Chapter 9. Rural Areas

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Executive Summary

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] 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] However, rural areas, seen as a dynamic, spatial category remain important for assessing the impacts of climate change and the prospects of adaptation. [9.1.1] A lack of focus on rural areas in policy making increases their vulnerability to climate change. [9.2]

Climate change in rural areas will take place in the context of many important economic, social and land-use trends *(very high confidence)*. 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.

Rural people in developing countries 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 *(high to very high confidence)*. Hunger and malnutrition remain prevalent among rural children in South Asia and Sub-Saharan Africa. In developing countries,the levels and distribution of rural policies are affected in complex and interacting ways by processes of commercialisation and diversification, food policies, and policies on land tenure. 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]

Prevailing development constraints, such as low levels of educational attainment, environmental degradation and gender inequality create additional vulnerabilities to climate change [9.4.4] *(high confidence)*. 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]. Specific livelihood niches such as pastoralism, mountain farming systems, and artisanal fisheries are vulnerable and at high risk of adverse impacts *(medium to high confidence),* partly due to neglect, misunderstanding or inappropriate policy towards them on the part of governments.

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. [9.3.2] *(medium confidence).* Impacts attributable to climate change include declining yields of major crops, extreme events such as droughts and storms, and geographically-specific impacts such as glacier melt in the Andes.

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 *(high confidence).* These 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] *(high confidence).* In certain countries shifts in agricultural production, of food and non-food crops, could take place. [9.3.3.1] Price rises, which may be induced by climate shocks apart from other factors [9.3.3.3.2], 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]

Climate change will lead to higher prices and increased volatility in agricultural markets, which might undermine global food supply security while affecting rural households depending on whether they are net-buyers or net-sellers of food. [9.3.3.3] (*medium to high confidence).* There is medium level agreement that deepening agricultural markets through trade reform and institutional efforts to improve the predictability and the reliability of the world trading system as well as by investing in additional supply capacity of small-scale farms in developing countries could help reduce market volatility and manage food supply shortages which might be caused by climate change [9.3.3.3.2]

Migration patterns will be driven by multiple factors of which climate change is only one [9.3.3.3.1] *(high confidence).*Given these multiple drivers of migration and the complex interactions which mediate migratory decision-making by individual or households, the detection of the effects of climate change on intra-rural and rural-to-urban migration remains a major challenge.

Climate policies, such as encouraging cultivation of biofuels, and payments under REDD, will have significant secondary impacts on land-use, and resulting negative impact on livelihoods, in some rural areas. [9.3.3.4] *(medium confidence).* These secondary impacts, and trade-offs between mitigation and adaptation in rural areas, have implications for governance.

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] *(high confidence).* Valuation of climate impacts needs to draw upon both monetary and non-monetary indicators. 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 is a growing body of literature on successful adaptation in rural areas, including documentation of practical experience [9.4.3]. Gender, the supply of information for decision-making, and the role of social capital in building resilience, are all key issues. [9.4.1] Constraints to adaptation come from lack of access to credit, land, water, technology, markets and information; and are particularly pronounced in developing countries. [9.4.4] *(high confidence)*

9.1. Introduction

9.1.1. Rationale for the Chapter

Rural areas, even after significant demographic shifts, still account for 3.3 billion people or almost half (47.9%) of the world's total population (UN-DESA Population Division 2012). The proportion of people in developing countries living in rural areas is higher than the global average, with 71.5% of the population (or about 608 million people) living in rural areas in the least developed countries, and 50.3% of the population (or about 2.5 billion people) living in rural areas in other less developed countries (excluding LDCs), – compared to only 22.3% of the population (or about 276 million people) in more developed countries.

The overwhelming majority of the world's rural population (3.1 billion people, or 91.7% of the world's rural population, or 44.0% of the world's total population) live in rural areas in less developed or least developed countries. Rural dwellers 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). At the same time, changes in land-use and livelihoods in rural areas make it less straightforward to link rural areas with agriculture or food production. Given the association of climate vulnerability with poverty and food insecurity, and the number of people living in rural areas in developing countries, these areas are significant sites for vulnerability to climate change. Much of the literature reviewed in this chapter therefore reflects these conditions, in which rural development issues (especially in developing countries) are closely intertwined with the physical impacts of climate change and the vulnerability of rural populations.

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" assesses 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. Adaptation strategies will need to address these vulnerabilities.

The chapter will complement the treatment of 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 (and in this regard will complement sections of Chapter 12 "Human Security"). 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. It will also draw out rural implications of climate change in different regions as covered in chapters 23-29.

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, in a process of definition that is often fraught with difficulties (IFAD 2010). 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). 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). The variations in definitions from country-to-country can best be described through several examples (from both developed and developing countries of different sizes):

- In Australia, "major urban areas" are defined as having a population of 100,000 and over; while "other urban areas" have a population of 1,000 to 99,999. "Rural areas" included small towns with a population of 200 to 999. (Australian Bureau of Statistics n.d.).
- In India, urban areas are defined essentially as those with populations of 5,000 or more, or where at least 75% of the male working population is non-agricultural, or having a density of population of at least 400 people per km^2 (Government of India, 2012).
- In Jamaica, a place is considered to be urban if it has a population of more than 2,000 people and provides a certain set of amenities and facilities that are deemed to indicate "modern living" (Statistical Institute of Jamaica, 2012).
- In the United States, rural areas are defined by the Bureau of the Census as consisting of all territory outside of 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).

Definitions of the rural are therefore variable between countries, recognized as problematic, and 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). One approach to reconciling this is through the increasing application of the concept of "peri-urban areas" (Simon *et al.*, 2006; Simon, 2008). These areas can be seen as rural locations that have "become more urban in character" (Webster 2002: 5); as sites where households pursue a wider range of income-generating activities while still residing in what appear to be "largely rural landscapes" (Learner and Eakin 2010: 1); or as locations in which rural and urban land uses coexist, whether in contiguous or fragmented units (Bowyer-Bower, 2006). A more elaborate conceptualization is offered by the Bahasa Indonesian term *desakota*, which is used in academic literature to incorporate arecognition of the diversified economic systems that exist across the urban-rural spectrum, and the closely interlinked, co-penetrating rural/urban livelihoods, communication, transport and economic systems (Desakota Study Team 2008; McGee 1991; Moench and Gyawali 2008).

Peri-urban or *desakota* systems therefore incorporate a change in the type of relationships between human society and ecosystems, and create shifts in the geographical and social distribution of risk and vulnerability (Pelling and Mustafa, 2010). The characteristics of these 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). Increased transport connectivity in peri-urban areas 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 strengthen adaptive capacity through providing new livelihood opportunities – 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).

While there have been some assessments of "land degradation" and "sustainability" in peri-urban areas (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. However, 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.

9.2. Findings of Recent Assessments

Table 9-1 summarises key findings on rural areas from AR4 (particularly Easterling *et al.*, 2007 on agriculture, Wilbanks *et al.*, 2007 on industry, settlement and society, and Klein *et al.* 2007 on links between adaptation and mitigation), and relevant findings from the International Assessment of Agricultural Knowledge, Science and Technology for Development (McIntyre, 2009). All these sources stress uncertainty, the importance of non-climate trends, complexity and context-specificity, in any findings on rural areas and climate change.

[INSERT TABLE 9-1 HERE
Table 9-1: Major findings of the IPCC Fourth Assessment Report and the International Assessment of Agricultural Science and Technology for Development.]

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 9-2 summarizes and compares the most important trends across the two groups of countries. Figure 9-1, Table 9-3, and Figure 9-2 focus on two specific trends in developing countries: demographic trends and trends in poverty indicators.

[INSERT TABLE 9-2 HERE
Table 9-2: 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: Trends in rural (red), urban (purple), and total (green) populations by region. Solid lines represent observed values and dotted lines represent projections. Source: United Nations, Department of Economic and Social Affairs/Population Division (2012).]

[INSERT TABLE 9-3 HERE
Table 9-3: Poverty indicators for rural areas of developing countries.]

[INSERT FIGURE 9-2 HERE
Figure 9-2: Demographic and poverty indicators for rural areas of developing countries, by region. R: percentage of rural population; A/R: agriculture as percentage of rural; P: incidence of poverty; RP: incidence of rural poverty; EP: incidence of extreme poverty; ERP: incidence of extreme rural poverty; R/EP : rural as percentage of those in extreme poverty. Source: Adapted from IFAD (2011).]

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 anthropogenic 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 anthropogenic climate change (see Paavola, 2008 as an example). Exposure to non-climate trends and shocks further complicate the issue (Nielsen and Reenberg, 2010). Warner and van der Geest (submitted), use the UNFCC terminology of "loss and damage" for evidence of observed impacts of changes in monsoon patterns, drought, flooding, coastal erosion and saline intrusion on rural livelihoods in nine countries in Africa, Asia and the Pacific, but specify that the research methods employed do not allow attribution of climatic stressors to underlying causes such as anthropogenic climate change. Box 18-4 of this report discusses the considerable potential of using Traditional Ecological Knowledge to detect climate trends, but also the difficulties of using it to attribute trends to anthropogenic climate change. 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 becomes more problematic if such work is implied to be 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 and cause direct loss of life. 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, or from changes in mean conditions. The detection and attribution of extreme events is discussed by 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). 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.

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 during the late 20th century, 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) since 1950. They note that opposite trends exist elsewhere, and that there is *low confidence* in any trend in drought in, for example, East Africa, although other authors, such as Lyon and DeWitt (2012) see a "recent and abrupt decline in the East African long rains" since 1999. Seneviratne *et al*. (2012) 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).

Handmer *et al*., (2012) discuss both observed and projected impacts of extreme events on human systems and ecosystems. Numerous examples are given of observed impacts of extreme events – especially heatwaves, droughts and floods – on water, ecosystems, and agriculture (particularly smallscale farming), though these are not explicitly attributed to climate change. The impacts of droughts on African agriculture in recent decades are noted. Significant impacts on settlement, infrastructure and tourism are discussed, though the major focus is on urban areas.

Important categories of extreme events causing negative impacts in rural areas include tropical storms and droughts: 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). Droughts produce severe economic distress in 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). Ericksen *et al*. (2012) review a variety of livestock mortality rates, up to 80% of livestock in some areas, for recent droughts in the Horn of Africa

Climate change impacts on agriculture and ecosystems run through rising temperature and changes in rainfall variability and seasonality as well as through extreme events. Lobell *et al.* (2011) adopt a different approach to and scale of analysis by examining global yields of the four major agricultural commodities, from 1980 to 2008, in relation to temperature trends and in relation to a counterfactual without climate trends. Yields of maize and wheat declined by 3.8 and 5.5% respectively relative to the counterfactual, which offset in some countries some of the gains from improved agricultural technology. Badjeck *et al*. (2010) discuss current and future impacts on fisherfolk across the world. Many local-level studies are subject to the attribution problems mentioned above, but Wellard *et al*. (2012) cautiously note a convergence of climate data with the perceptions of farmers and officials to the effect that over the last 30 years the rainfall in Malawi has become less predictable, that the rainy season is arriving later in the year causing delays in planting of the main crops, and that damaging dry spells during the rainy season have become more likely.

Glacial retreat in Latin America is one of the best evidenced 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 depend, which accord well with local perceptions of changes that are necessitating adaptation (Orlove, 2009). Other studies of the area focus both on observed changes in water availability and on glacial lake outburst floods, which are attributable to climate change (Bury *et al*., 2009; Carey, 2010, Carey *et al*. 2012). 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; Beaumier and Ford, 2010).

Migration associated with weather-related extremes or longer-term climate trends is discussed in Chapter 12, Table 12-3, with empirical examples of migrations linked to droughts, coastal storms, floods and sea level rise. Attribution of migration to climate change is extremely complex, as recognized by Black *et al*. (2011). Life in rural areas across the world typically involves complex patterns of rural-urban and rural-rural migration, which are modified or exacerbated by climate events and trends rather than solely caused by them. Black *et al*. (2011) see environmental drivers of migration as operating in combination with economic, political, social and demographic drivers. MacLeman and Hunter (2010), argue that analogies of historical migration trends associated with environmental change though not with global climate processes, such as the 1930s Dustbowl in the USA (Reuveny (2007) allow closer examination of such multiple causality.

9.3.3. Future Impacts

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. Biophysical impacts on non-food cash crops, in particular beverage crops, are discussed below.

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.

Some of the discussion here will involve issues of vulnerability, particularly contextual vulnerability, but this is discussed more fully in section 9.4 below.

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).

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). 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).

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 affect production decisions, management of knowledge, and marketing (Morton, 2007). Similarly access to diversification as an adaptation to climate extremes depends on gender, age, governance and institutions, as shown in studies in South Africa, Tanzania and Uganda (Goulden *et al.*, 2009).

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 will not 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 the agricultural water supply 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 experience 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 changes in water availability affecting the 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 meltwater 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 may increase rural depopulation and harm the development of rural communities in Southern Europe (Westhoek *et al.*, 2006). Given the rapid population growth, economic development and hence increasing completion over water resources (for both agricultural and non-agricultural uses) in the Middle East, the per capita availability of water will be reduced significantly for rural populations (see also Chapter 22) (Chenoweth J, *et al.*, 2011; Rochdane *et al.*, 2012; Iglesias *et al.*, 2010; Hanafi *et al.*, 2011, Sowers *et al.*, 2011; Verner, 2012: 166). 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 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, (or industrial crops), which represent an important source of livelihood in many rural areas. However they have received less attention than traditional agricultural crops when assessing the impacts of climate change. Relevant crops include cotton and other fibres, wine grapes, beverage crops, and a wide variety of others. Yields of several cash crops in the Middle East such as olives, apples and pistachios may decline if winter temperatures are too high (Verner, 2012). Literature on biofuels such as jatropha focuses on the impacts of biofuels on climate change rather than on the effects of climate on yields and other relevant variables in these agricultural systems. Where crops have dual use as food and biofuel (for example oilseeds, sugarcane, sugar beet, maize and wheat) impacts can be inferred from studies that focus on their use for food.

The findings of Easterling *et al.*, (2007), that cotton yields are likely to decrease as changes in temperature and precipitation overcome potential benefits of increasing carbon dioxide have been corroborated in other studies, where yield reductions have been estimated the order of 10% (Lee *et al.*, 2001) causing substantial economic losses. It is reported that the cotton cultivation in Israel will declined by 52% and 38% under the A2 and B2 scenarios, and that the net revenue will also decrease by 240% and 173% in the scenarios (Haim *et al.*, 2008: 433). Few systematic assessments have been done on other fibre crops such as jute, kenaf, and flax.

Climate change impacts on wine grapes have been extensively studied and documented. Climate impacts such as increasing number of hot days and decreasing frost risk may benefit some varieties. Lobell *et al*. (2006) assess the impacts of climate change on yields of six perennial crops in California by 2099. This paper presents that the production of wine grapes will experience relatively small changes compared to other commodities during the concerned period. The uncertainty analysis shows the yield variations are limited within 10% although Gatto et al. (2009) argue that the revenue of the industry in Napa, California could declined by 2034. Jones *et al*. (2005) indicate that future climate change will exceed climatic thresholds affecting ripening for existing varieties grown at the margins of their climatic limits. Warmer conditions could also lead to more poleward locations potentially becoming more conducive to grape growing and wine production.

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 9-4.

____ START BOX 9-1 HERE ____

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 in over 60 countries of the tropics of Africa, Asia and Latin America. 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 and temperatures have increased by 0.02ºC per year. They developed econometric models of the relationship between coffee productivity and fluctuations in temperature and precipitation, which gave an R-squared of 0.69 against historical data. Extrapolating the historical tendencies in temperature and precipitation to 2020 and applying their econometric model they predict 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 summarized below.

For Brazil, Pinto *et al*., (2004) have mapped the changes in area suitable for coffee production in the four main coffee producing states. A 3ºC increase in temperature and 15% increase in rainfall (taken from the general prediction of climate change for Southern Brazil in the IPCC 2001 report) would lead to major changes in the distribution of coffee producing zones. In the main coffee producing states of Minas Gerais and Sao Paulo the potential area for production would decline from 70-75% of the state to 20-25%, production in Gioas would be 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 3ºC 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 the A2a climate scenario using a statistical downscaling of the climate change data from 20 different GCM models used in the IPCC Fourth Assessment. They use WorldClim data to characterize the current distribution of coffee using 19 climatic variables and then use the climate data downscaled to 1, 5 and 10 km resolution to map where those conditions may occur in the future (2020 or 2050). 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 9-4). 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 a 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 2-2.5ºC. Although some local areas may have improved conditions for coffee production, e.g. high altitude areas of Guatemala, the overall predictions are for a reduction in area suitable for coffee production by 2050 in all countries studied.

____ END BOX 9-1 HERE ____

[INSERT TABLE 9-4 HERE
Table 9-4: Projected changes in areas suitable for production of tropical beverage crops by 2050.]

Food security, which is also discussed in Chapters 7 and 13, is now known to reflect a broader range of factors than merely food production (Sen, 1992). In three countries in Africa – Ethiopia, Malawi and Niger - mass mortality food crises since 2000 -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).

Post-harvest aspects of agriculture – storage on farm and commercially, handling and transport – have been relatively neglected in discussions of climate change, but will be affected by changes in temperature, rainfall, humidity, and by extreme events. Many adaptation opportunities are already understood by postharvest service providers, but getting postharvest knowledge into use at scale is a significant challenge (Stathers *et al*. submitted).

Rural food security is discussed extensively in the regional chapters of this report. Major themes include: for Africa the range of contributing factors including globalization (22.3.3.1.5), and the adaptation responses of farmers (22.3.3.16); for Asia (24.4.4) the regional variation in yields across crops and countries, and potential for adaptation; for North America the high food insecurity in Mexico and the vulnerability to climate change of food security in indigenous communities (26.6, 26.7); for Central and South America (27.3.4) the threats to the food security of the poor in specific agricultural regions, and the inter-linkages between food and bioenenergy and farmers' responses. Links between food security and agriculture trade are also discussed in 9.3.3.3 below.

Agricultural livelihoods are not restricted to crops, but also involve livestock in a variety of farming systems (Devendra *et al*. 2005). Thornton *et al*. (2009) view the impacts on livestock of climate change as a neglected research area, complicated by other drivers of change, broader development trends, rapid change in livestock systems, spatial heterogeneity and social inequality between livestock-keepers. Drawing on livestock science, range ecology and projected climate trends, they review some possible future impacts through quantity and quality of feeds, heat stress, water, disease and others. Impacts through drought will be significant, as will heat stress, particularly of *Bos taurus* cattle. Impacts through animal health and disease will be even harder to predict than other categories of impact (Thornton *et al*., 2009). Aggregating at the level of one country, Kabubo-Mariara (2009) shows that livestock production in Kenya is highly sensitive to climate change, whereby increased mean precipitation of 1% could reduce revenues by 6%.

Pastoralists, who are dependent on livestock grazed in arid, semi-arid or mountainous areas, represent a specific case, display very specific combinations of adaptive capacity, especially through mobility, and vulnerability, as discussed in 9.3.5 below. Ericksen *et al*. (2012), with particular reference to East Africa, discuss possibilities of loss of rangeland productivity, changes in rangeland composition towards browse species, and changes in herd dynamics through more frequent droughts as possible impacts. In the Middle East, rangelands will be under substantial climate stress which may reduce their carrying capacity, in light of the growing demand for meat products and the region's growing size livestock population (Verner, 2012: 166). Little *et al.* (2001) discuss impacts of floods, directly and through disease, on pastoral herds. 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%.

As extensive livestock production is associated with semi-arid areas marginal for cropping, some authors project shifts toward livestock production under climate change. Jones and Thornton (2009) identify major transition zones across Africa where increased probability of drought between now and 2050 will create conditions for shifts from cropping to livestock. 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 to determine species choice. These analyses 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). To Sallu *et al.* (2010), investment in and accumulation of physical assets, including land and livestock, can be a strategy to decrease vulnerability

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). 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. (Chapter 7, AR5, provides an assessment of the impacts of climate change on the biological and ecological processes in aquatic ecosystems and on livelihoods that depend on the fisheries and aquaculture sector).

Diversification into non-farm incomes might accelerate if climate-related risks of farm income failure increase as a result of climate change, although it is also determined by other factors such as poverty, income distribution, farm output, gender, labour and credit markets (Ellis, 2000). Such diversification would help households achieve low risk correlations between their livelihood components (Ellis, 2000).

