successful adaptation in rural areas, including both documentation of practical experience, and discussion of preconditions. Prevailing development constraints, such as low levels of educational attainment, environmental degradation and armed conflict create additional vulnerabilities which undermine rural societies' ability to cope with climate risks. The supply of information for decision-making, and the role of social capital in building resilience, are key issues.

9.5.2. Research Gaps

Research on climate change in rural areas, which truly takes in their nature as areas with shifting combinations of human activity, in which agriculture is important but not necessarily predominant, and with changing patterns of interaction with towns, is only just beginning. Such research will need to be developed, and extended to rural areas throughout the world.

Research is required on the valuation and costing of climate change impacts which take note of the complexity and specificity of rural areas, with special emphasis on non-marketed ecosystem services and specific populations that have not as yet been studied.

More research is needed on vulnerability, to identify the most vulnerable areas, populations and social categories, but it should include research on methodological questions such as conceptualizations of vulnerability, assessment tools, spatial scales for analysis, and the relations between short-term support for adaptation, policy contexts and development trajectories, and long-term resilience or vulnerability.

Research is needed on practical adaptation options, not only for agriculture but for non-agricultural livelihoods. Adaptation research must also look at adaptations to institutions, to better enable them to address lack of access to credit, markets, information, risk-sharing tools and property rights. Research into vulnerability, resilience and adaptation must all improve ways to integrate local and scientific knowledge.

Frequently Asked Questions

FAQ 0.1: Why are rural areas important in the study of climate change impacts, assessments and vulnerability?
Outline response:
- Importance of rural areas in extent, population, proportion of the world's poor, and pre-existing vulnerabilities
- *Relative* dependence on agriculture and natural resources
- Need to look at impacts on rural areas beyond impacts on agriculture.

FAQ 9.2: What are the differences and similarities relevant to climate change between rural areas in developed and developing countries?
Outline response:
- Major differences: in developing countries rural areas are more sharply characterised by poverty, isolation and low human development. Less the case in developed countries where they are increasingly characterised by close linkages to towns, commuting, and by recreation activities
- *Relative* dependence on agriculture and natural resources is a common factor, and this characterises many of the most important impacts
- In both regions rural areas are increasingly diverse (serving functions beyond agriculture) and that diversity is increasingly recognised
- Distance and marginality are also common factors, which inhibit adaptive capacity

FAQ 9.3: What will be the major categories of climate change impact on rural areas across the world?
Outline response:
Impacts will be experienced through:
- impacts on natural resource-dependent sectors, e.g. agriculture, forestry and fishing – and the livelihoods and incomes that are based on them (both through changing climate means and changing variability);
- impacts on less-managed ecosystems;
- impacts of extreme events on infrastructure and housing;
- as secondary impacts of climate policies;
- and also directly on human health

FAQ 9.4: What are or will be the major forms of adaptation in rural areas?

Outline response:

- Will depend on identifying the relevant risks, and then determining the most appropriate adaptation responses
- For livelihoods and incomes: adaptations to the projected changes in resource availability (altered farming and forestry systems and practices)
- Migration
- Modifications to infrastructure

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Table 9-1: Major demographic, poverty-related, economic, governance, and environmental trends in rural areas of developed and developing countries.