9.3.3.2. Infrastructure

Assessments of the impacts of climate change on infrastructure take a general or urban perspective and do not focus on rural areas, though rural impacts can be inferred. For example, river flooding and sea level rise will produce temporary loss of land and land activities, and transportation infrastructure particularly on coastal areas (Kirshen et al 2008). Climate change will affect current water management practices and the operation of existing water infrastructures, which are very likely to be inadequate to overcome the negative impacts of climate change on water supply reliability (Kundzewicz *et al.*, 2008). Some documented impacts on dams, reservoirs and irrigation infrastructure are: reduction of sediment load due to reductions in flows (associated with lower precipitation), this positively affects infrastructure operation (Wang *et al.*, 2007); impacts of climate variability and change on storage capacity that creates further vulnerability (Lane *et al.*, 1999); and failures in the reliability of water allocation systems (based on water use rights) due to reductions of streamflows under future climate scenarios (Meza *et al*., 2012).

9.3.3.3. Spatial and Regional Interconnections

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), as well as the spatial intermingling of rural and urban economic activities, labelled as desakota systems and discussed in Section 9.1.3 above. A trend to increase in urban areas can be associated with different spatial patterns, reflecting alternative development processes, e.g. periurbanisation versus counter-urbanisation (Rounsevell *et al*., 2007). 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.

9.3.3.3.1. Migration

Growing efforts are researching environmental migration, building on the AR4 conclusion that extreme events might 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). Hence, the link between internal migration and environmental stresses is contested. One school of thought shows migration (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). This may also affect human security (Brown and Crawford, 2008). Growing vulnerability to environmental change may also lead to an increase in abandonment of settlements (McLeman, 2011).

However, some estimates and forecasts of the potential number of displaced people because of climate change are being challenged by another body of literature which argues 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; McLeman and Hunter, 2010; Gemenne, 2011; Foresight, 2011; Cohen, 2004; Brown, IOM, 2008). Some studies have ascertained (Mertz *et al.,* 2007; Parnell and Walawege, 2011) that climatic variabiity is certainly one of the most significant catalyst for migration toward urban areas, as has been the case during the severe droughts occurred in the Sahel in the 70s and the 90s, but the current alarmist predictions of massive flows of refugees (so called ‘’environmental refugees’’ or ‘’environmental migrants’’), are not supported by past experiences of responses to droughts and extreme weather events and predictions for future migration flows are tentative at best (C. Tacoli, 2009; M’bow 2011). Similarly, a recent survey by Mertz *et al*. (2010) has argued that climate factors play a limited role in past adaptation options of sahelian farmers.

There have also been attempts to understand the nexus between migration and climate change through examining analogous experiences in the past and present in which climate variability is associated with particular kinds of population movements (McLeman and Hunter 2010). For example, in Ghana the causality of migration was established to be relatively clear in the case of sudden-onset environmental perturbations such as floods, whereas in case of slow-onset environmental deterioration, there was usually a set of overlapping causes - political and socioeconomic factors – which come into play (van der Geest, 2011). Given the multiple drivers of migration (Black *et al*., 2011) and the complex interactions which mediate migratory decision-making by individual or households (Raleigh, 2008; McLeman and Smit, 2006; Kniveton and Al., 2011, Blake and Al, 2011), the detection of the effects of climate change on intra-rural and rural-to-urban migration remains a major challenge.

9.3.3.3.2. Trade

Although agricultural exports accounted for only one sixth of world agricultural production and consumption (Anderson, 2010), it is the sector for which most data is available, and is the focus here. Between 2000 and 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). 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 several major producers, including Australia, Ukraine and the United States, creating shortage of cereals in international markets, the expansion of bio-fuels at the expense of food crop production, export controls, growing demand by emerging economies for secondary agricultural products such as meat, energy and feed crops, financial speculation – have led to a volatile and unpredictable trading environment (FAO, 2008; Timmer, 2010; Schmidhuber and Matuschke, 2010; Karapinar and Haberli, 2010; Headey , 2011).

Against this backdrop, climate change is expected to affect the pattern and volume of international agricultural 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. Recent studies produce even more pessimistic projections of climate change on food prices differentiated at the crop level than did AR4 (Easterling *et al.,* 2007). 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 CO_2 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 CO_2 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.*, 2009a). Other studies, using different models and scenario combinations, produce significantly different results in relation to price projections. For example, IFPRI using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) estimates additional price increases for 2050 (relative to no-climate change) of 32- 34 percent for maize (with baseline and pessimistic scenarios in relation to population and income growth (e.g. human well-being)), 18-20 percent for rice (with optimistic and pessimistic human well-being scenarios) and 23-24 percent for wheat (with baseline and pessimistic human well-being scenarios) (Rosegrant, *et al.,* 2008; Nelson *et al.*, 2010). This reflects the high level of uncertainty on price predictions (Rivera-Ferre and Ortega-Cerdà, 2011) and the caution needed to develop food policies.

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% for beef, pork and poultry respectively, 20%, 18%, 21% increases are projected for 2050 under climate change scenario for these three commodities respectively, without taking into account CO2 fertilization ((Nelson *et al.*, 2009a).

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.*, 2009b). 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.*, 2009b). 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.*, 2009b). 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.*, 2009b). 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*., 2009b). 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.

The literature highlights the potential role of international trade in managing the effects of climate change on agricultural productivity (Nelson *et al*., 2009; Huang *et al*., 2011:12; Jankowska, et al 2012). Models show that world trade volumes would need to increase substantially to offset the negative welfare effects of climate-change induced crop yield variability (Reimer and Li, 2009). This would also allow some countries to capitalize on new export opportunities arising from higher achievable yields, for example in Argentina (Asseng *et al*., 2013) or increasing heterogeneity of climate impacts on yields, for example in Tanzania (Ahmed *et al*., 2012). Similarly, it is projected that climate-induced food deficits occurring in low income developing countries will be supplied, fully or partly through food aid. Hence 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 might face additional operational challenges (Barrett and Maxwell, 2006; Harvey *et al*., 2010). Staple food trade might also save water resources, and hence contribute to adaptation efforts in rural areas, as the total volume of embedded water (“virtual water”) in trade is projected to decrease under climate change (Konar *et al.,* 2013).

The potential role that trade could play in managing the impacts of climate change will inevitably be affected by countries’ trade policies. For example, during the ‘food crisis’ of 2007–2008, dozens of countries instituted various forms of export restrictions on food staples, in order to maintain domestic availability of supplies, which created additional volatility in global markets (Anderson and Nelgen, 2012; Headey, 2011; Karapinar, 2011, 2012). Low-income countries are particularly vulnerable to such volatilities (FAO, 2008; Reimer and Li, 2009).
The emerging literature on the subjects illustrates that deepening agricultural markets through trade reform, improved market access, and institutional efforts to improve the predictability and the reliability of the world trading system as well as by investing in additional supply capacity of small-scale farms in developing countries could help reduce market volatility and offset supply shortages which might be caused by climate change (UNEP, 2009; WTO, 2009; Nelson *et al*., 2009a and 2009b; Reimer and Li, 2009; Ahmed *et al*., 2012).

9.3.3.3.3. 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).

9.3.3.3.4. 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), although differentials n knowledge access between rural and urban areas remain. 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). 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 both from and to rural areas.

Traditional Ecological Knowledge (TEK and also known by a variety of other terms), developed to adapt to past climate variability and change, can both be impacted by climate change and used and transformed in adaptation (Nyong, *et al.,* 2007). Ettenger (2012) discusses how seasonal hunting camps among the Cree of Northern Quebec that were the occasion for intergenerational knowledge transfer have been disrupted by changing bird migrations, while new technologies such as the internet, GPS and satellite phones have been integrated into livelihood strategies. Climate-change induced migration can threaten LTK transfer (Valdivia *et al*., 2010; Giles *et al*., 2013). Disaster management by cental government may undermine decentralization efforts, disfavouring TEK transfer (Dekens, 2008).

9.3.3.4. Second-Order Impacts of Climate Policy

Policy responses to climate change impact on rural people and can affect their livelihoods and environment. 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), or increased employment opportunities (del Río and Burguillo, 2008).

Social responses to these changes are expected (Molnar 2010) while some impacts have already been documented. One of the most analysed is the promotion of biofuel crops, which have been an extremely controversial issue in the last decade. Delucchi (2010) concludes that biofuels produced from conventional intensive agriculture will exacerbate stresses on water supplies, water quality, and land use, and thus will have impacts on rural areas (land-use change) and agriculture. Concerns have already been expressed about the impact of biofuel production on food security due to increase in food prices, increasing land concentration (and landgrabs), and competition for water (Eide, 2008; Müller *et al*., 2008). Gurgel *et al*. (2007) modeled potential production and implications of a global biofuels industry: estimated 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. Delucchi (2010) suggests developing biofuels programs with low inputs of fossil fuels and chemicals, that do not require irrigation, and that use land with little or no economic or ecological value in alternative uses (Plevin *et al*., 2010). This implies analysing each case in its context, including production for both local and global markets.

Another relevant climate-policy developed in the last few years under the UNFCCC umbrella has been the REDD mechanisms. Major criticisms of this instrument arise from the difficulties posed for the participation of communities in REDD programs and its potential in undermining a general decentralization of forest management (Phelps, Webb, and Agrawal 2010), which is shown to be essential for a sustainable management of forests and reducing vulnerability of forest-dependent communities. Campbell (2009) notes the presence of some ssynergies between mitigation through REDD and adaptation, but also trade-offs between REDD, rural incomes, and rural equity. To address these problems Sikor *et al*., (2010) suggest the recognition and operationalizing of forest peoples' rights through participation of communities in decision-making, equitable distribution of forest benefits, and recognition of their particular identities. This will require the implementation of a polycentric approach implying a nested forest and climate governance.

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. Valuation of impacts of climate change on rural areas is a difficult task and should reflect the significance of the ecological service categories for different stakeholders, including women (Kennet 2009) and minority groups, and ideally the valuations of unit changes in the levels of those services across management options. Valuations can be made at individualistic or communal levels (Farber *et al*., 2006). different understandings of value may exist (Spangenberg and Settele, 2010; Kosoy and Corbera, 2010), as well as different philosophical approaches to address it (from positivists to ethicists) (Weisbach and Sunstein, 2008), which makes more difficult to agree on valuation methodologies. 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 and climate variability 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) and for droughts in particular for Australia (Nelson *et al.,* 2007, Meinke and Stone 2005). 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). Würtenberger *et al*. (2006) developed a methodology to estimate environmental and socio-economic impacts of agricultural trade regarding virtual land use, and Adger *et al.* (2011) use qualitative methodologies to consider non-market and non-instrumental metrics of risk, based on principles of justice and recognition of individual and community identity, which they suggest should be considered in decision-making.

Integrated assessment models and cost-benefit tools have been criticised for not being a valid tool to assess intergenerational events, processes with high levels of uncertainty and irreversibility, for not considering equity concerns, power structures, or for assigning monetary values on the basis of incomplete information or assuming speculative judgments regarding the monetary value of, e.g. natural resources (Ackerman et al. 2009; Toman 2006; Kuik *et al.*, 2008), not recognising incommensurability (Aldred 2012). In recent years, various perspectives for valuing the economic impacts of climate change have come into focus including the feminist (Nelson 2008; Power 2009), deliberative (Zografos and Howarth 2010) or behavioural economics (Brekke and Johansson-Stenman 2008; Gowdy 2008), and the integration of economics with moral and political philosophy (Dietz *et al.*, 2008). Some common characteristics of these new approaches include transdisciplinarity, acknowledging the diversity of views and maintaining complexity in models. Research in this area although relatively recent, shows promise.

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 and to a lesser extent in parts of the developed 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 and Australia (Kokic *et al.,* 2007). 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 9-5.

[INSERT TABLE 9-5 HERE
Table 9-5: Illustrative sample of studies on economic value and changes in value from climate change.]

9.3.4.2. Other Rural Sectors: Water, Fisheries, Livestock, Mining

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). Monetary estimates of losses due to impacts on water resources are not generalizable. Among alternative approaches to value water resources, use of the water footprint tool (Hoekstra and Mekonnen, 2012) and the concept of virtual water has been suggested for informing policy-makers in water-scarce countries, such as Egypt.

Analysis of intergenerational valuation has shown to provide some interesting results in valuation of marine fisheries (Ainsworth and Sumaila 2005). For fisheries in rural coastal areas, some of the challenges faced include the valuation of environmental externalities such as breeding habitats, or mangroves, that might be lost due to climate change or other forces (Hall 2011). It has also been argued that the true worth of livelihoods dependent on fisheries in developing countries, where these constitute part of a diversified livelihood or subsistence strategy, requires a different set of metrics from those used in the developed world (Mills et al. 2011). Climate change can also have significant impacts on livestock keeping (Section 9.3.3.1 current chapter). Franco *et al.* (2011) reveal significant declines in forage for ranching in California under SRES scenarios B1 and A2. 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).

A relatively less researched area which may impact the livelihoods of rural communities is mining (Section 26.11.1.2). 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. As with other industrial sectors, the extent of loss would vary depending on the importance of the sector in the local economy (Backus *et al.*, 2012).

9.3.4.3. GDP and Economy-Wide Impacts

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 a 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 (ADB, 2009b). 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.

9.3.4.4. Extreme Weather Events, Sea-Level Rise

The climate change related extreme events that may 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 climate volatility from increase in extreme events, increases poverty in developing countries, particularly Bangladesh, Mexico, Indonesia and in Africa. 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 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. Scenario-based stakeholder engagement has been tested for coastal management planning under climate change threats (Tompkins *et al*., 2008) and to determine impacts and responses of extreme-events in coastal areas (Toth and Hizsnyik, 2008).

9.3.4.5. 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. To overcome some of the limitations, multicriteria analysis has been used for forest management (Fürstenau *et al*., 2007).

9.3.4.6. 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 in 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. For region specific health concerns from climate change, the reader is referred to the following sections: North America (26.8, chapter 26); Central and South America (27.3.7, chapter 27); Small islands (29.3.3, chapter 29); Australia (25.6.9, Chapter 25); Asia (24.4.6, chapter 24); Europe (23.5.1 and 23.5.2, Chapter 23); Africa (22.3.3.2, chapter 22).

9.3.5. Key Vulnerabilities and Risks

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), or even contradictory. Two main concepts of vulnerability exist (O'Brien *et al.,* 2007; R. Nelson *et al.,* 2010; Füssel, 2007):

- Vulnerability viewed as a combination of exposure to hazards, sensitivity and adaptive capacity, as used in the Fourth Assessment Report of the IPCC, 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 consequence of this is a downplaying of factors such as gender (V. Nelson *et al.,* 2002) or the status of indigenous people (O'Brien *et al*., 2009).
- Vulnerability viewed as arising from pre-existing socio-economic factors that make populations vulnerable to extreme events (or climate change), also called starting-point or contextual vulnerability, emphasizing climate change interactions with multiple processes of change and thus widening the It is assumed that vulnerability arises 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 knowledge (Brondizio and Moran, 2008). This type of assessment has grown in the last few years.

In line with these interpretations different methodologies exist to measure vulnerability (inductive and deductive methods (Nelson *et al*., 2010); vulnerability variable, unicriterial or econometric assessment, e.g. centered on examining changes in agricultural yield, and vulnerability indicator or multicriterial approach. Recent discussions in this field also relate to whether studies should be centered on the analysis of vulnerability or resilience. Vulnerability implies a key role for targeted international development assistance in helping the rural poor while resilience research emphasises more bottom-up forms of assistance that allow adaptive capacities and flexible governance structures, and considers that conventional development assistance can exacerbate vulnerability before and after shocks (McSweeney and Coomes, 2011a). Cannon and Muller-Mahn (2010) however, suggest that resilience as a focus is overly associated with the natural sciences while important social issues can be left behind in the assessments.

9.3.5.2. Drivers of Vulnerability and Risk

In this chapter we use vulnerability as a starting point, in which different trends can be observed in different situations, while we consider risk to be the product of impact, exposure and vulnerability. The most commonly used approaches to analyzing causes of vulnerability, use the concepts of entitlements or livelihoods in evaluating the multi-scale factors shaping people's assets. The importance and impact of drivers affecting vulnerability are seen as context and scale-dependent, although vulnerability is experienced locally, its causes and solutions occur at different social, geographic, and temporal scales (Ribot, 2010). Vulnerability in rural areas can be aggravated by non-climate factors which can operate at both individual and community levels (Eakin and Wehbe, 2009), and include the following:

- 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, Halsnæs *et al*., 2009; Mertz, Mbow *et al*., 2009)
- Gender inequalities (V. Nelson *et al*., 2002)
- Social, economic and institutional shocks and trends (e.g. urbanization, industrialization, prevalence of female-headed households, landlessness, short-time policy horizons, low literacy, high share of agriculture in GDP), as well as 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, Halsnæs *et al*., 2009; Parks and Roberts, 2006; Gbetibouo *et al*., 2010; Ahmed *et al.,* 2011; Cooper *et al*., 2008; Brondizio and Moran, 2008).

The adoption of different approaches in the analyses can result in contradictory findings regarding vulnerability in rural areas. Further, vulnerability being highly context-dependent, there are low levels of agreement on the direction in which some key factors may affect vulnerability or resilience in rural areas, including rainfed as opposed to irrigated agriculture, small-scale and family-managed farms, integration into world markets, or poverty. For instance, poverty has traditionally been considered a clear factor increasing vulnerability to climate change, but McSweeney and Coomes (2011a) found that climate-related disasters can change the structural factors, fostering local capacities for endogenous institutional changes that enhance community resilience, intergenerational equity and long-term ecological sustainability. Brouwer *et al*. (2007) contrary to expectations 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. Also Osbahr *et al*. (2008) found that diversification in rural areas does not always reduce vulnerability and can increase inequity within communities if it is not accompanied by reciprocity.

There is greater agreement on the importance for resilience of drivers such as access to land and natural resources, flexible local institutions and knowledge and information, and the association of gender inequalities with vulnerability. This section focuses on the following drivers of vulnerability to climate change: water, market orientation, institutions, access to resources, gender, migration and access to information and knowledge.

9.3.5.2.1. Acces to water

Access to drinking and irrigation water is considered an important factor driving vulnerability to climate change of rural populations. Availability of water is also linked to other indicators such as income, agricultural employment and nutritional status in the household (Halsnæs and Trærup, 2009). Reducing vulnerability requires a reduction of the multiple non-climate-related pressures on freshwater resources (e.g. water pollution, high water withdrawals) together with improvement of water supply and sanitation in developing countries (Kundzewicz *et al*., 2008). It is agreed that water supply will be adversely affected by climate change, but vulnerability of populations will also be determined by other elements, such as the role of institutions in facilitating the access to water, or people's demand, which in turn is influenced by local cultural norms (Wutich *et al*., 2012) and perceptions of vulnerability which may differ between men and women Larson, Ibes,and White 2011. Improvements in technologies can reduce the perception of water scarcity and increase water demand without reductions in underlying vulnerability (El-Sadek, 2010; Sowers *et al*., 2011). 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).

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) emphasised the role of drought-tolerant crops. It is important, both for rain-fen and irrigated agriculture, to promote water harvesting strategies, including storage and conservation.

9.3.5.2.2. Market orientation

Some authors argue that opening markets to international trade increases vulnerability of small farmers and poor people. However, linkages among international, regional and local markets are not clear, including how global prices affect regional and local prices in the long term (Ulimwengu *et al*., 2009). Market integration reduces the capacity of indigenous systems for dealing with climate risk in Bolivia (Valdivia *et al*., 2010) and Mozambique (Eriksen and Silva, 2009), and in the Sahel favours a shift towards cash-cropping a narrow range of commodities that increased dryland degradation (Fraser *et al*., 2011) as in Honduras (McSweeney and Coomes, 2011a), by accelerating socioeconomic stratification or focusing incomes in a single crop. Ruel *et al*. (2010) suggest that excessive dependence on cash income increases vulnerability of the urban poor compared with the rural poor, who can have access to other type of assets. According to Brooks *et al*. (2009) the dominant development paradigm favouring transitions from tradition to modernization, economic growth and globalization, does not favour action under uncertainty. They suggest the need for new models of development built *around* environmental constraints and opportunities which search for a balance between productivity and resilience.

On the other hand, Jones and Thorton (2009) estimated that rainfed mixed 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. Thus, each case needs to be analysed within its complexity considering interactions among all factors that can affect vulnerability, to avoid magic recipes which can work in one place but not in other (Rivera-Ferre *et al*., submitted).

Regarding the scale of farms, 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, monocropp 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 history demonstrates small farmers are highly resilient as they face numerous changes and that the value of local knowledge in climate change studies has received little attention. For Eakin (2005), the shift in support to agriculture from subsistence to commercial agriculture in Mexico reduced smallholders resilience for climatic variations.

9.3.5.2.3. Institutions, access to resources, and governance

Vulnerability and livelihood security are closely linked to the institutional environment. Institutions and their networks 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 influencing vulnerability (Agrawal and Perrin 2008; Berman *et al.*, 2012). According to Agrawal and Perrin (2008) local institutions (as organizations) influence livelihoods in three manners: through distribution of risks related to climate hazards they can structure how particular social groups will be affected by them; they determine the incentive structures for household and community level adaptation responses; and they mediate external interventions (e.g. finances, knowledge and information, skills training) into local contexts, and articulate between local and extra-local social and political processes through which adaptation efforts unfold. In that manner, rural institutions structure risk and sensitivity in the face of climate hazards by enabling or disabling individual and collective action (Ribot, 2010). Governance structures and communication flows are important, as shown in a Swiss mountain region vulnerable to climate change (Ingold *et al.*, 2010). The knowledge and perceptions of decision-makers are important. Romsdahl *et al.*(2013) show that local government decision-makers in the US Great Plains resist seeing climate change as within their responsibilities, which has contributed to low levels of planning for either adaptation or mitigation, and thus to greater vulnerability, but that a reframing of issues around current resource management priorities could allow proactive planning.

According to Leach *et al.* (1999) institutions (as the rules of the game in society) mediate vulnerability by shaping access to resources as composed by endowments, entitlements and capabilities of different social actors. Anderson *et al.* (2010) associate flexible local institutions in dryland societies, primarily for resource management, with resilience to climate change and vulnerability reduction. Lack of access to assets, among which land is an important one, is accepted to be an important factor increasing vulnerability in rural people (McSweeney and Coomes, 2011a). The breakdown of traditional land tenure systems increases vulnerability (Fraser *et al.*, 2011; Dougill *et al.*, 2010) in many different ways. Lack of access to land is a multi-causal process, among which climatic change is just but one. For instance, Dougill *et al.* (2010) shows that land privatization in Bostwana has increased vulnerability of poorer communal pastoralist, although it has helped the wealthier farmers, remaining a route to enhance resilience as this private land-owning group has become less vulnerable. Brouwer *et al.* (2007) found that individuals with less access to natural productive resources are more vulnerable to flooding, being even higher when disparities of distribution at the community level are also higher. Lack of access to productive land is also linked to migration and conflicts. Obioha (2008) shows how reduction of access to productive land due to climatic changes increases communal civil violent conflicts in Nigeria.

9.3.5.2.4. Migration

The relationship of vulnerability to migration is complex. Vulnerable people can migrate, both as a coping and as an adaptive strategy, depending on the temporal scale of that migration. Areas of out-migration can experience reduced vulnerability if migrants send remittances, or increased vulnerability 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 can experience an excessive demographic growth, which increases pressure over scarce resources, as it is being experienced in the semiarid tropics (Cooper *et al.*, 2008) or Africa (Obioha, 2008). Brondizio and Moran (2008) found that in-migration in the Amazon brought people with knowledge that is ill-adapted to the local environment.

9.3.5.2.5. Gender

Gender was a "latecomer" to the climate debate (Denton, 2004), but patterns of vulnerability reflects gender-related inequalities, of special relevance to rural areas in the developing world (Denton, 2002; Vincent *et al.,* 2010; V. 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), in crucial key dimensions for coping with climate-related change, including inequalities in access to wealth, new technologies, education, information, and other resources such as land. The major issues concerning gender and climate change in rural areas, not only in terms of vulnerability but also of enabling adaptation, are reviewed in Box 9-2.

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Box 9-2. Gender and Climate Change in Rural Areas

Differences in access to resources between men and women can create gender inequalities, which in turn leads to differential vulnerabilities and capacities to adapt (Nelson *et al*., 2002; Adger, 2006; O'Brien *et al*., 2007). Whilst recognised in AR4 (Adger *et al*., 2007) and SREX (IPCC, 2012), evidence since then has become stronger, with additional case studies on the gendered dimensions of climate change (e.g. Nelson and Stathers, 2009; Vincent *et al*., 2010). The social constructions of gender roles and responsibilities mean that women are typically disadvantaged relative to men. Due to greater levels of out-migration by men, women are disproportionately represented in rural areas, and globally women in rural areas make up one quarter of global population (Inter-Agency Task Force on Rural Women, 2012). As a result, it is essential that a chapter on rural areas be gender-sensitive. This box summarises the gender elements of vulnerability, impacts, and adaptation in rural areas.

Gendered differences exist in experiences of the multiple stresses that affect rural areas. Access to land shows strong differences between men and women, as do labour markets (FAO, 2010) and access to non-farm entrepreneurship (Rijkers and Costa, 2012). Less than 20% of the world's landholders are women, but women still play a disproportionate role in agriculture. On average women make up around 43% of the agricultural labour force in developing countries; in South Asia almost 70% of employed women work in agriculture, and more than 60% in sub-Saharan Africa (Inter-Agency Task Force on Rural Women, 2012). Climate change increases vulnerability through male out-migration that increases the work to women; cropping and livestock changes that affect gender division of labour; increased difficulty in accessing resources (fuelwood and water) and increased conflicts over natural resources. These factors can make rural women more vulnerable than men, in terms of reductions in resources, potential loss of employment and raised food prices (e.g. Tandon, 2007; Rossi and Lambrou, 2008; Ruel et al, 2009). Evidence for gendered vulnerability to climate change in rural areas exists in Africa (e.g. Omolo, 2011; Huisman, 2005).

In additional to differential access to resources and property rights, gender-ascribed social roles and responsibilities can also mean that women are differentially affected by climate extremes. Women are generally more vulnerable to the impacts of extreme events, such as floods and tropical cyclones. This occurs due to a combination of being close to the homestead, not having access to information (such as early warnings), and lacking the skills to survive, such as swimming. As well as differential immediate effects of extreme events, women are typically disadvantaged relative to men in the relief and recovery period (Alam and Collins, 2010). Lack of gender-sensitivity in emergency camps (e.g. different sanitation facilities) can put women's personal security at risk; and as social constructions of gender determine that they should be responsible for taking care of other household members; although there have been calls to add nuances to these differences (Cupples, 2007). Although there is little agreement in the role of environmental migration in response to climate change, women are disadvantaged in accessing this option (Foresight: Migration and Global Environmental Change, 2011).

Enabling adaptation of men and women requires a gender-sensitive approach that recognises and addresses the differential vulnerabilities. Not taking a gender-sensitive perspective can risk reinforcing existing vulnerabilities (Figueiredo and Perkins, 2012; Arora-Jonsson, 2011). However it is also important to move beyond generic gender differences and examinegender alongside other factors (Tschakert, 2013). Government interventions to improve production through cash-cropping and non-farm enterprises, for example, typically advantage men over women since cash income is seen as a male activity in rural areas (Gladwin et al, 2001); whilst rainwater and conservation-based adaptation initiatives may require additional labour which women do not necessarily have (Baiphethi et al, 2008). Encouraging gender-equitable access to education and strengthening of social capital are among the best means of improving adaptation of rural women farmers (Below et al, 2012; Goulden et al, 2009; Vincent et al, 2010). Similarly recognising preferences in accessing adaptation-enabling information is important: in South Africa, for example, it was observed that women preferred to hear seasonal forecasts through extension agents, as opposed to over the radio like men (Archer, 2003); whilst in Ghana information is broadcast over the radio, but women only hear it if they happen to be in the company of men who are listening (Nab and Korenteng, 2012).

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9.3.5.2.6. Knowledge and information

Knowledge and information debates are very much linked to institutions, since knowledge is in itself is a component of institutions. Lack of access to information and knowledge of rural people is suggested as a factor that increases vulnerability, mostly among poor people, which can also affect the above mentioned drivers. What is not so much agreed in the literature is what type of knowledge is best to reduce vulnerability. Some authors suggest the need for local responses and indigenous knowledge to reduce vulnerability (Valdivia *et al*., 2010), and call for an integration of local knowledge into climate policies (Nyong *et al*., 2007), 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 also important, shared knowledge and lessons learned from previous climatic stresses provide vital entry points for social learning and enhanced adaptive capacity (Tschakert, 2007). However, access to information is not always a guarantee of success. 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, as well as to understand prevailing local cultures and norms.

It is also important in the debate how knowledge is produced, managed, and disseminated within the formal institutional structure to address vulnerability issues. A local case-study in Sweden shows that limited co-operation between local sector organisations, lack of local co-ordination, and an absence of methods and traditions to build institutional knowledge exist, posing barriers to manage vulnerability (Glaas *et al*., 2010). To address this it is suggested that local institutional structure must be flexible and encourage institutional learning and knowledge transfer, implementing communication mechanisms between public authorities, other knowledge producers, and civil society to favour more reliable assessments of local vulnerabilities (Glaas *et al.,* 2010). Moumouni and Idrissou (2013 and forthcoming) examine the lack of co-ordination in Benin between climate policies and the policies and practices which govern agricultural research and extension, while good practice at project level could be harnessed to foster collective learning of farmers and other agricultural stakeholders, and thus adapataion to climate change.

The importance of access to knowledge and information has also been addressed with other drivers, suggesting that the combined pressure of climate change–induced decreased access to resources, the institutional vacuum, the loss of esteem for authorities, and the loss of trust in cultural knowledge accentuates the need to address governance to improve access to resources, access to information, mutual understanding of the role of knowledge systems for the interpretation of climate change and variability, and relevant institutional capacities (Kronik and Verner, 2010). In this direction, an alternative mode of interaction to the science and practice one-way interaction often used to address vulnerability, adaptation and resilience, in which different experts, risk-bearers, and local communities are involved and knowledge and practice is contested, co-produced and reflected upon it (Vogel *et al.,* 2007).

9.3.5.3. Outcomes

The outcome of vulnerability is the result of and interaction of the driving forces that determine vulnerability. This section analyses how different drivers may affect specific vulnerable groups in rural areas, that is pastoralists, mountain farmers and artisanal fisherfolk. Box 9-3 takes a specific economic sector important in rural areas, and demonstrates the interplay of vulnerability and exposure.

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Box 9-3. Tourism and Rural Areas

The three major market segments of tourism most likely to be affected by climate change are rural-based, namely, coastal tourism, nature-based tourism and winter sports tourism) (Scott *et al*., 2012). Tourism is a significant rural landuse in many parts of the world, yet compared to other economic sectors in rural areas, the impacts of climate change are typically under-researched. In the Caribbean, for example, tourism has overtaken agriculture in terms of economic importance, with several regional states (including the Bahamas, the Cayman Islands and St Lucia) receiving more than 60 percent of their GDP from this industry (Meyer, 2006). Coastal environments elsewhere in the world are also characterised by dependence on rural tourism, and are known to be vulnerable to cyclones and sea level rise (Klint *et al.,* 2011; Payet, 2007).

Terrestrial natural resource-based tourism is also a significant foreign exchange earner in many countries. In sub-Saharan Africa, between 25 and 40% of mammal species in national parks are likely to become endangered by 2080, assuming no species migration (and 10-20% with the opportunity for migration) (Thuiller *et al.,* 2006). There are also many rural environments viewed as "iconic" or having cultural significance that are vulnerable to climate change. In South Africa, for example, the Cape Floral (fynbos) ecosystem has a high level of species endemism which will be vulnerable to the projected increase in dry conditions (Midgley *et al*., 2002; Boko *et al*., 2007). The projected increase in climate change-related hazards, such as glacial lake outbursts, landslides, debris flows and floods, will likely affect trekking in the Nepali Himalayas (Nyaupune and Chhetri, 2009).

The development of tourism has, in many cases, increased levels of exposure to climate change impacts. In the Caribbean, for example, tourism has led to considerable coastal development in the region (Potter, 2000), which may exacerbate vulnerability to sea-level rise. In many cases, the carbon emissions resulting from participating in rural tourism threaten the very survival of the areas being visited. This is often the case for very remote locations, for example polar bear tourism in Canada (Dawson *et al*., 2010), dive tourism in Vanuatu (Klint *et al*., 2012). Although on aggregate resource consumption of tourists and locals has been shown to be similar in developed county contexts (e.g. in Italy – Patterson *et al*., 2007); in many developing countries resources used by tourists are much higher than locals (e.g. in Nepal - Nepal, 2008).

Despite the potential impacts of climate change on rural tourism, there is little evidence of significant concern, which impedes adaptive responses. Surveys in both the upper Norrland area of northern Sweden and New Zealand showed that climate change is not perceived to pose a major threat in the short term, relative to other business risks perceived by small business owners and tourism operators (Broudera and Landmarka, 2011; Hall, 2006).

That said, there is evidence that, with planned adaptation, tourism can flourish in rural areas under climate change. In the Costa Brava region of Spain, for example, although the increasing temperatures and reduced water availability is projected to negatively impact tourism in the current high seasons, there is scope to shift to the current shoulder seasons, namely April, May, September and October (Ribas *et al*., 2010). Recognition of the opportunities for adaptation have also necessitated reassessment of the extent of the potential impacts of climate change on the tourism industry in rural areas. Using snowmaking as an adaptation in the eastern North American ski industry suggests that even the warmest scenario only poses a minor risk to four out of six areas (Scott *et al*., 2006).

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9.3.5.3.1. Pastoralists

Pastoralists have developed successful strategies for responding to climate variability, especially what Krätli *et al.* (2013) refer to as "strategic mobility" in pursuit of high-quality grazing, in combination with shorter-term coping strategies (Morton, 2006), for example in the Afar region of Ethiopia (Davies and Bennett, 2007). These strategies suggest that a strong adaptive capacity is intrinsic to pastoralism (Davies and Nori, 2008). However, traditional practices such as pastoral mobility are declining , which increases the vulnerability of people in arid and semiarid regions (Lioubimtseva and Henebry, 2009; Fraser *et al*., 2011). Drought may become famine because of privatization policies that limit pastoral mobility making pastoralists dependent on rainfed agriculture (Smucker and Wisner 2008). 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 increased vulnerability of pastoralism (Cooper *et al*., 2008).

These constraints arise from a range of social, economic, environmental and political pressures external to pastoralism that bring about "induced vulnerability" (Krätli *et al.,* 2013): especially encroachment on rangelands, inappropriate land policy, undermining of pastoral culture and values, and economic policies promoting uniformity and competition over diversity and complementarity. Other authors list as constituents of increased vulnerability: population growth; increased conflict over natural resources; changed market conditions and access to services under liberalisation; concentration of political power in national centres; and perceptions that pastoralists are backward (Dougill *et al*., Fraser, and Reed, 2010; Rivera-Ferre and López-i-Gelats, 2012; Smucker and Wisner, 2008; Dong *et al,*. 2011). These in turn can be seen as results of what Reynolds *et al*., (2007) conceptualise as two key features of dryland populations: remoteness, and distance from the centres and priorities of decision-makers or "distant voice". However Dong *et al*. (2011) and Sietz *et al*. (2011) stress the geographic differentiation of pastoral systems (and more broadly of dryland systems with which they overlap).

9.3.5.3.2. Mountain farmers

Mountain ecosystems have been identified as extremely vulnerable to climate change (IPCC 2007), and thus populations have a high exposure to climate change. A detailed understanding of climate change impacts in mountain areas is difficult because of physical inaccessibility and scarcity of resources for research in mountain states and regions (Singh *et al.,* 2011), as well as more generic uncertainties relating to climate projection. However, agreement exists that impacts will include melting of glaciers, flooding or increasing probability of fires (Nogués-Bravo *et al*., 2007; Beniston, 2003). This will in turn have strong impacts on agriculture and livestock-based activities in these areas (e.g., changes in plants, pastures and water availability; slope instability; new diseases) as well as on tourism-based activities (Scott, 2006). But mountain dwellers, as pastoralists in drylands, are adapted to live in steep and harsh and variable conditions, and thus have a variety of strategies to adapt and foster resilience to changing climatic conditions. However, to develop their strategies they need to overcome other drivers that can affect their vulnerability in different contexts. For instance, in most developed countries, mountains are becoming depopulated (Gellrich *et al*., 2007; López-i-Gelats, 2013; Gehrig-Fasel *et al*., 2007) given the extreme climatic conditions, their remoteness and subsequent isolation, while in developing countries there is a trend towards increasing population (e.g. tropical mountain areas) (Lama and Devkota, 2009; Huber *et al*., 2005). The impacts of the projected warming on mountain farming, as well as their adaptation strategies, differ spatially because the socioeconomic role of mountains varies significantly between industrialized and industrializing or non-industrialized countries (Nogués-Bravo *et al*., 2007). Mountain grasslands in developed countries are usually managed via a sub-exploitation model that involves the intensive use of the most productive areas and the abandonment of those regions where production is economically less viable (López-i-Gelats *et al*., 2011). In contrast, mountain grasslands in developing countries remain centers of fodder and livestock production. Thus, two general trends are identified in world mountain grasslands, while temperate grasslands tend to suffer from conversion to agriculture, and land abandonment where livestock raising is less feasible (Gellrich *et al*., 2008); in tropical grasslands the main cause of degradation is overgrazing, linked to processes of demographic growth. Land privatization, loss of grazing rights, or changes in land use (e.g., development of infrastructure) also affect mountain farmers both in developed and developing countries (Tyler *et al*., 2007; Xu *et al*., 2008).

9.3.5.3.3. Artisanal fisherfolk

Small coastal and riparian rural communities face several drivers that increase their vulnerability, which remain largely ignored by mainstream fisheries policy analysts; for example, the likely impact of demographic, health and disease trends, or of wider development policy trends (Hall, 2011), pressure from other resources (e.g. water, agriculture, coastal defense), unbalanced property-rights; lack of adequate health systems, potable water, or sewage and drainage (Badjeck *et al*., 2010). The most important drivers affecting small-scale fisheries can be grouped into: international trade and globalization of markets; technology; climate and environment; health and disease; demography; development patterns and aquaculture; for instance, freshwater fisheries are threatened by increasing irrigation, while vulnerability of coastal fisheries increases with mangrove loss to aquaculture facilities in response to growing markets for prawns (Hall, 2011). Another difficulty faced by fisheries-based livelihoods is the neglect of governments and researchers, which is more centred on industrial fishing leaving aside artisanal ones (Mills *et al*., 2011). Management systems, property rights and institutions are extremely important in fisheries. Given the complexity of fisheries management and the particular open ecosystem in which this activity is carried out, the existing discussions about fisheries management are complex but also advanced in terms of introducing ecosystem rights and participation principles into management (Andrew and Evans, 2011; Charles, 2011), which in other fields are essential for reducing vulnerability, adapting to climate change and favouring sustainable societies.

9.4. Adaptation and Managing Risks

9.4.1. Framing Adaptation

As the previous sections outlined, it is virtually certain that there will be impacts of climate change in rural areas in both developed and developing countries for which adaptation is required. AR4 stated with very high confidence that adaptation to climate change is already taking place, but on a limited basis. Since then, evidence has increased such that there is very high confidence that adaptation is taking place in rural areas. 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). In developing countries, there is high confidence that adaptation could 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). In Ethiopia, for example,"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).

9.4.2. Decisionmaking for Adaptation

Decision-making for adaptation takes place at a variety of levels, and can be public or private. At the national and local levels, law and policies can enable planned adaptation (Stuart-Hill and Schulze, 2010). Evidence for policies to support adaptation exists from across the world, but tends to be greater in developed countries. In Australia, the Queensland government has set policies in anticipation of sea level rise, and in New Zealand the revised Coastal Policy Statement requires a minimum 100-year time frame for coastal planning (see Box 25-2). Australia also has a comprehensive water resources policy designed to deal with scarcity (see Box 25-3). In northern Canada, some territorial governments in Northern Canada have developed climate change strategies that promote further adaptation such as providing hunter support programs (Ford et. al., 2010)(see also chapter 26). However, in the Great Plains of the US, less than 20% of jurisdictions have developed plans on either climate adaptation or climate mitigation (Romsdahl *et al*., 2013).

At the local level, many adaptations are examples of private decisions for adaptation. As shown with very high confidence in AR4, such 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). 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).

There is increasing evidence that public decision-making for adaptation can be strengthened by understanding the decision-making of rural people in context (Bryan *et al*., 2009). Local and indigenous knowledge for responding to weather events and a changing climate has been observed in, for example, the Peruvian Andes (see chapter 26), Samoa (Lefale, 2010 – see chapter 29), the Solomon Islands (Rasmussen et al, 2009 – see chapter 29), Canada (Ford et al, 2007) and the Indo-Gangetic Plains (Rivera-Ferre et al, 2013).