	Developed countries	**Developing countries**
Demographic Trends	Rural areas account for 75% of land area and 25% of population in OECD countries (OECD 2006). Rural population has peaked (absolute numbers) in Europe and North America. Rural depopulation in some places, but some counter-urbanization elsewhere.	Rural population has already peaked in Latin America and Caribbean, East and South East Asia; expected to peak around 2025 in Middle East, North Africa, South and Central Asia; around 2045 in sub-Saharan Africa. Despite declining growth rates, rural population still a majority in all sub-regions of Asia (72% in South Asia) and 60-70% in Africa (although proportions vary regionally). (IFAD, 2010; World Bank, 2007; and see Figure 9-1)
Dependence on agriculture	Agriculture accounts for only 13% of rural employment in the EU (2006), and less than 10% on average across developed countries; however, has a strong indirect influence on rural economies. Increased competition as a result of economic globalization has resulted in agriculture no longer being the main pillar of the rural economy in Europe. Economic policies are primary drivers. (Marsden, 1999, Lopez-Gelats, 2009) Climate change not expected to cause drastic decrease in agricultural land availability in EU (Mijl *et al.*, 2006).	Proportion of rural population engaged in agriculture declining in all regions: currently 14% in South America, 23% in Middle East, 71% in Eastern Africa. Driven by growth of small manufacturing and tourism, commuting to towns, dependence on pensions and remittances. Agriculture still provides jobs for 1.3 billion smallholders and landless workers (World Bank, 2008). Non-agricultural including labour-based and migration-based livelihoods increasingly existing alongside (and complementing) farm-based livelihoods. Agricultural initiatives and growth still important for adaptation and for small holders in Africa and Asia; (Osbahr *et al*. 2008; Collier *et al*. 2008; Kotir, 2010; Ravallion and Dutt, 1996; Rao, 2005)
Poverty and Inequality	Per capita GDP in rural areas of OECD countries is only 83% of national average (but significant variation within and between countries): driven by out-migration, aging, lower educational attainment, lower productivity of labour, low levels of public services.	Rates of poverty (percentage of population living on less than US $ 2/day) and extreme poverty (percentage of population living on less than US $ 1.25/day) falling in rural areas in most parts of the world; but rural poverty and rural extreme poverty rising in sub-Saharan Africa. Hunger and malnutrition prevalent among rural children in South Asia and Sub-Saharan Africa (UN, 2010; IFAD, 2010; World Bank, 2007). See Figure 9-2 and Table 9-2.
Economic, Policy, Governance Trends	Shift from agricultural (production) to leisure (consumption) activities; focus on broader amenity values of rural landscapes for recreation, tourism, and forests, ecosystem services. (Bunce, 2008; OECD, 2006;	Structural adjustment and economic liberalisation have encouraged shift to commercial agriculture and diversification (Bryceson, 2002). Interlinkages between land tenure, food

	Rounsevell *et. al.,* 2007) Agricultural subsidies under pressure from international trade negotiations and domestic budgetary constraints. 'New rural paradigm' in OECD countries focuses on investments rather than subsidies, and targets a range of rural economic sectors. Policy and economic changes more important factors than climatic change in shaping rural areas (Audsley *et al.,* 2006)	security and biofuel policies impact rural poverty (see Chapter 7, section 7.1 and 7.3.2 for further details) Climate, food and fuel prices, environmental resources and diseases create adverse conditions for specific communities (O'Brien *et al*., 2009; Casale *et al*., 2010; Bunce *et al.,* 2009) Decentralization of governance in South Asia. Movements towards land reform in some parts of Asia (Kumar, 2010). Emergence of economies in transition, characterised in places by co-existence of leading and lagging regions; political and democratic decentralization expanding leading to increasing complexity of policy (World Bank, 2007).
Environmental Degradation	Different socio-economic scenarios have varying impacts on land use and agricultural biodiversity (Reidsma *et al.,* 2006).	Resource degradation, environmentally fragile lands subject to overuse and population pressures, exacerbate social and environmental challenges. Multiple stressors increase risk, reduce resilience and exacerbate vulnerability among rural communities from extreme events and climate change impacts (See Chapter 13, Section 13.2.6 for further details).
Rural-Urban Linkages and Transformations	Changes in land-use and land-cover patterns at urban-rural fringe affected by new residential development, local government planning decisions, and environmental regulations (Brown *et al*., 2008).	Significant share of manufacturing activities take place in rural areas. Significant share of non-agricultural activities, except in Middle East. Rural-urban migrants tend to be in working age cohort, therefore reducing size of rural workforce, and migration is adopted for escaping poverty (Brown *et al*., 2008). Conventional rural to urban migration, except in some cases such as Caribbean where international migrants return to rural areas (Potter., 2005).

Table 9-2: Poverty indicators for rural areas of developing countries.

	Incidence of poverty (%)		Incidence of rural poverty (%)		Incidence of extreme poverty (%)		Incidence of extreme rural poverty (%)		Rural people as % of those in extreme poverty	
	1988	2008	1988	2008	1988	2008	1988	2008	1988	2008
Developing World	69.1	51.2	83.2	80.9	45.1	27.0	54.0	34.2	80.5	71.6

Source: adapted from IFAD, 2010

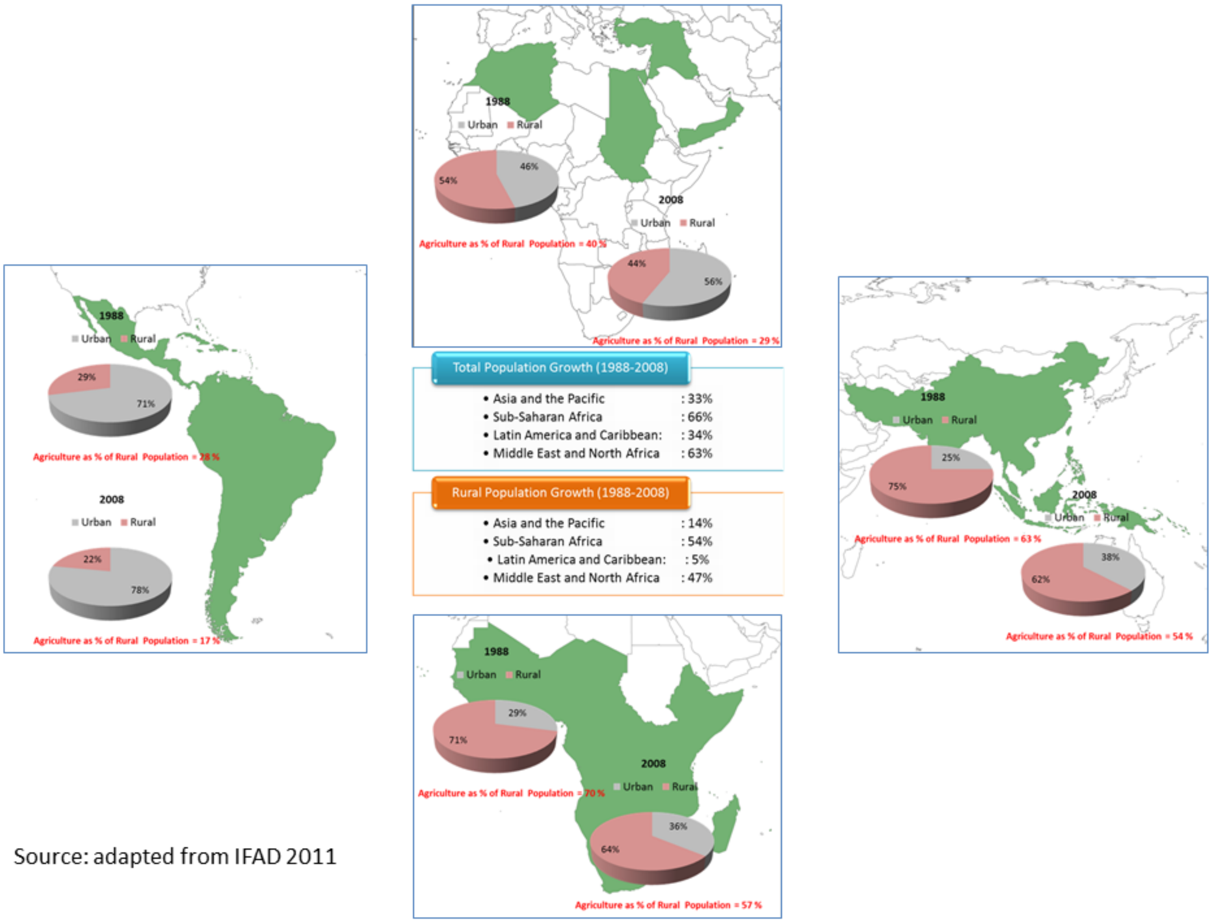
Table 9-3: Projected changes in areas suitable for production of tropical beverage crops by 2050.