9.4.3. Practical Experiences of Adaptation in Rural Areas

There are wide-ranging and manifold examples of adaptation in rural areas, in both developed and developing countries. These practical experiences of adaptation are found in agriculture, water, forestry and biodiversity, and fisheries.

9.4.3.1. Agriculture

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 – for example, planting, harvesting and watering/fertilizing existing crops; using different varieties, diversifying crops; implementing management practices such as shading and conservation agriculture (see Table 9-6).

[INSERT TABLE 9-6 HERE
Table 9-6: Examples of adaptations in the agricultural sector in different regions.]

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; Rivera-Ferre *et al*., 2013), and more efficient irrigation, particularly in rural drylands (Thomas, 2008).

Adaptations are also evident among small-scale livestock farmers (Rivera-Ferre and López-i-Gelats, 2012; (Kabubo-Mariara, 2009, 2008), who use many different strategies, including changing herd size and composition, grazing and feeding patterns, or diversifying their livelihoods, also they may use new varieties of fodder crops suited to the changing conditions (Salema *et al*., 2010).

Diversified farms are more resilient than specialized ones (Seo, 2010); but rural societies also diversify their income sources beyond agriculture, which in many contexts 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).

9.4.3.2. Water

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. 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). 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).

Whilst the majority of focus on adaptation concerning water relates to its availability, it is also important to remember that many rural areas are subject to riverine or coastal flooding. In the low-lying Netherlands protection measures have been employed, including increasing river runoff, increasing storage for water (Delta Committee, 2008; Kabat *et al.*, 2009), and small scale containment of flood risks through increasing compartmentalisation (Klijn *et al.*, 2009). 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).

[INSERT TABLE 9-7 HERE
Table 9-7: Examples of adaptations in the water sector observed in different regions.]

9.4.3.3. Forestry and Biodiversity

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. Ecological restoration, where required, is another effective adaptation measure – Benayas *et al.* (2009), in a meta-analysis of 89 studies, estimated this technique enhances the provision of biodiversity and environmental services by 44% and 25%, respectively. Moreover, ecological restoration increases the potential for carbon sequestration and promotes community organization, economic activities and livelihoods in rural areas (Chazdon, 2008), as seen in examples of the Brazilian Atlantic Forest (Calmon *et al.*, 2011; Rodrigues *et al.*, 2011). In other parts of 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 have been shown to 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).

Community involvement in natural resources management and biodiversity conservation is highlighted as critical, with community-managed natural areas experiencing lower rates of deforestation than non-community-managed ones (Porter-Bolland et al, 2012). In Central and South America, protected areas of restricted use reduced fire substantially, but multi-use protected areas are even more effective; and that in indigenous reserves the incidence of forest fire was reduced by 16% as compared to non-protected areas (Nelson and Chomitz, 2011). Reflecting the growing evidence for community-based management and wise use, an emerging mechanism for ecosystem-based adaptation includes payment for ecosystem services (PES) (Montagnini and Finney, 2011), although there is virtually no peer-reviewed literature on PES specifically for emissions reduction (Campbell, 2009). Particularly developed in Central and South America (see table 27-5 for examples of PES schemes in Latin America), communities can be paid for collecting scientific data to contribute to research and monitoring protocols (Luzar *et al*., 2011), or for actively managing natural resources.

9.4.3.4. Fisheries

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. Selective use of fishing gear is a recommended management measure, based on 15 global sites, to ensure sustainable harvesting of remaining fish stocks (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 (based on a multi-faceted social adaptive capacity index they used in the study), although the more environmentally-sensitive parts of Madagascar will be priorities for intervention assistance (McClanahan *et al*., 2009). As with terrestrial natural resources, evidence from the marine resources sphere shows that fisheries co-management, involving local fishermen and allowing limited extraction of resources, favour a balance between resource conservation and livelihoods, e.g in Brazil (Francini-Filho and Moura, 2008), and the improvement of livelihoods, as well as the cultural survival of traditional populations (Hastings, 2011; Moura *et al*., 2009). Given the complexity of fisheries management and the particular open ecosystem in which this activity is carried out, the existing discussions about fisheries (adaptive) management are complex but also advanced in terms of introducing ecosystem, rights and participation principles into management (Andrew and Evans 2011; Charles 2011), which are essential to reduce vulnerability and adapt to climate change. Box 25-6 details vulnerability and adaptation in rural areas in Australia.

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Box 9-4. 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).

_____ END BOX 9-4 HERE _____

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Box 9-5. 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 9-6. 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

The Fourth Assessment Report stated with very high confidence that there are substantial limits and barriers to adaptation (Adger *et al.*, 2007). Since that time additional evidence has shown that barriers do exist to adaptation – and that these barriers are both hard (physical) and soft (financial, social and cultural).

Lack of access to credit, water and land are 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 education, markets, credit and information about adaptation to climate change, including technological and institutional methods are important (Hassan and Nhemachena, 2008).

Rural households' lack of access to technologies and markets is also a major barrier to adaptation for certain production systems. 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 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. 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). Relevant information includes that on agricultural technologies that can be used in adaptation, but in developing countries agricultural research and extension systems are not integrated with climate planning to deliver this, as discussed by Moumouni and Idrissou (2013) for Benin. There is now an important literature on dissemination of short-term or seasonal weather forecasts to farmers in developing countries, as detailed in Box 9-7.

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Box 9-7. Factors Influencing Uptake and Utility of Climate Forecasts

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 who had taken part in appropriate participatory processes 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 taken part (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 (Box 9-2). 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). The IPCC SREX report identified the use of forecasts as a risk management measure (IPCC, 2012)

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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. Over 90% of rural people worldwide live in developing countries.

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 are prevalent among rural children in South Asia and Sub-Saharan Africa, and recent hikes and volatility in priced of food exacerbated hunger and malnutrition among rural households, many of which are net food buyers. In developing countries,the levels and distribution of rural policies are affected in complex and interacting ways by processes of commercialisation and diversification, food policies, and policies on land tenure. 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. Stronger rural-urban linkages through migration, transfer of public and private remittances, regional and international trade, inflow of investment and diffusion of knowledge (through new information and communication technologies) are more positive developments. 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, with regard to the difficulties of attributing extreme events to climate change, the status of local knowledge, and the action of non-climate shocks and trends. However, evidence for observed impacts, both of extreme events and other categories, is increasing. Impacts attributable to climate change include declining yields of major crops, some extreme events such as droughts and storms, and geographically-specific impacts such as glacier melt in the Andes.

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, livestock, fisheries 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. In certain countries shifts in agricultural production, of food and non-food crops, could take place. 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.

Climate change will lead to higher prices and increased volatility in agricultural markets, which might undermine global food supply security while affecting rural households, depending on whether they are net-buyers or net-sellers of food. The emerging literature suggests that deepening agricultural markets through trade reform and institutional efforts to improve the predictability and the reliability of the world trading system as well as by investing in additional supply capacity of small-scale farms in developing countries could help reduce market volatility and mitigate food supply shortages which might be caused by climate change

Migration patterns will be driven by multiple factors of which climate change is only one. Given these multiple drivers of migration and the complex interactions which mediate migratory decision-making by individual or households, the detection of the effects of climate change on intra-rural and rural-to-urban migration remains a major challenge.

Climate policies, such as encouraging cultivation of biofuels, and payments under REDD, will have significant secondary impacts on land-use, and resulting negative impact on livelihoods, in some rural areas. These secondary impacts, and trade-offs between mitigation and adaptation in rural areas, have implications for governance.

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. Specific livelihood niches such as pastoralism and artisanal fisheries are vulnerable and at high risk of adverse impacts, partly due to neglect, misunderstanding or inappropriate policy towards them on the part of governments.

There is a growing body of literature on successful adaptation in rural areas and constraints upon it, including both documentation of practical experience, and discussion of preconditions. In developing countries adaptation can be linked to other development initiatives aiming for poverty reduction or improvement of rural areas, and "low regrets" measures to respond to current variability can shift the trajectory from disaster-focused to longer-term vulnerability reduction. Prevailing development constraints, such as low levels of educational attainment, environmental degradation, and gender inequalities 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 (food crops, non-food crops and livestock) 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 and diverse categories of rural people throughout the world. One relevant area will be that of improving understanding of the respective roles of climate and other factors in rural-urban and rural-rural migration.

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. Research is also needed on the trade-offs and synergies between adaptation and mitigation in rural areas, and the appropriate governance structures to enhance synergy.

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 manage knowledge, both local and scientific, for adaptation.

Frequently Asked Questions

FAQ 9.1: Why are rural areas important in the study of climate change impacts, assessments, and vulnerability?
No clear and unique definition of rural areas exist in literature, however it is clear that human settlements do not only include urban areas. Nearly half of the world's population, approximately 3.3 billion, lives in open country areas. This is particularly true in developing and least developed countries, where more than 50% and 75% of the population respectively lives in rural areas. These human settlements are strongly dependent on natural resources and agriculture which influences their socioeconomic structures, and therefore highly sensitive to climate variations – and even recent diversification is typically still natural resource-dependent (e.g. tourism, recreation). In addition, these regions are usually characterized by pre-existing vulnerabilities which can aggravate climate change impacts.

Isolation and marginality remain as factors that significantly affect adaptive capacity in rural areas and increase vulnerability.

There are important differences between rural areas in developing and developed countries. Rural areas in developing countries are characterized by higher prevalence of poverty, isolation and lower human development. In developed countries these features are also present, but they are usually associated and influenced by the proximity to towns, and their role as a place for recreational activities.

FAQ 9.2: What will be the major climate change impacts and adaptations in rural areas across the world?
Given the strong dependence on natural resources, impacts of climate change in rural areas will, be primarily observed as changes in the productivity of primary sectors, such as agriculture, forestry and fishing. Secondary (manufacturing) industries, and the livelihoods and incomes that are based on them, will in turn be substantially affected. Extreme events associated with climate change will also affect rural areas, mainly via heat stress, drought and flooding that impact on infrastructure (i.e. dams, roads, buildings, telecommunications and irrigation systems). Depending on the magnitude these extreme events can trigger economic and political turmoil, as well as migration. Existing isolation and marginalisation create current vulnerability which, in combination with exposure to climate change, increases the risks of adverse impacts.

Adaptation options are context-specific and will depend on the correct identification of relevant risks and the adaptive capacities of rural people with differing access to natural, financial, human and social capital. Examples of rural adaptations include modifying farming and fishing practices, introducing new species and varieties as well as recovering old ones, diversification, water management, modifying infrastructure and technology decisions, and both formal and informal risk sharing mechanisms. Adaptation will also include changes in institutional and governance structures.

References

ABI, 2005: Financial risks of climate change. Association of British Insurers (ABI), London, pp. 39.

ABI, 2010: Financial risks of climate change. In: ABI RESEARCH PAPER NO 19. Association of British Insurers (ABI), London, UK, pp. 107.

Ackerman, F., S.J. DeCanio, R.B. Howarth, and K. Sheeran, 2009: Limitations of integrated assessment models of climate change. *Climatic Change*, 95(3-4), 297-315.

ADB, 2009: Climate change and migration in Asia and the Pacific, Executive Summary. Asian Development Bank, Philippines, pp. 38.

ADB, 2009: Understanding and responding to climate change in developing Asia. Asian Development Bank, Philippines, pp. 223.

ADB and IFPRI, 2009: Building climate resilience in the agriculture sector in Asia and the Pacific. Asian Development Bank, Philippines, pp. 304.

ADB., 2009: The economics of climate change in Southeast Asia: a regional review. Asian Development Bank, Philippines, pp. 223.

Adepetu, A. and A. Berthe, 2007: Vulnerability of Rural Sahelian Households to Drought: Options for Adaptation. A Final Report Submitted to Assessments of Impacts and Adaptations to Climate Change (AIACC). In: Project No. AF 92, Washington DC.

Adger, W.N., J. Barnett, F.S. Chapin III, and H. Ellemor, 2011: This Must Be the Place: Underrepresentation of Identity and Meaning in Climate Change Decision-Making. *Global Environmental Politics*, 11(2), 1-25.

Adger, W.N., 2006: Vulnerability. *Global Environmental Change*, 16(3), 268-281.

Afifi, T., 2011: Economic or Environmental Migration? The Push Factors in Niger. *International Migration*, 49(Suppl.1), e95-e124.

Agrawal, A. and N. Perrin, 2008: Climate Adaptation, Local Institutions and Rural Livelihoods. In: IFRI Working Paper W08I-6. School of Natural Resources and Environment, University of Michigan, Michigan, USA.

Agrawala, A., 2009: The Role of Local Institutions in Adaptation to Climate Change. In: World Bank Proceedings of Social Dimensions of Climate Change, March 5-6, 2008, pp. 65.

Agrawala, S. and M. Carraro, 2010: Assessing the role of microfinance in fostering adaptation to climate change. In: OECD Environmental Working Paper No. 15. OECD publishing, Paris, pp. 37.

Ahmed, S.A., N.S. Diffenbaugh, T.W. Hertel, and W.J. Martin, 2012: Agriculture and Trade Opportunities for Tanzania: Past Volatility and Future Climate Change. *Review of Development Economics*, 16(3), 429-447.
Ahmed, S.A., N.S. Diffenbaugh, and T.W. Hertel, 2009: Climate volatility deepens poverty vulnerability in developing countries. *Environmental Research Letters*, 4(3), 034004.
Ahmed, S.A., N.S. Diffenbaugh, T.W. Hertel, D.B. Lobell, N. Ramankutty, A.R. Rios, and P. Rowhani, 2011: Climate volatility and poverty vulnerability in Tanzania. *Global Environmental Change*, 21(1), 46-55.
Ainsworth, C.H. and U.R. Sumaila, 2005: Intergenerational valuation of fisheries resources can justify long-term conservation: a case study in Atlantic cod (Gadus morhua). *Canadian Journal of Fisheries and Aquatic Sciences*, Vol. 62 Pages: 1104-1110 2005, 62(5), 1104-1110.
Aksoy, M.A. and F. Ng, 2010: The Evolution of Agricultural Trade Flows. In: Research Working Paper 5308. World Bank, Washington, USA, pp. 35.
Alderman, H. and T. Haque, 2006: Countercyclical safety nets for the poor and vulnerable. *Food Policy*, 31(4), 372-383.
Aldred J., 2012: Climate change uncertainty, irreversibility and the precautionary principle. *Cambridge Journal of Economics*, 36(5), 1051-1072.
Allen, A., 2006: Understanding environmental change in the context of rural-urban interactions. In: *The Peri-Urban Interface: approaches to sustainable natural and human resource use*. [McGregor, D., D. Simon, and D. Thompson(eds.)]. Earthscan, London, pp. 30-43.
Allison, E.H., A.L. Perry, M. Badjeck, W. Neil Adger, K. Brown, D. Conway, A.S. Halls, G.M. Pilling, J.D. Reynolds, N.L. Andrew, and N.K. Dulvy, 2009: Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries*, 10(2), 173-196.
Amede, T., M. Menza, and Awlachew,S.AMEDE,Awlachew,S.B., 2011: Zai improves nutrient and water productivity in the ethiopian highlands. *Experimental Agriculture*, 47(Supplement S1), 7-20.
Anderson, K., 2010: Agricultural Policies: Past, Present and Prospective under Doha. In: *Food Crises and the WTO*. [Karapinar, B. and C. Haberli(eds.)]. Cambridge University Press, Cambridge, pp. 167-184.
Anderson, S. and Morton, J. and Toulmin, C, 2009: Climate change for agrarian societies in drylands: implications and future pathways. In: *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*. [Mearns, R. and A. Norton (ed.)]. World Bank, Washington, DC, .
Anderson, K., 2010: Globalization's effects on world agricultural trade. *Philosophical Transactions of the Royal Society B*: Biological Sciences, 365(1554), 3007-3021.
Anderson, K. and S. Nelgen, 2012: Trade Barrier Volatility and Agricultural Price Stabilization. *World Development*, 40(1), 36-48.
Andrew, N.L. and L. Evans, 2011: Approaches and Frameworks for Management and Research in Small-scale Fisherie. In: *Small-Scale Fisheries Management: Frameworks and Approaches for the Developing World*. [Pomeroy, R.S. and N. Andrew(eds.)]. CABI, Wallingford, UK;Cambridge, MA, pp. 16-34.
Anseeuw, W., M. Boche, T. Breu, M. Giger, J. Lay, P. Messerli, and K. Nolte, 2012: Transnational Land Deals for Agriculture in the Global South. In: *Analytical Report based on the Land Matrix Database*. CDE/CIRAD/GIGA, Bern/Montpellier/Hamburg, pp. 50.
Antwi-Agyei, P., E.D.G. Fraser, A.J. Dougill, L.C. Stringer, and E. Simelton, 2012: Mapping the vulnerability of crop production to drought in Ghana using rainfall, yield and socioeconomic data. *Applied Geography*, 32(2), 324-334.
Anwar, M.R., G. O'Leary, D. McNeil, H. Hossain, and R. Nelson, 2007: Climate change impact on rainfed wheat in south-eastern Australia. *Field Crops Research*, 104(1-3), 139-147.
Archer, E., E. Mukhala, S. Walker, M. Dilley, and K. Masamvu, 2007: Sustaining agricultural production and food security in Southern Africa: an improved role for climate prediction? *Climatic Change*, 83, 287-300.
Archer, E.R.M., 2003: Identifying underserved end-user groups in the provision of climate information. *Bulletin of the American Meteorological Society*, 84(11), 1525-1532.
Armah, A.K., G. Wiafe, and D.G. Kpelle, 2005: Sea-level rise and coastal biodiversity in West Africa: a case study from Ghana. In: *Climate Change and Africa*. [Low, P.S. (ed.)]. Cambridge University Press, Cambridge, UK, pp. 204-217-217.
Arndt, C. and F. Tarp, 2000: Agricultural Technology, Risk, and Gender: A CGE Analysis of Mozambique. *World Development*, 28(7), 1307-1326.
Assad, E.D., H.S. Pintor, J.Z. Junior, and A.M.H. Avila, 2004: Climatic changes impact in agroclimatic zonning of coffee in Brazil. *Pesquisa Agropecuaria Brasileira*, 39(11), 1057-1064.

Asseng, S., M.I.:. Travasso F., and G.O. Magri, 2013: Has climate change opened new opportunities for wheat cropping in Argentina? *Climatic Change*, 117(1-2), 181-196.
Audsley, E., K.R. Pearn, C. Simota, G. Cojocaru, E. Koutsidou, M.D.A. Rousevell, M. Trnka, and V. Alexandrov, 2006: What can scenario modelling tell us about future European scale agricultural land use, and what not? *Environmental Science & Policy*, 9(2), 148-162.
Baca, M., P. Laderach, O. Ovalle, and J. Haggar, 2010: Quantifying the impact of climate change on Mesoamerican farmers livelihoods and develop community-based adaptation strategies.Proceedings of Tropentag, September 14-16, 2010, Zurich, Switzerland, .
Backus G.A., Lowry T.S., and Warren D.E., 2013: The near-term risk of climate uncertainty among the U.S. states. *Climatic Change*, 116(3-4), 495-522.
Badjeck, M., E.H. Allison, A.S. Halls, and N.K. Dulvy, 2010: Impacts of climate variability and change on fishery-based livelihoods. *Marine Policy*, 34(3), 375-383.
Baiphethi, M.N., M. Viljoen, and G. Kundhlande, 2008: Rural women and rainwater harvesting and conservation practices: Anecdotal evidence from the Free State and Eastern Cape. *Agenda*, 22(78), 163-171.
Bandiera, O. and I. Rasul, 2006: Social networks and technology adoption in northern Mozambique. *The Economic Journal*, 116(514), 869-902.
Barbier, B., H. Yacouba, H. Karambiri, M. Zorome, and B. Some, 2009: Human Vulnerability to Climate Variability in the Sahel: Farmers' Adaptation Strategies in Northern Burkina Faso. *Environmental Management*, 43, 790-803.
Barrett, C.B. and D.G. Maxwell, 2006: Towards a global food aid compact. *Food Policy*, 31(2), 105-118.
Bartsch, A., T. Kumpula, B.C. Forbes, and F. Stammler, 2010: Detection of snow surface thawing and refreezing in the eurasian arctic with QuikSCAT: Implications for reindeer herding. *Ecological Applications*, 20(8), 2346-2358.
Batisani, N. and B. Yarnal, 2010: Rainfall variability and trends in semi-arid Botswana: Implications for climate change adaptation policy. *Applied Geography*, 30(4), 483-489.
Beaumier, M.C. and J.D. Ford, 2010: Food insecurity among Inuit women exacerbated by socioeconomic stresses and climate change. *Canadian Journal of Public Health*, 101(3), 196-201.
Bell, A.R., N.L. Engle, and M.C. Lemos, 2011: How does diversity matter? the case of Brazilian river basin councils. *Ecology and Society*, 16(1), 42.
Bellon, M.R., D. Hodson, and J. Hellin, 2011: Assessing the vulnerability of traditional maize seed systems in Mexico to climate change. *Proceedings of the National Academy of Sciences of the United States of America*, 108(33), 13432-13437.
Below, T.B., K.D. Mutabazi, D. Kirschke, C. Franke, S. Sieber, R. Siebert, and K. Tscherning, 2012: Can farmers' adaptation to climate change be explained by socio-economic household-level variables? *Global Environmental Change*, 22(1), 223-235.
Beniston, M., 2010: Impacts of climatic change on water and associated economic activities in the Swiss Alps. *Journal of Hydrology*, 412, 291-296.
Berman, R., C. Quinn, and J. Paavola, 2012: The role of institutions in the transformation of coping capacity to sustainable adaptive capacity. *Environmental Development*, 2(0), 86-100.
Biazin, B., G. Sterk, M. Temesgen, A. Abdulkedir, and L. Stroosnijder, 2011: Rainwater harvesting and management in rainfed agricultural systems in sub-Saharan Africa – A review. *Physics and Chemistry of the Earth, Parts A/B/C*, in press.
Biemans, H.,Haddeland,I., P. Kabat, F. Ludwig, R.W.A. Hutjes, J. Heinke, W. von Bloh, and D. Gerten, 2011: Impact of reservoirs on river discharge and irrigation water supply during the 20th century. *Water Resources Research*, 47, 1-15.
Bigano, A., J.M. Hamilton, and R.S.J. Tol, 2007: The impact of climate change on domestic and international tourism: A simulation study. *The Integrated Assessment Journal*, Vol. 7 (1) 25–49.
Bigano, A., F. Bosello, R. Roson, and R.S.J. Tol, 2008: Economy-wide impacts of climate change: a joint analysis for sea level rise and tourism. *Mitigation and Adaptation Strategies for Global Change*, 13(8), 765-791.
Binns, T. and R. Maconachie, 2006: Re-evaluating people-environment relationships at the rural-urban interface: how sustainable is the peri-urban zone in Kano, northern Nigeria? In: *The Peri-Urban Interface: approaches to sustainable natural and human resource use*. [McGregor D, Simon D, Thompson D (ed.)]. Earthscan, London, pp. 211-228.