Crop	Countries	Change in total area by 2050	Change in distribution by 2050
Coffee	Guatemala, Costa Rica, Nicaragua, El Salvador, Honduras, Mexico	Between 38 and 89% decline in area suitable for production	Minimum altitude suitable for production rises from 600 to 1000 m.a.s.l.
	Kenya	Substantial decline in suitability of western highlands, some decline in area optimal for production in eastern highlands	Minimum altitude for production rise from 1000 to 1400 m.a.sl.
Tea	Kenya	Majority of western highlands loose suitability, while looses are compensated by gains at higher altitude in eastern highlands	Optimum altitude for production change from 1500-2100 m.a.s.l. to 2000-2300 m.a.s.l.
	Uganda	Considerable reduction in suitability for production across all areas	Optimal altitude change from 1450-1650 m.a.s.l. to 1550-1650 m.a.s.l.
Cocoa	Ghana, Ivory Coast	Considerable reduction in area suitable for production; almost total elimination in Ivory Coast	Optimal altitude changes from 100-250 m.a.s.l. to 450-500 m.a.s.l.

Sources: CIAT, 2010; CIAT, 2011b; CIAT, 2011c; Laderach *et al.*, 2010

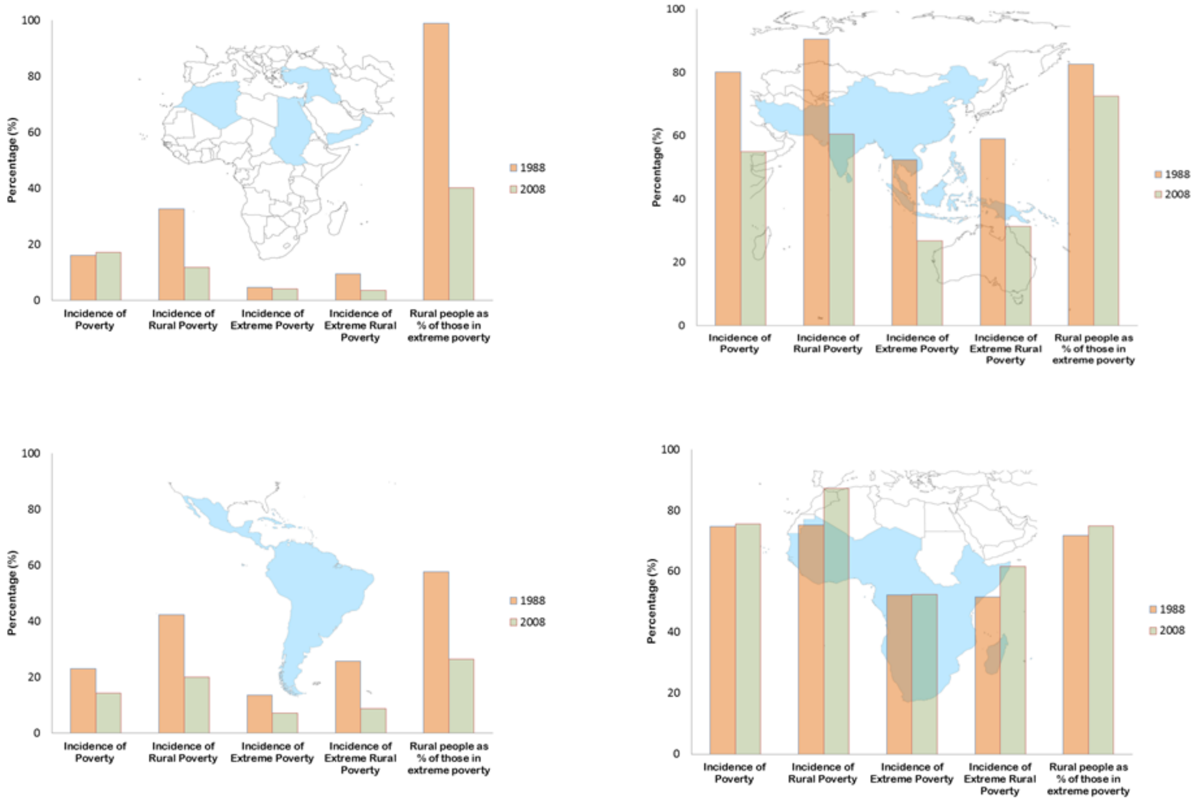
Table 9-4: Illustrative sample of studies on economic value and changes in value from climate change.

Study : Author /s	Country / Region	Findings and Estimates
Vaghefi *et al*., 2011	Malaysia (2 degrees C rise in temperature)	Annual economic loss in rice production: $ 54.17 million
Zhai and Zhuang, 2009	South East Asian countries : Thailand, Vietnam, Philippines	GDP reduction from loss of agricultural productivity by 2080: 1.7-2.4%
Guiteras, 2007	India	GDP reduction from agricultural losses: 1-1.8% Consumption reduction for poor: 18%
ADB and IFPRI, 2009	Asia	Annually spending for coping with adverse agricultural impacts between 2010-2050: $4.2 - $ 5 billion
Mendelsohn *et al*., 2010	Mexico	Decline in farmland values for each degree of warming: 4-6000 pesos
Mendelsohn *et al*., 2007	U.S. A. (10% average increase in temperature)	Fall in crop land values for rural communities: 13%
Mendelsohn and Reinsborough, 2007	Canada (increasing precipitation) U.S.A. (increasing temperature)	Mixed effects with some improved profits Adverse impacts on farming
Wittrock *et al*., 2011	Canada (Canadian Global Model 2)	Crop losses under drought: CAN$ 7-171 per hectare
Franco *et al*., 2011	California (B1 – low emissions and A2 – medium emissions scenarios)	Annual Agricultural losses upto $3billion Flooding increases losses
World Bank, 2010a	Mozambique (Dynamic CGE model)	Damages to agriculture, hydropower and infrastructure (including coastal areas) by 2050: $7.6 billion
Mideksa, 2010	Ethiopia (Cline, CGCM2 and PCM)	Decline in GDP from agriculture and linked sectors: 10% from benchmark levels
Dinar *et al*., 2008	11 African countries (Ricardian analysis; various climate scenarios)	By 2100: Total losses of $48.2 billion to gains of $ 90 billion In 2020 for 1.6% warmer and 3.7% dryer climate: net farm revenues decline by upto 25%
Nelson *et al*., 2009	Africa (A2 scenario; CSIRO and NCAR models)	Food security impacts Decline in calore consumption per capita per day by: 500 calories
Schlenker and Roberts, 2010	Africa (A1B scenario; WCRP CMIP3)	Losses for crops except Cassava: likelihood of 95% that losses exceed 7% 5% probability that losses exceed 27%
ECLAC, 2010a, b	Guatemala, Belize, Costa Rica, Honduras (SRES A2 and B2; Regional climate models)	Losses in gross value of production upto 25% (Guatemala, followed by other countries)
Seo and Mendelsohn, 2008	South America (SRES A1; Canadian Climate Centre)	Loss in incomes of farmers by: 2020: 14% 2060: 20%
Sanghi and Mendelsohn, 2008	Brazil (Climate predictions from 14 GCMs)	Annual damages between: 1 – 39%
Fallon and Betts, 2010	Southern Europe (2 degrees C rise in temperature)	Increased costs of agricultural production
Olesena *et al*., 2011	Hungary, Serbia, Bulgaria, Romania	Negative impacts for crops in continental climatic zone



Source: adapted from IFAD 2011

Figure 9-1: Key demographic indicators in rural areas of developing countries.



Source: adapted from IFAD 2011

Figure 9-2: Poverty indicators for rural areas of developing countries, by region.