Black R., Kniveton D., and Schmidt-Verkerk K., 2011: Migration and climate change: Towards an integrated assessment of sensitivity. *Environment and Planning*, 43(2), 431-450.
Black, R., W.N. Adger, N.W. Arnell, S. Dercon, A. Geddes, and D. Thomas, 2011: The effect of environmental change on human migration. *Global Environmental Change*, 21, Supplement 1(0), S3-S11.
Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo, and P. Yanda, 2007: Africa. In: *Climate Change2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [Parry, M.L., J.P. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson(eds.)]. Cambridge University Press, Cambridge,UK, pp. 433-467.
Bonatti, M., E. Gentile, A.C.F.d. Vasconcelos, L.H.I. Ribeiro Homem, L.R. D'Agostini, and S.L. Schlindwein, 2012: Vulnerability to climate change and different perceptions of social actors: Thinking about motivation problems. Climatic Change, (manuscript draft).
Boone, R.B., K.A. Galvin, M.B. Coughenour, J.W. Hudson, P.J. Weisberg, C.H. Vogel, and J.E. Ellis, 2004: Ecosystem modelling adds value to a South African climate forecast. *Climatic Change*, 64, 317-340.
Bowyer-Bower, T., 2006: The inevitable illusiveness of 'sustainability' in the peri-urban interface: the case of Harare. In: *The Peri-Urban Interface: approaches to Sustainable natural and human resource use*. [McGregor, D., D. Simon, and D. Thompson(eds.)]. Routledge, London, pp. 150-164.
Boyd, R. and M.E. Ibarraran, 2009: Extreme climate events and adaptation: an exploratory analysis of drought in Mexico. *Environment and Development Economics*, 14(3), 371-395.
Brekke, K.A. and O. Johansson-Stenman, 2008: The behavioural economics of climate change. *Oxford Review of Economic Policy*, 24(2), 280-297.
Brondizio, E.S. and E.F. Moran, 2008: Human dimensions of climate change: the vulnerability of small farmers in the Amazon. *Philosophical Transactions of the Royal Society B*, 363(1498), 1803-1809.
Brooks, N., N. Grist, and K. Brown, 2009: Development Futures in the Context of Climate Change: Challenging the Present and Learning from the Past. *Development Policy Review*, 27(6), 741-765.
Brouder, P. and L. Lundmark, 2011: Climate change in Northern Sweden: intra-regional perceptions of vulnerability among winter-oriented tourism businesses. *Journal of Sustainable Tourism*, 19(8), 919-933.
Brouwer, R. and J. Nhassengo, 2006: About Bridges and Bonds: Community Responses to The 2000 Floods in Mabalane District, Mozambique. *Disasters*, 30(2), 234-255.
Brouwer, R., S. Akter, L. Brander, and E. Haque, 2007: Socioeconomic vulnerability and adaptation to environmental risk: A case study of climate change and flooding in Bangladesh. *Risk Analysis*, 27(2), 313-326.
Brown D.G., Robinson D.T., Zellner M., Rand W., Riolo R., Page S.E., Nassauer J.I., Low B., Wang Z., and An L., 2008: Exurbia from the bottom-up: Confronting empirical challenges to characterizing a complex system. *Geoforum*, 39(2), 805-818.
Brown, O., A. Hammill, and R. Mcleman, 2007: Climate change as the 'new' security threat: implications for Africa. *International Affairs*, 83(6), 1141-1154.
Brown, O., 2008: Migration and Climate Change. In: *IOM Migration Research Series No 31*. International Organization for Migration, Geneva, Switzerland, pp. 54.
Brown, O. and A. Crawford, 2008: Climate change: A new threat to stability in West Africa? Evidence from Ghana and Burkina Faso. *African Security Review*, 17(3), 39-57.
Brown, S., A.S. Kebede, and R.J. Nicholls, 2011: Sea-Level Rise and Impacts in Africa, 2000 to 2100 . School of Civil Engineering and the Environment, University of Southampton, Southampton, UK, pp. 215.
Bryan, E., T.T. Deressa, G.A. Gbetibouo, and C. Ringler, 2009: Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science and Policy*, 12, 413-426.
Bryceson, D.F., 2002: The Scramble in Africa: Reorienting Rural Livelihoods. *World Development*, 30(5), 725-739.
Bunce, M., 2008: The 'leisuring' of rural landscapes in Barbados: new spatialities and the implications for sustainability in small island states. *Geoforum*, 39(2), 969-979.
Bunce, M., S. Rosendo, and K. Brown, 2009: Perceptions of climate change, multiple stressors and livelihoods on marginal African coasts. Environment, Development and Sustainability, 12(3), 407-440.
Burke, M.B., D.B. Lobell, and L. Guarino, 2009: Shifts in African crop climates by 2050, and the implications for crop improvement and genetic resources conservation. *Global Environmental Change*, 19(3), 317-325.
Burte, J.D.P., A. Coudrain, and S. Marlet, 2011: Use of water from small alluvial aquifers for irrigation in semi-arid. *Revista Ciência Agronômica*, 42, 635-643.

Bury J.T., French A., Mark B.G., Huh K.I., McKenzie J.M., Baraer M., Zapata Luyo M.A., and Gomez Lopez R.J., 2011: Glacier recession and human vulnerability in the Yanamarey watershed of the Cordillera Blanca, Peru. *Climatic Change*, 105(1), 179-206.
Butt, T.A., B.A. McCarl, and A.O. Kergna, 2006: Policies for reducing agricultural sector vulnerability to climate change in Mali. *Climate Policy*, 5, 583-598.
Byass, P., 2009: Climate change and population health in Africa: where are the scientists? *Global Health Action*, 2, 4.
Calzadilla, A., T. Zhu, K. Rehdanz, R.S.J. Tol, and C. Ringle, 2009: Economywide Impacts of Climate Change on Agriculture in Sub-Saharan Africa. In: IFPRI Discussion Paper 00873. International Food Policy Research Institute, Washington DC, USA, pp. 33.
Calzadilla, A., K. Rehdanz, and R.S.J. Tol, 2011: Trade liberalization and climate change: a computable general equilibrium analysis of the impacts on global agriculture. *Water*, 3(2), 526-550.
Camargo, M.B.P., 2010: The impact of climatic variability and climate change on arabic coffee crop in Brazil. *Bragantia*, 69(1), 239-247.
Cameron, E.S., 2012: Securing Indigenous politics: A critique of the vulnerability and adaptation approach to the human dimensions of climate change in the Canadian Arctic. *Global Environmental Change*, 22(1), 103-114.
Campbell, D., D. Barker, and D. McGregor, 2011: Dealing with drought: Small farmers and environmental hazards in southern St. Elizabeth, Jamaica. *Applied Geography*, 31(1), 146-158.
Cannon, T. and D. Müller-Mahn, 2010: Vulnerability, Resilience and Development Discourses in Context of Climate Change. *Natural Hazards*, 55(3), 621-625.
Carey, M., 2010: *In the shadow of melting glaciers : climate change and Andean society*. Oxford University Press, New York, .
Carey, M., C. Huggel, J. Bury, C. Portocarrero, and W. Haeberli, 2012: An integrated socio-environmental framework for glacier hazard management and climate change adaptation: lessons from Lake 513, Cordillera Blanca, Peru. *Climatic Change*, 112(3-4), 3-4.
Casale, M., S. Drimie, T. Quinlan, and G. Ziervogel, 2010: Understanding vulnerability in southern Africa: comparative findings using a multiple-stressor approach in South Africa and Malawi. *Regional Environmental Change*, 10(2), 157-168.
Casillas, C.E. and D.M. Kammen, 2010: The Energy-Poverty-Climate Nexus. *Science*, 330(6008), 1181-1182.
Castro, A.P., D. Taylor, and D.W. Brokensha, 2012: *Climate Change and Threatened Communities: Vulnerability, Capacity, and Action*. Practical Action Publishing, Bourton on Dunsmore, UK, pp. 224.
Challinor, A., T. Wheeler, C. Garforth, P. Craufurd, and A. Kassam, 2007: Assessing the vulnerability of food crop systems in Africa to climate change. *Climatic Change*, 83(3), 381-399.
Challinor, A., 2009: Towards the development of adaptation options using climate and crop yield forecasting at seasonal to multi-decadal timescales. *Environmental Science & Policy*, 12(4), 453-465.
Chambers, R. and G.R. Conway, 1992: Sustainable rural livelihoods : practical concepts for the 21st century. Institute of Development Studies (IDS), Brighton, U.K., pp. 29.
Chatterjee, K., A. Chatterjee, and S. Das, 2005: Case Study 2: India Community Adaptation to Drought in Rajasthan. *IDS Bulletin*, 36(4), 33-52.
Chenoweth, J.,P., A. Bruggeman J., Z. Levin, M. Lange, E. Xoplaki, and M. Hadjikakou, 2011: The impact of climate change on the water resources of the eastern Mediterranean and Middle East region: modeled changes and socio-economic implications. *Water Resources Research*, 47(6), W06506.
Chigwada, J., 2005: Case Study 6: Zimbabwe Climate Proofing Infrastructure and Diversifying Livelihoods in Zimbabwe. *IDS Bulletin*, 36(4), 103-116.
Chopra, K. and P. Dasgupta, 2008: Assessing the economic and ecosystem services contribution of forests: issues in modelling, and an illustration. *International Forestry Review*, 10(2), 376-386.
CIAT, 2010: Climate adaptation and mitigation in the Kenyan coffee sector. International Center for Tropical Agirculture, Cali, Colombia, pp. 42.
CIAT, 2011a: Future Climate Scenarios for Kenya's Tea Growing Areas. International Center for Tropical Research (CIAT), Cali, Colombia, pp. 33.
CIAT, 2011b: Future Climate Scenarios for Uganda's Tea Growing Areas. International Center for Tropical Research (CIAT), Cali, Colombia, pp. 29.
CIAT, 2011c: Predicting the Impact of Climate Change on the Cocoa-Growing Regions in Ghana and Cote d'Ivoire. International Center for Tropical Agriculture (CIAT), Cali, Colombia, pp. 35.

Cinner, J.E., T.R. McClanahan, T.M. Daw, N.A.J. Graham, J. Maina, S.K. Wilson, and T.P. Hughes, 2009: Linking Social and Ecological Systems to Sustain Coral Reef Fisheries. *Current Biology*, 19(3), 206-212.
Cocklin C., Dibden J., and Gibbs D., 2008: Competitiveness versus 'clean and green'? The regulation and governance of GMOs in Australia and the UK. *Geoforum*, 39(1), 161-173.
Coe, R. and R.D. Stern, 2011: Assessing and addressing climate-induced risk in sub-Saharan rainfed agriculture: Lessons learned. *Experimental Agriculture*, 47, 395-410.
Cohen, B., 2004: Urban growth in developing countries: a review of current trends and a caution regarding existing forecasts. *World Development*, 32(1), 23-51.
Coles, A.R. and C.A. Scott, 2009: Vulnerability and adaptation to climate change and variability in semi-arid rural Southeastern Arizona, USA. *Natural Resources Forum*, 33(4), 297-309.
Collier, P., G. Conway, and T. Venables, 2008: Climate change and Africa. *Oxford Review of Economic Policy*, 24(2), 337-353.
Connell, D. and Q. Grafton, 2011: *Basin Futures. Water reform in the Murray-Darling Basin*. [ANU E-Press (ed.)], Canberra,Australia, pp. 500.
Conway, D. and E.L.F. Schipper, 2011: Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia. *Global Environmental Change*, 21, 227-237.
Cooper, P.J.M., J. Dimes, K.P.C. Rao, B. Shapiro, B. Shiferaw, and S. Twomlow, 2008: Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? *Agriculture, Ecosystems and Environment*, 126, 24-35.
COPA-COGECA, 2003: Assessment of the impacts of the heat wave and drought of summer 2003 on agriculture and forestry. COPA-COGECA.
Cordalis, D. and D.B. Suagee, 2008: The effects of climate change on American Indian and Alaska Native Tribes. *Natural Resources & Environment*, 22(3), 45.
Costello, A., M. Abbas, A. Allen, S. Ball, S. Bell, R. Bellamy, S. Friel, N. Groce, A. Johnson, M. Kett, M. Lee, C. Levy, M. Maslin, D. McCoy, B. McGuire, H. Montgomery, D. Napier, C. Pagel, J. Patel, J.A.P. de Oliveira, N. Redclift, H. Rees, D. Rogger, J. Scott, J. Stephenson, J. Twigg, J. Wolff, and C. Patterson, 2009: Managing the health effects of climate change. *The Lancet*, 373(9676), 1693-1733.
Crane, T.A., C. Roncoli, and G. Hoogenboom, 2011: Adaptation to climate change and climate variability: The importance of understanding agriculture as performance. *NJAS-Wageningen Journal of Life Sciences*, 57, 179-185.
Crane, T.A., C. Roncoli, J. Paz, N. Breuer, K. Broad, K.T. Ingram, and G. Hoogenboom, 2010: Forecast skill and farmers' skills: seasonal climate forecasts and agricultural risk management in the Southeastern United States. *Weather, Climate, and Society*, 2(1), 44-59.
Cruz, R.V., H. Harasawa, M. Lal, S. Wu, Y. Anokhin, B. Punsalmaa, Y. Honda, M. Jafari, C. Li and N. Huu Ninh, 2007: Asia. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (ed.)]. Cambridge University Press, Cambridge, UK, pp. 469-506.
Cunguara, B. and I. Darnhofer, 2011: Assessing the impact of improved agricultural technologies on household income in rural Mozambique. *Food Policy*, 36(3), 378-390.
Dasgupta, P., 2009: Valuation of Ecosystem Services: Methodologies, Illustrations and Use. In: *Handbook of Environmental Economics in India*. [Chopra, K. and V. Dayal(eds.)]. Oxford University Press, Delhi, pp. 137-150.
Dasgupta, P., 2008: Nature in economics. *Environmental & Resource Economics*, 39(1), 1-7.
Dasgupta, S., B. Laplante, C. Meisner, D. Wheeler, and J. Yan, 2009: The impact of sea level rise on developing countries: a comparative analysis. *Climatic Change*, 93(3-4), 3-4.
Dasgupta, S., B. Laplante, C. Meisner, D. Wheeler, and J. Yan, 2007: The impact of sea level rise on developing countries : a comparative analysis. In: *World Bank Policy Research Working Paper 4136*. World Bank, Development Research Group, Sustainable Rural and Urban Development Team, [Washington, D.C.].
Davies, J. and M. Nori, 2008: Managing and Mitigating Climate Change through Pastoralism. *Policy Matters*, 16, 127-162.
Davies, J. and R. Bennett, 2007: Livelihood adaptation to risk: Constraints and opportunities for pastoral development in Ethiopia's Afar region. *Journal of Development Studies*, 43(3), 490-511.

Dawson, J., E.J. Stewart, H. Lemelin, and D. Scott, 2010: The carbon cost of polar bear viewing tourism in Churchill, Canada. *Journal of Sustainable Tourism*, 18(3), 319-336.
de Haas, H., 2011: Mediterranean migration futures: Patterns, drivers and scenarios. *Global Environmental Change*, 21, Supplement 1(0), S59-S69.
De Sherbinin A., Warner K., and Ehrhart C., 2011: Casualties of climate change. *Scientific American*, 304(1), 64-71.
De Silva, C.S., E.K. Weatherhead, J.W. Knox, and J.A. Rodriguez-Diaz, 2007: Predicting the impacts of climate change - A case study of paddy irrigation water requirements in Sri Lanka. *Agricultural Water Management*, 93, 19-29.
Defra, 2011: Statistical Digest of Rural England 2011. Defra; Government Statistical Service, UK.
Dekens, J., 2008: Local Knowledge on Flood Preparedness: Examples from Nepal and Pakistan. In: *Indigenous Knowledge for Disaster Risk Reduction: Good Practices and Lessons Learned from Experiences in the Asia-Pacific Region*. [Shaw, R., N. Uy, and J. Baumwoll(eds.)]. UN ISDR Asia and Pacific, Bangkok, Thailand, pp. 35-40.
del Río, P. and M. Burguillo, 2008: Assessing the impact of renewable energy deployment on local sustainability: Towards a theoretical framework. *Renewable and Sustainable Energy Reviews*, 12(5), 1325-1344.
Delucchi, M.A., 2010: Impacts of Biofuels on Climate Change, Water Use, and Land Use. *Annals of the New York Academy of Sciences*, 1195(1), 28-45.
Denton, F., 2002: Climate change vulnerability, impacts, and adaptation: why does gender matter? *Gender and Development*, 10(2), 10-20.
Denton, F., 2004: Gender and climate change: giving the "latecomer" a head start. *IDS Bulletin*, 35(3), 42-49.
Deressa, T.T., R.M. Hassan, C. Ringler, T. Alemu, and M. Yesuf, 2009: Determinants of farmers’ choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, 19, 248-255.
Deryng, D., W.J. Sacks, C.C. Barford, and N. Ramankutty, 2011: Simulating the effects of climate and agricultural management practices on global crop yield. *Global Biogeochemical Cycles*, 25, GB2006.
Desakota Study Team, 2008: Re-imagining the Rural-Urban Continuum: Understanding the Role Ecosystem Services Play in the Livelihoods of the Poor in Desakota Regions Undergoing Rapid Change. Institute for Social and Environmental Transition-Nepal (ISET-N), Kathmandu, Nepal, pp. 124.
Devendra, C., J. Morton, B. Rischowsky, and D. Thomas, 2005: Livestock Systems. In: *Livestock and Wealth Creation: Improving the Husbandry of Livestock Kept by the Poor in Developing Countries*. [Owen, E., A. Kitalyi, N. Jayasuriya, and T. Smith(eds.)]. Nottingham University Press, Nottinghamn, Uk;, .
Devereux, S., 2009: Why does famine persist in Africa? *Food Security*, 1(1), 25-35.
Diaz-Chavez, R., 2006: Measuring sustainability in peri-urban areas: case study of Mexico City. In: *The Peri-Urban Interface: approaches to sustainable natural and human resource use*. [McGregor D, Simon D, Thompson D (ed.)]. Earthscan, London, pp. 246-265.
Dietz, S., C. Hepburn, and N. Stern, 2007: Economics, Ethics and Climate Change. *Ssrn Elibrary*, 25.02.2013.
Dockerty, T., A. Lovett, K. Appleton, A. Bone, and G. Sunnenberg, 2006: Developing scenarios and visualisations to illustrate potential policy and climatic influences on future agricultural landscapes. *Agriculture Ecosystems and Environment*, 114(1), 103-120.
Döll, P., 2009: Vulnerability to the impact of climate change on renewable groundwater resources: A global-scale assessment. *Environmental Research Letters*, 4(3), 035006.
Dong S., Wen L., Liu S., Zhang X., Li X., Li J., Li Y., Lassoie J.P., and Yi S., 2011: Vulnerability of worldwide pastoralism to global changes and interdisciplinary strategies for sustainable pastoralism. *Ecology and Society*, 16(2).
Dougill, A.J., E.D.G. Fraser, and M.S. Reed, 2010: Anticipating vulnerability to climate change in dryland pastoral systems: using dynamic systems models for the Kalahari. *Ecology and Society*, 15(2), 17.
Dube, O.P. and M.B.M. Sekhwela, 2007: Community Coping Strategies in Semiarid Limpopo Basin Part of Botswana: Enhancing Adaptation Capacity to Climate Change. In: *AIACC Working Paper No. 47* April 2007, Washington DC.
Eakin, H., 2005: Institutional change, climate risk, and rural vulnerability: Cases from central Mexico. *World Development*, 33(11), 1923-1938.
Eakin, H. and A.L. Luers, 2006: Assessing the vulnerability of social-environmental systems. *Annual Review of Environment and Resources*, 31(1), 365-394.

Eakin, H. and K. Appendini, 2008: Livelihood change, farming, and managing flood risk in the Lerma Valley, Mexico. *Agriculture and Human Values*, 25(4), 555-566.
Eakin, H. and L.A. Bojórquez-Tapia, 2008: Insights into the composition of household vulnerability from multicriteria decision analysis. *Global Environmental Change*, 18(1), 112-127.
Eakin, H., L.A. Bojorquez-Tapia, R. Monterde Diaz, E. Castellanos, and J. Haggar, 2011: Adaptive capacity and social-environmental change: theoretical and operational modeling of smallholder coffee systems response in Mesoamerican Pacific Rim. *Environmental Management*, 47(3), 352-367.
Eakin, H.C. and M.B. Wehbe, 2009: Linking local vulnerability to system sustainability in a resilience framework: two cases from Latin America. *Climatic Change*, 93(3-4), 355-377.
Easterling, W., P. Aggarwal, P. Batima, K. Brander, L. Erda, M. Howden, A. Kirilenko, J. Morton, J.-F. Soussana, S. Schmidhuber, and F. Tubiello, 2007: Food, fibre and forest products. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, U.K.; New York, pp. 273-313.
Ebi, K.L., 2008: Adaptation costs for climate change-related cases of diarrhoeal disease, malnutrition, and malaria in 2030. *Globalization and Health*, 4(9), 9.
ECLAC, 2009: Economics of Climate Change in Latin America and the Caribbean – Summary 2009. Economic Commission for Latin America and the Caribbean (ECLAC), Santiago, Chile, pp. 68.
ECLAC, 2009: The Economics of Climate Change in Central America – Summary 2010. Economic Commission for Latin America and the Caribbean (ECLAC), Santiago, Chile, pp. 146.
ECLAC, 2010: Economics of Climate Change in Latin America and the Caribbean – Summary 2010. Economic Commission for Latin America and the Caribbean (ECLAC), Santiago, Chile, pp. 107.
Eide, A., 2008: The right to food and the impact of biofuels (agrofuels). FAO, Rome, pp. 60.
Eliasch, J., 2008: *Climate change financing global forests : the Eliasch review*. Earthscan, London; Sterling, VA, .
Ellis, F., 1999: Rural livelihood diversity in developing countries: evidence and policy implications. *ODI Natural Resource Perspectives*, (40), 4.
Ellis, F., 2000: The Determinants of Rural Livelihood Diversification in Developing Countries. *Journal of Agricultural Economics*, 51(2), 289-302.
El-Sadek, A., 2010: Virtual water trade as a solution for water scarcity in Egypt. *Water Resources Management*, 24(11), 2437-2448.
Ensor, J. and R. Berger, 2009: *Understanding Climate Change Adaptation: Lessons from Community-Based Approaches*. Practical Action Publishing, Bourton on Dunsmore,UK, pp. 208.
Erenstein, O., K. Sayre, P. Wall, J. Hellin, and J. Dixon, 2012: Conservation agriculture in maize- and wheat-based systems in the (sub)tropics: lessons from adaptation initiatives in South Asia, Mexico, and Southern Africa. *Journal of Susainable Agriculture*, 36(2), 180-206.
Ericksen, P., J. de Leeuw, Thornton P., M. Said, M. Herrero, and A. Notenbaert, 2012: Climate change in Sub-Saharan Africa: what consequences for pastoralism? . In: *Pastoralism and Development in Africa: Dynamic Change at the Margins*. [Catley, A., J. Lind, and I. Scoones(eds.)]. Routledge, London, New York, .
Ericksen, P.J., 2008: What is the vulnerability of a food system to global environmental change? *Ecology and Society*, 13(2), 14.
Ericksen, P.J., 2008: Conceptualizing food systems for global environmental change research. *Global Environmental Change*, 18(1), 234-245.
Eriksen, S.H. and K. O'Brien, 2007: Vulnerability, poverty and the need for sustainable adaptation measures. *Climate Policy*, 7(4), 337-352.
Eriksen, S. and J. Lind, 2009: Adaptation as a political process: adjusting to drought and conflict in Kenya's drylands. *Environmental Management*, 43, 817-835.
Ettenger, K., 2012: Aapuupayuu (the weather warms up): climate change and the Eeyouch (Cree) of Northern Quebec". In: *Climate Change and Threatened Communities: Vulnerability, capacity and action*. [Castro, A.P., D. Taylor, and D.W. Brokensha(eds.)]. Practical Action Publishing, Rugby, UK;, .
Fairhead, J. and M. Leach, 2005: The Centrality of the Social in African Farming. *IDS Bulletin*, 36(2), 86-90.
Falloon, P. and R. Betts, 2010: Climate impacts on European agriculture and water management in the context of adaptation and mitigation-The importance of an integrated approach. *Science of the Total Environment*, 408(23), 5667-5687.
FAO, 2008: Policy Measures Taken by Governments to Reduce the Impact of Soaring Prices. In: *Crop Prospects and Food Situation,* Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 13-17.

FAO, 2011: The state of forest resources – a regional analysis. In: *State of the World's Forests 2011*. Food and Agriculture Organization of the United Nations, Rome, pp. 1-27.
FAO, 2011: *State of the World's Forests 2011*. Rome, Italy, pp. 164.
Farber, S., R. Costanza, D.L. Childers, J. Erickson, K. Gross, M. Grove, C.S. Hopkinson, J. Kahn, S. Pincetl, A. Troy, P. Warren, and M. Wilson, 2006: Linking ecology and economics for ecosystem management. *Bioscience*, 56(2), 121-133.
Figueiredo, P. and P.E. Perkins, Women and water management in times of climate change: participatory and inclusive processes. *Journal of Cleaner Production*, (online).
Findlay, A.M., 2011: Migrant destinations in an era of environmental change. *Global Environmental Change*, 21, Supplement 1(0), S50-S58.
Fischlin, A., G.F. Midgley, J.T. Price, R. Leemans, B. Gopal, C. Turley, M.D.A. Rounsevell, O.P. Dube, J. Tarazona, and A.A. Velichko, 2007: Ecosystems, their properties, goods, and services. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, pp. 211-272.
Fisher, M., M. Chaudhury, and B. McCusker, 2010: Do forests help rural households adapt to climate variability? evidence from Southern Malawi. *World Development*, 38(9), 1241-1250.
Forbes, B.C. and T. Kumpula, 2009: The ecological role and geography of reindeer (*Rangifer tarandus*) in Northern Eurasia. *Geography Compass*, 3/4, 1356-1380.
Ford, J.D., L. Berrang-Ford, M. King, and C. Furgal, 2010: Vulnerability of Aboriginal health systems in Canada to climate change. *Global Environmental Change*, 20(4), 668-68ß.
Ford, J.D. and T. Pearce, 2010: What we know, do not know, and need to know about climate change vulnerability in the western Canadian Arctic: a systematic literature review. *Environmental Research Letters*, 5(1), 9.
Foresight: *Migration and Global Environmental Change, 2011: Final Project Report*. The Government Office for Science, London, pp. 236.
Franco, G., D.R. Cayan, S. Moser, M. Hanemann, and M. Jones, 2011: Second California Assessment: integrated climate change impacts assessment of natural and managed systems. *Climatic Change*, 109(Suppl. 1), 1-19.
Fraser, E.D.G., A.J. Dougill, K. Hubacek, C.H. Quinn, J. Sendzimir, and M. Termansen, 2011: Assessing vulnerability to climate change in dryland livelihood systems: conceptual challenges and interdisciplinary solutions. *Ecology and Society*, 16(3), 3.
Fuessel, H., 2007: Vulnerability: A generally applicable conceptual framework for climate change research. *Global Environmental Change*, 17(2), 155-167.
Furgal, C. and T. Prowse, 2008: Northern Canada. In: *From impacts to adaptation: Canada in a changing climate. 2007* [Lemmen, D.S., F.J. Warren, J. Lacroix, and E. Bush(eds.)]. Government of Canada, Ottawa,Canada, pp. 61-118.
Gachathi, F.N. and S. Eriksen, 2011: Gums and resins: The potential for supporting sustainable adaptation in Kenya's drylands. *Climate and Development*, 3(1), 59-70.
Gatto, J., B. Kim, P. Mahdavi, H. Namekawa, and H. Tran, 2009: The Future Impact of Climate Change on the California Wine Industry and Actions the State of California Should Take to Address It. International Policy Studies Program, Stanford University, Stanford, USA, pp. 52.
Gay, C., F. Estrada, C. Conde, H. Eakin, and L. Villers, 2006: Potential impacts of climate change on agriculture: A case of study of coffee production in Veracruz, Mexico. *Climatic Change*, 79(3-4), 259-288.
Gbetibouo, G.A., R.M. Hassan, and C. Ringler, 2010: Modelling farmers' adaptation strategies for climate change and variability: The case of the Limpopo Basin, South Africa. *Agrekon: Agricultural Economics Research, Policy and Practice in Southern Africa*, 49(2), 217-234.
Gbetibouo, G.A., C. Ringler, and R. Hassan, 2010: Vulnerability of the South African farming sector to climate change and variability: An indicator approach. *Natural Resources Forum*, 34(3), 175-187.
Geerts, S. and D. Raes, 2009: Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas. *Agricultural Water Management*, 96(9), 1275-1284.
Geerts, S., D. Raes, and M. Garcia, 2010: Using AquaCrop to derive deficit irrigation schedules. , 98(1), 213-216. *Agricultural Water Management*, 98(1), 213-216.
Gehrig-Fassel, J., A. Guisan, and N.E. Zimmermann, 2007: Tree line shifts in the Swiss Alps: climate change or land abandonment? *Journal of Vegetation Science*, 18(4), 571-582.

Gellrich, M., P. Baur, B. Koch, and N.E. Zimmermann, 2007: Agricultural land abandonment and natural forest re-growth in the Swiss mountains: A spatially explicit economic analysis. *Agriculture, Ecosystems&Environment*, 118(1-4), 93-108.
Gellrich, M., P. Baur, B.H. Robinson, and P. Bebi, 2008: Combining classification tree analyses with interviews to study why sub-alpine grasslands sometimes revert to forest: A case study from the Swiss Alps. *Agricultural Systems*, 96(1-3), 124-138.
Gemenne, F., 2011: Why the numbers don't add up: A review of estimates and predictions of people displaced by environmental changes. *Global Environmental Change*, 21, Supplement 1(0), S41-S49.
Giannakopoulos, C., P. Le Sager, M. Bindi, M. Moriondo, E. Kostopoulou, and C.M. Goodess, 2009: Climatic changes and associated impacts in the Mediterranean resulting from a 2 degrees C global warming. *Global and Planetary Change*, 68(3), 209-224.
Gilles, J.L., J.L. Thomas, C. Valdivia, and E.S. Yucra, 2013: Laggards or leaders: conservers of traditional agricultural knowledge in Bolivia. *Rural Sociology*, 78(1), 51-74.
Glaas, E., A. Jonsson, M. Hjerpe, and Y. Andersson-Sköld, 2010: Managing climate change vulnerabilities: formal institutions and knowledge use as determinants of adaptive capacity at the local level in Sweden. *Local Environment*, 15(6), 525-539.
Gladwin, C.H., A.M. Thomson, J.S. Peterson, and A.S. Anderson, 2001: Addressing food security in Africa via multiple livelihood strategies of women farmers. Food Policy, 26(2), 177-207.
GOI, 2012: Implication of Terms Used in Indian Censuses. Government of India Office of the Registrar:General and Census Commissioner, http://censusindia.gov.in/Data_Products/Library/Indian_perceptive_link/Census_Terms_link/censusterms.html .
Gough, K. and P. Yankson, 2006: Conflict and cooperation in environmental management in peri-urban Accra, Ghana. In: *The Peri-Urban Interface: approaches to sustainable natural and human resource use*. [McGregor, D., D. Simon, and D. Thompson(eds.)]. Earthscan, London, pp. 196-2010.
Goulden, M., L.O. Naess, K. Vincent, and W.N. Adger, 2009: Diversification, networks and traditional resource management as adaptations to climate extremes in rural Africa: opportunities and barriers. In: *Adapting to Climate Change: Thresholds, Values and Governance*. [Adger, W.N., I. Lorenzoni, and K. O'Brien(eds.)]. Cambridge University Press, Cambridge, pp. 448-464.
Goulden, M., D. Conway, and A. Persechino, 2009a: Adaptation to climate change in international river basins in Africa: a review. *Hydrological Sciences*, 54(5), 805-828.
Gowdy, J.M., 2008: Behavioral economics and climate change policy. *Journal of Economic Behavior and Organization*, 68(3-4), 632-644.
Gray, C. and V. Mueller, 2012: Drought and Population Mobility in Rural Ethiopia. *World Development*, 40(1), 134-145.
GTZ/CafeDirect/Sangana Commodities Ltd, 2011: Climate Change and Coffee: training for coffee organizations and extension services. GTZ, Eschborn, Germany, pp. 42.
Gubert, F. and C.J. Nordman, 2010: Migration trends in North Africa: focus on Morocco, Tunisia and Algeria. *OECD Journal:General Papers*, 15(4), 75-108.
Guiteras, R., 2007: The impacts of climate change on Indian agriculture. In: *Department of Economics Working Paper*. Massachutes Institue of Technology, Cambridge, pp. 53.
Gurgel, A., J.M. Reilly, and S. Paltsev, 2007: Potential land use implications of global biofuels industry. *Journal of Agricultural & Food Industrial Organization*, 5(2), Article 9.
Gyampoh, B.A., M. Idinoba, and S. Amisah, 2008: Water scarcity under a changing climate in Ghana: options for livelihoods adaptation. *Development*, 51, 415-417.
Haggar, J., 2009: Impact of climate change on coffee farming households in Central America and steps for adaptation in the future.[Rapidel, B., O. Roupsard, M. Navarro(eds.)]. Proceedings of International Workshop on Modelling Agroforestry Systems, CATIE, Costa Rica, pp. 99-104.
Hagler, R., 1998: The global timber supply/demand balance to 2030: has the equation changed. A Multi-Client Study by Wood Resources International., Reston, Virgina, USA, pp. 206.
Haim, D., M. Shechter, and P. Berliner, 2008: Assessing the impact of climate change on representative field crops in Israeli agriculture: a case study of wheat and cotton. *Climatic Change*, 86(3-4), 425-440.
Hall, S.J., 2011: Climate Change and Other External Drivers in Small-scale Fisheries: Practical Steps for Responding. In: *Small-Scale Fisheries Management: Frameworks and Approaches for the Developing World*.

[Pomeroy, R.S. and N. Andrew(eds.)]. CABI Publishing, Wallingford, Oxfordshire, UK ; Cambridge, MA, pp. 132-159.
Hall, C.M., 2006: New Zealand tourism entrepreneur attitudes and behaviours with respect to climate change adaptation and mitigation. *International Journal of Innovation and Sustainable Development*, 1(3), 229-237.
Halsnaes, K. and S. Traerup, 2009: Development and Climate Change: A Mainstreaming Approach for Assessing Economic, Social, and Environmental Impacts of Adaptation Measures. *Environmental Management*, 43(5), 765-778.
Hamilton, J.M., D.J. Maddison, and R.S. Tol, 2005: Climate change and international tourism: A simulation study. *Global Environmental Change*, 15(3), 253-266.
Hamisi, H.I., M. Tumbo, E. Kalumanga, and P. Yanda, 2012: Crisis in the wetlands: Combined stresses in a changing climate – Experience from Tanzania. *Climate and Development*, 4(1), 5-15.
Hanafi, S., J.C. Mailhol, J.C. Poussin, and A. Zairi, 2012: Estimating water demand at irrigation scheme scales using various levels of knowledge: applications in northern Tunisia. *Irrigation and Drainage*, 61(3), 341-347.
Handmer, J., Y. Honda, Z.W. Kundzewicz, N. Arnell, G. Benito, J. Hatfield, I.F. Mohamed, P. Peduzzi, S. Wu, B. Sherstyukov, K. Takahashi, and Z. Yan, 2012: Changes in impacts of climate extremes: human systems and ecosystems. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi et al.(eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 231-290.
Hansen, J.W., S.J. Mason, L. Sun, and A. Tall, 2011: Review of seasonal climate forecasting for agriculture in sub-Saharan Africa. *Experimental Agriculture*, 47(2), 205-240.
Hart, L.G., E.H. Larson, and D.M. Lishner, 2005: Rural definitions for health policy and research. *American Journal of Public Health*, 95(7), 1149-1155.
Harvey, J., 2007: A view from the north: rural areas in 2016: vibrant or vacant? *Agriculture & Rural Development*, 14(1), 52-55.
Hassan, R., 2010: The double challenge of adapting to climate change while accelerating development in sub-Saharan Africa. *Environment and Development Economics*, 15, 661-685.
Hassan, R. and C. Nhemachena, 2008: Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agriculture and Resource Economics*, 2(1), 83-104.
Hatcho, N., S. Ochi, and Y. Matsuno, 2010: The evolution of irrigation development in Monsoon Asia and historical lessons. *Irrigation and Drainage*, 59(1), 4-16.
Headey, D., 2011: Rethinking the global food crisis: The role of trade shocks. *Food Policy*, 36(2), 136-146.
Heemskerk, M., A. Norton, and L. de Dehn, 2004: Does public welfare crowd out informal safety nets? ethnographic evidence from rural Latin America. *World Development*, 32(6), 941-955.
Hein, L., M.J. Metzger, and A. Moreno, 2009: Potential impacts of climate change on tourism; a case study for Spain. *Current Opinion in Environmental Sustainability*, 1(2), 170-178.
Hein, L., M.J. Metzger, and R. Leemans, 2009: The local impacts of climate change in the Ferlo, Western Sahel. *Climatic Change*, 93(3-4), 465-483.
Heltberg, R. and M. Bonch-Osmolovskiy, 2011: Mapping vulnerability to climate change. *Ssrn Elibrary*, 12.05.2012.
Heltberg, R., P.B. Siegel, and S.L. Jorgensen, 2009: Addressing human vulnerability to climate change: Toward a 'no-regrets' approach. *Global Environmental Change*, 19(1), 89-99.
Henson, S. and R. Loader, 2001: Barriers to agricultural exports from developing countries: the role of sanitary and phytosanitary requirements. *World Development*, 29(1), 85-102.
Hertel, T.W., M.B. Burke, and D.B. Lobell, 2010: The poverty implications of climate-induced crop yield changes by 2030. *Global Environmental Change*, 20(4), 577-585.
Hertsgaard, M., 2011: The Great Green Wall: African farmers beat back drought and climate change with trees. *Scientific American* .
Hess J.J., Malilay J.N., and Parkinson A.J., 2008: Climate change. The importance of place. *American Journal of Preventive Medicine*, 35(5), 468-478.
Hochrainer, S., R. Mechler, and G. Pflug, 2009: Climate change and financial adaptation in Africa. Investigating the impact of climate change on the robustness of index-based microinsurance in Malawi. *Mitigation and Adaptation Strategies for Global Change*, 14, 231-250.

Hoekstra, A.Y. and M.M. Mekonnen, 2012: The water footprint of humanity. *Proceedings of the National Academy of Sciences*, 109(9), 3232-3237.
Holder, C.D., 2006: 2006: The hydrological significance of cloud forests in the Sierra de las Minas biosphere reserve, Guatemala. *Geoforum*, 37(1), 82-93.
Hole, D.G., B. Huntley, J. Arinaitwe, S.H.M. Butchart, Y.C. Collingham, L.D.C. Fishpool, D.J. Pain, and S.G. Willis, 2011: Toward a management framework for networks of protected areas in the face of climate change. *Conservation Biology*, 25(2), 305-315.
Holt-Gimenez, E., 2002: Measuring farmers' agroecological resistance after hurricane Mitch in Nicaragua: A case study in participatory, sustainable land management impact monitoring. *Agriculture Ecosystems & Environment*, 93(1-3), 87-105.
Horton, G., L. Hanna, and B. Kelly, 2010: Drought, drying and climate Change: emerging health issues for ageing Australians in rural areas. *Australasian Journal on Ageing*, 29(1), 2-7.
Huang, H., M. von Lampe, and F. van Tongeren, 2011: Climate change and trade in agriculture. *Food Policy*, 36, Supplement 1(0), S9-S13.
Huber, U., H.K.M. Bugman, and M.A. Reasoner (eds.), 2005: An overview of current knowledge. In: *Global Change and Mountain Regions*. Springer Netherlands, pp. 652.
Huisman, H., 2005: Contextualising chronic exclusion: female-headed households in semi-arid Zimbabwe. *Tijdschrift Voor Economische En Sociale Geografie*, 96(3), 253-263.
Hulme, M., R. Doherty, T. Ngara, and M. New, 2005: Global warming and African climate change: a reassessment. In: *Climate Change and Africa*. [Low, P.S. (ed.)]. Cambridge,UK, pp. 40.
Huntjens, P., L. Lebel, C. Pahl-Wostl, J. Camkin, R. Schulze, and N. Kranz, 2012: Institutional design propositions for the governance of adaptation to climate change in the water sector. *Global Environmental Change*, 22(1), 67-88.
IAASTD, 2009: *International Assessment of Agricultural Knowledge, Science and Technology for Development: Global Report*. Island Press, Washington, DC, USA, McIntyre, B.D.;Herren, H.R.; Wakhungu, J.; Watson,R.T.; ed., pp. 590.
IFAD, 2010: *Rural Poverty Report 2011. New realities, new challenges: New opportunities for tomorrow's generation*. IFAD, Rome, pp. 319.
Iglesias, A., R. Mougou, and M.Q. Moneo S., 2010: Towards adaptation of agriculture to climate change in the Mediterranean. *Regional Environmental Change*, 11((Suppl.1)), 159-196.
Immerzeel, W.W., L.P.H. Van Beek, and M.F.P. Bierkens, 2010: Climate change will affect the Asian water towers. *Science*, 328(5984), 1382-1385.
Ingold, K., J. Balsiger, and C. Hirschi, 2010: Climate change in mountain regions: how local communities adapt to extreme events. *Local Environment*, 15(7), 651-661.
Ionescu, C., R.J.T. Klein, J. Hinkel, K.S.K. Kumar, and R. Klein, 2009: Towards a formal framework of vulnerability to climate change. *Environmental Modeling & Assessment*, 14(1), 1-16.
IPCC, 2000: *Intergovernmental Panel for Climate Change. Special Report on Emission Scenarios*. Cambridge University Press, Cambridge,UK, pp. 570.
IPCC, 2007: *Climate Change 2007: Synthesis Report, Summary for Policymakers*. In: Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, pp. 22.
IPCC (ed.), 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley, Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 582.
Isik, M. and S. Devadoss, 2006: An analysis of the impact of climate change on crop yields and yield variability. *Applied Economics*, 38(7), 835-844.
Jankowska, M.M., D. Lopez-Carr, C. Funk, G.J. Husak, and Z.A. Chafe, 2012: Climate change and human health: Spatial modeling of water availability, malnutrition, and livelihoods in Mali, Africa. *Applied Geography*, 33(0), 4-15.
Jiang, L. and K. Hardee, 2011: How do recent population trends matter to climate change. *Population Research Policy Review*, 30(2), 287-312.

Johnson, C.A. and K. Krishnamurthy, 2010: Dealing with displacement: Can "social protection" facilitate long-term adaptation to climate change? *Global Environmental Change*, 20(4), 648-655.
Johnson, J.E. and D.J. Welch, 2010: Marine Fisheries Management in a Changing Climate: A Review of Vulnerability and Future Options. Reviews in Fisheries Science, 18(1), 106-124.
Jones, P. and P.K. Thornton, 2009: Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change. *Environmental Science and Policy*, 12(4), 427-437.
Juana, J.S., K.M. Strzepek, and J.F. Kirsten, 2008: Households' welfare analyses of the impact of global change on water resources in South Africa. *Agrekon: Agricultural Economics Research, Policy and Practice in Southern Africa*, 47(3), 309-326.
Kabubo-Mariara, J., 2009: Global warming and livestock husbandry in Kenya: Impacts and adaptations. *Ecological Economics*, 68(7), 1915-1924.
Kabubo-Mariara, J., 2008: Climate change adaptation and livestock activity choices in Kenya: An economic analysis. *Natural Resources Forum*, 32, 131-141.
Kahinda, J.M., A.E. Taigbenu, and R.J. Boroto, 2010: Domestic rainwater harvesting as an adaptation measure to climate change in South Africa. *Physics and Chemistry of the Earth*, 35, 742-751.
Kalame, F.B., J. Nkem, M. Idinoba, and M. Kanninen, 2009: Matching national forest policies and management practices for climate change adaptation in Burkina Faso and Ghana. *Mitigation and Adaptation Strategies for Global Change*, 14, 135-151.
Kamuanga, J.B.M., J. Somda, Y. Sanon, and H. Kagoné (eds.), 2008: *Livestock and regional market in the Sahel and West Africa. Potentials and challenges*. Paris, France, pp. 151.
Karapinar, B. and C. Häberli, 2010: *Food Crises and the WTO*. Cambridge University Press, Cambridge; New York, pp. 384.
Karapinar, B., 2011: Export restrictions and the WTO Law: how to reform the 'Regulatory Deficiency'. *Journal of World Trade*, 45(6), 1139-1155.
Karapinar, B., 2012: Defining the legal boundaries of export restrictions: A case law analysis. *Journal of International Economic Law* , 1-37.
Kashaigili, J.J., K. Rajabu, and P. Masolwa, 2009: Freshwater management and climate change adaptation: Experiences from the Great Ruaha River catchment in Tanzania. *Climate and Development*, 1(3), 220-228.
Kennet, M., 2009: The costs of women's unequal pay and opportunity: transforming the unbalanced structure of our economy to meet the challenges of today: climate change, poverty and the twin crises of the economy and economics. International Journal of Green Economics, 3(2), 107-129.
Kepe, T., 2008: Beyond the numbers. Understanding the value of vegetation to rural livelihoods in Africa. *Geoforum*, 39(2), 958-968.
Kim, S., 2010: Fisheries development in northeastern Asia in conjunction with changes in climate and social systems. *Marine Policy*, 34(4), 803-809.
Klein, R.J.T., S. Huq, F. Denton, T.E. Downing, R.G. Richels, J.B. Robinson, and F.L. Toth, 2007: Inter-relationships between adaptation and mitigation. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (ed.)]. Cambridge University Press, Cambridge, UK, pp. 745-777.
Klemm O, Schemenauer RS, Lummerich A, Cereceda P, Marzol V, Corell D, van Heerden J, Reinhard D, Gherezghiher T, Olivier J, Osses P, Sarsour J, Frost E, Estrela MJ, Valiente JA, and Fessehaye GM, 2012: Fog as a fresh-water resource: overview and perspectives. *Ambio*, 41(3), 221-34.
Klint L.M., Jiang M., Law A., DeLacy T., Filep S., Calgaro E., Dominey-Howes D., and Harrison D., 2012: Dive tourism in Luganville, Vanuatu: Shocks, stressors, and vulnerability to climate change. *Tourism in Marine Environments*, 8(1-2), 91-109.
Klint L.M., Wong E., Jiang M., Delacy T., Harrison D., and Dominey-Howes D., 2012: Climate change adaptation in the Pacific Island tourism sector: Analysing the policy environment in Vanuatu. *Current Issues in Tourism*, 15(3), 247-274.
Klopper, E., C.H. Vogel, and W.A. Landman, 2006: Seasonal climate forecasts – Potential agricultural-risk management tools? *Climatic Change*, 76, 73-90.
Kniveton, D., C. Smith, and S. Wood, 2011: Agent-based model simulations of future changes in migration flows for Burkina Faso. *Global Environmental Change*, 21, S34-S40.

Knox, J.W., T.M. Hess, A.M. Daccache, and M.P. Ortola, 2011: What are the projected impacts of climate change on food crop productivity in Africa and Asia? DFID, Cranfield, pp. 71.
Knueppe, K., 2011: The challenges facing sustainable and adaptive groundwater management in South Africa. *Water SA*, 37(1), 67-79.
Kokic, P., R. Nelson, H. Meinke, A. Potgieter, and J. Carter, 2007: From rainfall to farm incomes-transforming advice for Australian drought policy. I. Development and testing of a bioeconomic modelling system. *Australian Journal of Agricultural Research*, 58(10), 993-1003.
Konar, M., Z. Hussein, N. Hanasaki, D.L. Mauzerall, and I. Rodriguez-Iturbe, 2013: Virtual water trade flows and savings under climate change. *Hydrology and Earth System Sciences*, 10, 67-101.
Kosoy, N. and E. Corbera, 2010: Payments for ecosystem services as commodity fetishism. *Ecological Economics*, 69(6), 1228-1236.
Kotir, J.H., 2011: Climate change and variability in Sub-Saharan Africa: a review of current and future trends and impacts on agriculture and food security. *Environment, Development and Sustainability*, 13(3), 587-605.
Kranz, N., T. Menniken, and J. Hinkel, 2010: Climate change adaptation strategies in the Mekong and Orange-Senqu basins: What determines the state-of-play? , 13 (7), 648-659. *Environmental Science & Policy*, 13(7), 648-649.
Kratli, S., C. Huelsebusch, S. Brooks, and B. Kaufmann, 2012: Pastoralism: A critical asset for food security under global climate change. *Animal Frontiers*, 3(1), 42-50.
Kronik, J. and D. Verner, 2010: Indigenous peoples and climate change in Latin America and the Caribbean. World Bank, Washington, D.C., .
Krysanova, V., H. Buiteveld, D. Haase, F.F. Hattermann, K. van Niekerk, K. Roest, P. Martinez-Santos, and M. Schlüter, 2008: Practices and lessons learned in coping with climatic hazards at the river-basin scale: floods and drought. *Ecology and Society*, 13(2), 32.
Krysanova, V., C. Dickens, J. Timmerman, C. Varela-Ortega, M. Schlueter, K. Roest, P. Huntjens, F. Jaspers, H. Buiteveld, E. Moreno, J.d.P. Carrera, R. Slamova, M. Martinkova, I. Blanco, P. Esteve, K. Pringle, C. Pahl-Wostl, and P. Kabat, 2010: Cross-Comparison of Climate Change Adaptation Strategies Across Large River Basins in Europe, Africa and Asia. *Water Resources Management*, 24(14), 4121-4160.
Kuik, O., B. Buchner, M. Catenacci, A. Goria, E. Karakaya, and R.S.J. Tol, 2008: Methodological Aspects of Recent Climate Change Damage Cost Studies. *Integrated Assessment*, 8(1), 19-40.
Kumar, A., 2010: A Review of Human Development Trends in South Asia: 1990-2009. In: *Human Development Research Paper Series*, Nr. 2010/44. United Nations Development Programme, New York, pp. 52.
Kumssa, A. and J.F. Jones, 2010: Climate change and human security in Africa. *International Journal of Sustainable Development and World Ecology*, 17(6), 453-461.
Kundzewicz, Z.W., L.J. Mata, N.W. Arnell, P. Döll, B. Jimenez, K. Miller, T. Oki, Z. Sen, and I. Shiklomanov, 2008: The implications of projected climate change for freshwater resources and their management. *Hydrological Sciences Journal*, 53(1), 3-10.
Kundzewicz, Z.W. and P. Döll, 2009: Will groundwater ease freshwater stress under climate change? *Hydrological Sciences Journal*, 54(4), 665-675.
Kurukulasuriya, P., R. Mendelsohn, R. Hassan, J. Benhin, T. Deressa, M. Diop, H.M. Eid, K.Y. Fosu, G. Gbetibouo, S. Jain, A. Mahamadou, R. Mano, J. Kabubo-Mariara, S. El-Marsafawy, E. Molua, S. Ouda, M. Ouedraogo, I. Séne, D. Maddison, S.N. Seo, and A. Dinar, 2006: Will African Agriculture Survive Climate Change? *The World Bank Economic Review*, 20(3), 367-388.
Kurz W.A., Dymond C.C., Stinson G., Rampley G.J., Neilson E.T., Carroll A.L., Safranyik L., and Ebata T., 2008: Mountain pine beetle and forest carbon feedback to climate change. *Nature*, 452(7190), 987-990.
Laderach, P., M. Lundy, A. Jarvis, J. Ramirez, E.P. Portilla, and K. Schepp, 2008: Predicted impact of climate change on coffee-supply chains. International Centre for Tropical Agriculture (CIAT), Managua, Nicaragua.
Läderach, P., J. Haggar, C. Lau, A. Eitzinger, O. Ovalle, M. Baca, A. Jarvis, and M. Lundy, 2010: Mesoamerican Coffee: Building a Climate Change Adaptation Strategy. In: CIAT policy brief. CIAT, Cali, Colombia, pp. 4.
Lal, P., J. Alavalapati, and E. Mercer, 2011: Socio-economic impacts of climate change on rural United States. *Mitigation and Adaptation Strategies for Global Change*, (7), 1381-2386.
Lama, S. and B. Devkota, 2009: Vulnerability of Mountain Communities to Climate Change And Adaptation Strategies. *Journal of Agriculture and Environment*, 10, 76-83.
Langyintuo, A.S. and C. Mungoma, 2008: The effect of household wealth on the adoption of improved maize varieties in Zambia. *Food Policy*, 33(6), 550-559.

Larsen, P., S. Goldsmith, O. Smith, M. Wilson, K. Strzepek, P. Chinowsky, and B. Saylor, 2008: Estimating Future Costs for Alaska Public Infrastructure At Risk from Climate Change. *Global Environmental Change*, 18(3), 442-457.
Larson, K., D.C. Ibes, and D.D. White, 2011: Gendered Perspectives About Water Risks and Policy Strategies: A Tripartite Conceptual Approach. *Environment and Behaviour*, 43(3), 415-438.
Latif, M. and N.S. Keenlyside, 2009: El Niño/ Southern Oscillation Response to Global Warming. *Proceedings of the National Academy of Sciences*, 106(49), 20578-20583.
Leach, M., R. Mearns, and I. Scoones, 1999: Environmental Entitlements: Dynamics and Institutions in Community-Based Natural Resource Management. *World Development*, 27(2), 225-247.
Lemmen, D.S., F.J. Warren, J. Lacroix, and E. Bush, 2008: From impacts to adaptation : Canada in a changing climate 2007. Government of Canada, Ottawa, pp. 448.
Lerner, A.M. and H. Eakin, 2010: An obsolete dichotomy? Rethinking the rural/urban interface in terms of food security and production in the Global South. *Geographical Journal*, 177(4), 311-320.
Lin, B.B., 2011: Resilience in agriculture through crop diversification: Adaptive management for environmental. *Bioscience*, 61(3), 183-193.
Lin, E., X. Yang, S. Ma, H. Ju, L. Guo, W. Xiong, Y. Li, and Y. Xu, 2005: Case Study 1: China Benefiting from Global Warming: Agricultural Production in Northeast China. *IDS Bulletin*, 36(4), 15-32.
Linne, K., 2011: 4C Climate code: additional, verifiable, voluntary. Climate Change Adaptation and Mitigation in the Kenyan coffee sector. Sangana PPP, GIZ.
Lioubimtseva, E. and G.M. Henebry, 2009: Climate and environmental change in arid Central Asia: Impacts, vulnerability, and adaptations. *Journal of Arid Environments*, 73(11), 963-977.
Little, P.D., H. Mahmoud, and D.L. Coppock, 2001: When deserts flood: risk management and climatic processes among East African pastoralists. *Climate Research*, 19, 149-159.
Lobell D.B., Burke M.B., Falcon W.P., Naylor R.L., Tebaldi C., and Mastrandrea M.D., 2008: Prioritizing climate change adaptation needs for food security in 2030. *Science*, 319(5863), 607-610.
Lobell, D.B., W. Schlenker, and J. Costa-Roberts, 2011: Climate Trends and Global Crop Production Since 1980. *Science Science*, 333(6042), 616-620.
Lobell, D.B., C.B. Field, K.N. Cahill, and C. Bonfils, 2006: Impacts of future climate change on California perennial crop yields: Model projections with climate and crop uncertainties. *Agricultural and Forest Meteorology*, 141(2-4), 208-218.
López-i-Gelats, F., M.J. Milán, and J. Bartolomé, 2011: Is farming enough in mountain areas? Farm diversification in the Pyrenees. *Land Use Policy*, 28(4), 783-791.
López-i-Gelats, F., 2013: Is Mountain Farming No Longer Viable? In: *The Future of Mountain Agriculture*. [Mann, S. (ed.)]. Springer Geography, Berlin, Germany, pp. 89-104.
López-i-Gelats, F., J.D. Tàbara, and J. Bartolomé, 2009: The rural in dispute: Discourses of rurality in the Pyrenees. *Geoforum*, 40(4), 602-612.
Loughnan, M., N. Nicholls, and N. Tapper, 2010: Mortality-temperature thresholds for ten major population centres in rural Victoria, Australia. *Health & Place*, 16(6), 1287-1290.
Lyon B. and Dewitt D.G., 2012: A recent and abrupt decline in the East African long rains. *Geophysical Research Letters*, 39(2).
MacDonald, A., R. Calow, D. MacDonald, W.G. Darling, and B.E.O. Dochartaigh, 2009: What impact will climate change have on rural groundwater supplies in Africa? *Hydrological Sciences Journal*, 54(4), 690-703.
Madzwamuse, M., 2010: Climate Governance in Africa. Adaptation Strategies and Institutions. Heinrich Boell Stiftung, Cape Town, pp. 110.
Magrin, G.O.,Travasso,M.I., G.R. Rodríguez, S. Solman, and M. Núñez, 2009: Climate change and wheat production in Argentina. *International Journal of Global Warming*, 1(1), 214-226.
Malley, Z.J.U., M. Taeb, T. Matsumoto, and H. Takeya, 2007: Environmental change and vulnerability in the Usangu plain, southwestern Tanzania: Implications for sustainable development. *International Journal of Sustainable Development & World Ecology*, 14(2), 145-159.
Mallick, D.L., A. Rahman, M. Alam, A.S.M. Juel, A.N. Ahmad, and S.S. Alam, 2005: Case Study 3: Bangladesh Floods in Bangladesh: A Shift from Disaster Management Towards Disaster Preparedness. *IDS Bulletin*, 36(4), 53-70.
Marsden, T., 1999: Rural Futures: The Consumption Countryside and its Regulation. *Sociologia Ruralis*, 39(4), 501-526.

Marshall A., 2012: Existing agbiotech traits continue global march. *Nature Biotechnology*, 30(3).
Martine,G., Guzmán,J., 2002: Population, poverty, and vulnerability: Mitigating the effects of natural disasters. Environment Change and Security Project Report, 8, 45-68.
Mawdsley, J.R., R. O'Malley, and D.S. Ojima, 2009: A Review of Climate-Change Adaptation Strategies for Wildlife Management and Biodiversity Conservation. *Conservation Biology*, 23(5), 1080-1089.
Mbow, C., O. Mertz, A. Diouf, K. Rasmussen, and A. Reenberg, 2008: The history of environmental change and adaptation in eastern Saloum-Senegal-Driving forces and perceptions. *Global and Planetary Change*, 64(3-4), 210-221.
McClanahan, T.R., J.E. Cinner, N.A.J. Graham, T.M. Daw, J. Maina, S.M. Stead, A. Wamukota, K. Brown, V. Venus, and N.V.C. Polunin, 2009: Identifying Reefs of Hope and Hopeful Actions: Contextualizing Environmental, Ecological, and Social Parameters to Respond Effectively to Climate Change. *Conservation Biology*, 23(3), 662-671.
McGee T.G, 1991: The emergence of desakota regions in Asia: expanding a hypothesis. In: *The Extended Metropolis: Settlement Transition in Asia*. [Ginsburg, N., Koppel, B., McGee, T.G. (ed.)]. University of Hawaii Press, Honolulu, pp. 3-26.
McLeman, R.A. and L.M. Hunter, 2010: Migration in the context of vulnerability and adaptation to climate change: insights from analogues. *Wiley Interdisciplinary Reviews: Climate Change*, 1(3), 450-461.
McLeman, R.A., 2011: Settlement abandonment in the context of global environmental change. *Global Environmental Change*, 21(Suppl. 1), S108-S120.
McSweeney K. and Coomes O.T., 2011: Climate-related disaster opens a window of opportunity for rural poor in northeastern Honduras. *Proceedings of the National Academy of Sciences of the United States of America*, 108(13), 5203-5208.
McSweeney, K., 2002: Who Is “Forest-Dependent”? Capturing Local Variation in Forest-Product Sale, Eastern Honduras. *The Professional Geographer*, 54(2), 158-174.
MDBA, Proposed Basin Plan. In: Publication 192/11.Draft plan prepared for the Commonwealth of Australia [Murray-Darling Basin Authority (ed.)], Canberra, Australia, pp. 226.
Meiners, C., L. Fernandez, F. Salmeron, and A. Ramos, 2010: Climate variability and fisheries of black hakes (Merluccius polli and Merluccius senegalensis) in NW Africa: A first approach. *Journal of Marine Systems*, 80(3-4), 243-247.
Meinke, H. and R. Stone, 2005: Seasonal and inter-annual climate forecasting: The new tool for increasing preparedness to climate variability and change in agricultural planning and operations. *Climatic Change*, 70(1-2), 221-253.
Mendelsohn, R., A. Basist, P. Kurukulasuriya, and A. Dinar, 2007: Climate and Rural Income. *Climatic Change*, 81(1), 101-118.
Mendelsohn, R. and M. Reinsborough, 2007: A Ricardian analysis of US and Canadian farmland. *Climatic Change*, 81(1), 9-17.
Mendelsohn, R., P. Christensen, and J. Arellano-Gonzalez, 2010: A Ricardian analysis of Mexican farms. *Environment and Development Economics*, 15(2), 153-171.
Mendelsohn, R., 2008: The Impact of Climate Change on Agriculture in Developing Countries. *Journal of Natural Resources Policy Research*, 1(1), 5-19.
Mertz, O., C. Mbow, A. Reenberg, L. Genesio, E.F. Lambin, S. D’haen, M. Zorom, K. Rasmussen, D. Diallo, B. Barbier, I. Bouzou Moussa, A. Diouf, J.Ø. Nielsen, and I. Sandholt, 2011: Adaptation strategies and climate vulnerability in the Sudano-Sahelian region of West Africa. *Atmospheric Science Letters*, 12, 104-108.
Mertz, O., C. Mbow, J.O. Nielsen, A. Maiga, D. Diallo, A. Reenberg, A. Diouf, B. Barbier, I.B. Moussa, M. Zorom, I. Ouattara, and D. Dabi, 2010: Climate factors play a limited role for past adaptation strategies in West Africa. *Ecology and Society*, 15(4), art25.
Mertz, O., K. Halsnaes, J.E. Olesen, and K. Rasmussen, 2009: Adaptation to Climate Change in Developing Countries. *Environmental Management*, 43(5), 743-752.
Meza, F.J. and D. Silva, 2009: Dynamic adaptation of maize and wheat production to climate change. *Climatic Change*, 94(1-2), 143-156.
Meze-Hausken, E., A. Patt, and F. Steffen, 2009: Reducing climate risk for micro-insurance providers in Africa: A case study of Ethiopia. *Global Environmental Change*, 19(1), 66-73.
Mideksa, T.K., 2010: Economic and distributional impacts of climate change: The case of Ethiopia. *Global Environmental Change*, 20(2), 278-286.

Midgley, G.F., L. Hannah, D. Millar, M.C. Rutherford, and L.W. Powrie, 2002: Assessing the vulnerability of species richness to anthropogenic climate change in a biodiversity hotspot. *Global Ecology and Biogeography*, 11(6), 445-451.
Millner, A. and R. Washington, 2011: What determines perceived value of seasonal climate forecasts? A theoretical analysis. *Global Environmental Change*, 21(1), 209-218.
Mills, D.J., L. Westlund, G. de Graaf, Y. Kura, R. Willman, and K. Kelleher, 2011: Under-reported and Undervalued: Small-scale Fisheries in the Developing World. In: *Small-Scale Fisheries Management: Frameworks and Approaches for the Developing World*, [Pomeroy, R.S. and N. Andrew(eds.)]. CABI, Wallingford, UK;Cambridge, MA, pp. 1-15.
Misselhorn, A.A., 2009: Is a focus on social capital useful in considering food security interventions? Insights from KwaZulu Natal. *Development Southern Africa*, 26(2), 189-208.
Moench, M. and D. Gyawali, 2008: Final Report Desakota, Part II A. Reinterpreting the Urban-Rural Continuum. Conceptual foundations for understanding the role ecosystem services play in the livelihoods of the poor in regions undergoing rapid change. DFID, pp. 27.
Molini, V., M. Keyzer, B. van den Boom, W. Zant, and N. Nsowah-Nuamah, 2010: Safety Nets and Index-Based Insurance: Historical Assessment and Semiparametric Simulation for Northern Ghana. *Economic Development and Cultural Change*, 58(4), 671-712.
Molnar, J.J., 2010: Climate Change and Societal Response: Livelihoods, Communities, and the Environment. *Rural Sociology*, 75(1), 1-16.
Molua, E.L., 2009: An empirical assessment of the impact of climate change on smallholder agriculture in Cameroon. *Global and Planetary Change*, 67(3-4), 205-208.
Molua, E.L., 2009: Accommodation of climate change in coastal areas of Cameroon: selection of household-level protection options. *Mitigation and Adaptation Strategies for Global Change*, 14, 721-735.
Montenegro, A. and R. Ragab, 2010: Hydrological response of a brazilian semi-arid catchment to different land use and climate change scenarios: A modelling study. *Hydrological Processes*, 24(19), 2705-2723.
Morton, J., 2006: Pastoralist Coping Strategies and Emergency Livestock Market Intervention. In: *Pastoral Livestock Marketing in Eastern Africa: Research and Policy Challenges*, [McPeak, J.G. and P.D. Little(eds.)]. ITDG Publications, Bourton on Dunsmore,Uk, pp. 227-246.
Morton, J.F., 2007: The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, 104(50), 19680-19685.
Mougou, R., M. Mansour, A. Iglesias, R.Z. Chebbi, and A. Battaglini, 2011: Climate change and agricultural vulnerability: a case study of rain-fed wheat in Kairouan, Central Tunisia. *Regional Environmental Change*, 11, S137-S142.
Moumouni, I. and L. Idrissou, 2012: Innovation Systems for Agriculture and Climate in Benin: an Inventory. , AFAAS, FARA and NRI, Accra. In: Climate Learning for African Agriculture Working Paper No.3, Accra, Ghana.
Mukheibir, P., 2008: Water Resources Management Strategies for Adaptation to Climate-Induced Impacts in South Africa. *Water Resources Management*, 22, 1259-1276.
Müller A., Schmidhuber J., Hoogeveen J., and Steduto P., 2008: Some insights in the effect of growing bio-energy demand on global food security and natural resources. *Water Policy*, 10(SUPPL. 1), 83-94.
Müller C., Cramer W., Hare W.L., and Lotze-Campen H., 2011: Climate change risks for African agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, 108(11), 4313-4315.
Munich Re, 2004: Annual Review: natural catastrophes 2003. Munich Re, Munich.
Nelson, G., A. Palazzo, C. Ringler, T. Sulser, and M. Batka, 2009: The Role of International Trade in Climate Change Adaptation. In: *ICTSD–IPC Platform on Climate Change, Agriculture and Trade, Issue Paper No.4*. International Centre for Trade and Sustainable Development and International Food & Agricultural Trade Policy Council, Geneva, Switzerland; Washington DC, USA, pp. 16.
Nelson, G.C., M.W. Rosegrant, A. Palazzo, I. Gray, C. Ingersoll, R. Robertson, S. Tokgoz, T. Zhu, T.B. Sulser, C. Ringler, S. Msangi, and L. You, 2010: *Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options*. IFPRI research monograph, Washington DC, USA, pp. 130.
Nelson, J.A., 2008: Economists, value judgments, and climate change: A view from feminist economics. *Ecological Economics*, 65(3), 441-447.
Nelson, R., P. Kokic, and H. Meinke, 2007: From rainfall to farm incomes-transforming advice for Australian drought policy. II. Forecasting farm incomes. *Australian Journal of Agricultural Research*, 58(10), 1004-1012.

Nelson, R., P. Kokic, S. Crimp, H. Meinke, and S.M. Howden, 2010: The vulnerability of Australian rural communities to climate variability and change: Part I-Conceptualising and measuring vulnerability. *Environmental Science & Policy*, 13(1), 8-17.
Nelson, V., K. Meadows, T. Cannon, J. Morton, and A. Martin, 2002: Uncertain predictions, invisible impacts, and the need to mainstream gender in climate change adaptations. *Gender and Development*, 10(2), 51-59.
Nelson, V. and T. Stathers, 2009: Resilience, power, culture, and climate: a case study from semi-arid Tanzania, and new research directions. *Gender & Development*, 17(1), 81-94.
Nepal, S.K., 2008: Tourism-induced rural energy consumption in the Annapurna region of Nepal. *Tourism Management*, 29(1), 89-100.
Ngoundo, M., C.E. Kan, Y.C. Chang, S.L. Tsai, and I. Tsou, 2007: Options for water saving in tropical humid and semi-arid regions using optimum compost application rates. *Irrigation and Drainage*, 56(1), 87-08.
Niasse, M., A. Afouda, and A. Amani, 2004: Reducing impacts on water resources, wetlands and desertification : elements for a Regional Strategy for Preparedness and Adaptation. IUCN, Gland, Switzerland and Cambridge,UK, pp. 66.
Nicholls, R.J., N. Marinova, J.A. Lowe, S. Brown, P.D.G. Vellinga Di., J. Hinkel, and R.S.J. Tol, 2011: Sea-level rise and its possible impacts given a 'beyond 4 degrees C world' in the twenty-first century. *Philosophical Transactions of the Royal Society A*, 369(1934), 161-181.
Nielsen, J.Ø., S. D'haen, and A. Reenberg, 2012: Adaptation to climate change as a development project: A case study from Northern Burkina Faso. *Climate and Development*, forthcoming.
Nielsen, J.Ø. and A. Reenberg, 2010: Cultural barriers to climate change adaptation: A case study from Northern Burkina Faso. Global Environmental Change, 20, 142-152.
Nielsen, J.O. and A. Reenberg, 2010: Temporality and the problem with singling out climate as a current driver of change in a small West African village. *Journal of Arid Environments*, 74(4), 464-474.
Niemi, E.G., M. Buckley, C. Neculae, and S. Reich, 2009: An Overview of Potential Economic Costs to Washington of a Business-As-Usual Approach to Climate Change. The Program on Climate Economics, Climate Leadership Initiative, Institute for a Sustainable Environment, University of Oregon, Oregon, pp. 47.
Nkala, P., N. Mango, and P. Zikhali, 2011: Conservation Agriculture and Livelihoods of Smallholder Farmers in Central Mozambique. *Journal of Sustainable Agriculture*, 35(7), 757-779.
Nkem, J.N., R. Munang, and B. Jallow, 2011: Decentralizing Solutions For Rural Water Supply Under Climate Impacts In Sub-Saharan Africa. *Environment:Science and Policy for Sustainable Development*, 53(2), 14-17.
Nogués-Bravo, D., M.B. Araújo, M.P. Errea, and J.P. Martínez-Rica, 2007: Exposure of global mountain systems to climate warming during the 21st Century. *Global Environmental Change*, 17(3-4), 420-428.
Notter, B., L. MacMillan, D. Viviroli, R. Weingartner, and H. Liniger, 2007: Impacts of environmental change on water resources in the Mt. Kenya region. *Journal of Hydrology*, 343(3-4), 266-278.
Noy, I., 2009: The Macroeconomic Consequences of Disasters. *Journal of Development Economics*, 88(2), 221-231.
Nyaupane, G.P. and S. Poudel, 2011: Linkages among biodiversity, livelihood, and tourism. *Annals of Tourism Research*, 38(4), 1344-1366.
Nyaupane, G. and N. Chhetri, 2009: Vulnerability to Climate Change of Nature-Based Tourism in the Nepalese Himalayas. *Tourism Geographies*, 11(1), 95-119.
Nyong, A., F. Adesina, and B. Osman Elasha, 2007: The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitigation and Adaptation Strategies for Global Change*, 12, 787-797.
O'Brien, G., P. O'Keefe, H. Meena, J. Rose, and L. Wilson, 2008: Climate adaptation from a poverty perspective. *Climate Policy*, 8, 194-201.
O'Farrell, P.J., P.M.L. Anderson, S.J. Milton, and W.R.J. Dean, 2009: Human response and adaptation to drought in the arid zone: lessons from southern Africa. *Southern African Journal of Science*, 105, 34-39.
Obioha, E.E., 2008: Climate Change, Population Drift and Violent Conflict over Land Resources in Northeastern Nigeria. *Journal of Human Ecology*, 23(3), 311-324.
O'Brien, K., T. Quinlan, and G. Ziervogel, 2009: Vulnerability interventions in the context of multiple stressors: lessons from the Southern Africa Vulnerability Initiative (SAVI). *Environmental Science & Policy*, 12(1), 23-32.
O'Brien, K., R. Leichenko, U. Kelkar, H. Venema, G. Aandahl, H. Tompkins, A. Javed, S. Bhadwal, S. Barg, L. Nygaard, and J. West, 2004: Mapping vulnerability to multiple stressors: climate change and globalization in India. *Global Environmental Change*, 14(4), 303-313.

O'Brien, K., S. Eriksen, L.P. Nygaard, and A. Schjolden, 2007: Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy*, 7(1), 73-88.
OECD, 2006: The new rural paradigm : policies and governance. Organisation for Economic Co-operation and Development, Paris, pp. 155.
OECD, 2009: Integrating climate change adaptation into development co-operation : policy guidance. Organisation for Economic Co-operation and Development, Paris, France, pp. 193.
Ogawa-Onishi Y., Berry P.M., and Tanaka N., 2010: Assessing the potential impacts of climate change and their conservation implications in Japan: A case study of conifers. *Biological Conservation*, 143(7), 1728-1736.
Olsson, L. and A. Jerneck, 2010: Farmers fighting climate change from victims to agents in subsistence livelihoods. *Wiley Interdisciplinary Reviews: Climate Change*, 1(3), 363-373.
Oluoko-Odingo, A.A., 2011: Vulnerability and Adaptation to Food Insecurity and Poverty in Kenya. *Annals of the Association of American Geographers*, 101(1), 1-20.
Omolo, N., 2011: Gender and climate change-induced conflict in pastoral communities: Case study of Turkana in northwestern Kenya. *African Journal on Conflict Resolution*, 10(2), 81-102.
Openshaw, K., 2005: Natural resources: population growth and sustainable development in Africa. In: *Climate Change and Africa*. [Low, P.S. (ed.)]. Cambridge, UK, pp. 123-123.
Orindi, V.A. and A. Ochieng, 2005: Case Study 5: Kenya Seed Fairs as a Drought Recovery Strategy in Kenya. *IDS Bulletin*, 36(4), 87-102.
Orlove, B., 2009: The past, present and some possible futures of adaptation. In: *Adapting to Climate Change. Thresholds, Values, Governance*. [Adger, W.N., I. Lorenzoni, and K.L. O'Brien (eds.)]. Cambridge University Press, Cambridge, pp. 131-164.
Osbahr, H., C. Twyman, N.W. Adger, and D.S.G. Thomas, 2008: Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique. *Geoforum*, 39(6), 1951-1964.
Osbahr, H., C. Twyman, W.N. Adger, and D.S.G. Thomas, 2010: Evaluating Successful Livelihood Adaptation to Climate Variability and Change in Southern Africa. *Ecology and Society*, 15(2), 27.
Osgood, D. and D. Warren, 2007: Drought insurance in Malawi. In: *Climate Risk Management in Africa. Learning from Practice*. [Hellmuth, M. (ed.)]. International Research Institute for Climate and Society (IRI), Columbia, New York, pp. 75-87.
Ostrom, E., 2009: A Polycentric Approach for Coping with Climate Change. *Ssrn Elibrary*, 12.05.2012.
Paavola, J., 2008: Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science & Policy*, 11(7), 642-654.
Parks, B.C. and J.T. Roberts, 2006: Globalization, vulnerability to climate change, and perceived injustice. *Society & Natural Resources*, 19(4), 337-355.
Parnell, S. and R. Walawege, 2011: Sub-Saharan African urbanisation and global environmental change. *Global Environmental Change*, 21, Supplement 1(0), S12-S20.
Patt, A.G. and D. Schroeter, 2008: Perceptions of climate risk in Mozambique: Implications for the success of adaptation strategies. *Global Environmental Change*, 18(3), 458-467.
Patt, A., N. Peterson, M. Carter, M. Velez, U. Hess, and P. Suarez, 2009: Making index insurance attractive to farmers. *Mitigation and Adaptation Strategies for Global Change*, 14(8), 737-753.
Patt, A., P. Suarez, and U. Hess, 2010: How do small-holder farmers understand insurance, and how much do they want it? Evidence from Africa. *Global Environmental Change*, 20(1), 153-161.
Patterson, T.M., V. Niccolucci, and S. Bastianoni, 2007: Beyond “more is better”: Ecological footprint accounting for tourism and consumption in Val di Merse, Italy. *Ecological Economics*, 62(3–4), 747-756.
Pearce, T.D., J.D. Ford, J. Prno, F. Duerden, J. Pittman, M. Beaumier, L. Berrang-Ford, and B. Smit, 2011: Climate change and mining in Canada. *Mitigation and Adaptation Strategies for Global Change*, 16(3), 347-368.
Pelling, M., Mustafa, D., 2010: Vulnerability, disasters and poverty in desakota systems. In: Political and Development Working Paper Series Number 31. King's College London, London, pp. 26.
Pérez, A.A., B.H. Fernández, and R.C. Gatti, 2010: *Building resilience to climate change: ecosystem-based adaptation and lessons from the field*. Gland, Switzerland, pp. 164.
Perry, B.D., D. Grace, and K. Sones, 2011: Current drivers and future directions of global livestock disease dynamics. *Proceedings of the National Academy of Sciences*, .
Peterson, N.D., K. Broad, B. Orlove, C. Roncoli, R. Taddei, and M. Velez, 2010: Participatory processes and climate forecast use: Socio-cultural context, discussion, and consensus. *Climate and Development*, 2(1), 14-29.

Phelps, J., E.L. Webb, and A. Agrawal, 2010: Does REDD+ Threaten to Recentralize Forest Governance? *Science*, 328(5976), 312-313.
Piguet, E., 2008: Climate change and forced migration. In: Research Paper No. 153. UNHCR, Policy Development and Evaluation Service, Geneva, Switzerland.
Pinto, H. and E. Assad, 2008: Global Warming and the New Geography of Agricultural Production in Brazil. The British Embassy, Brasília, Brazil, pp. 42.
Pinto, H.S., J. Zullo Junior, and E.D. Assad, 2006: Impact assessment study of climate change on agricultural zoning. *Meteorological Applications*, 13(Supplement S1), 69-80.
Pinto, H.S., E.D. Assad, J. Zullo, and O. Brunini, 2007: Acqueimiento Global e a Agricultura .
Plevin, R.J., M. O'Hare, A.D. Jones, M.S. Torn, and H.K. Gibbs, 2010: Greenhouse Gas Emissions from Biofuels' Indirect Land Use Change Are Uncertain but May Be Much Greater than Previously Estimated. *Environmental Science & Technology*, 44(1), 8015-8021.
PNCC, 2007: Vulnerabilidad y Adaptación Al Cambio Climático En Bolivia. Resultados De Un Proceso De Investigación Participativa En Las Regiones Del Lago Titicaca y Los Valles Cruceños. [UNDP and República de Bolivia, Programa Nacional de Cambios Climáticos (PNCC) (eds.)], pp. 141.
Potter, R.B., D. Conway, and J. Phillips, 2005: *The experience of return migration: Caribbean perspectives*. Ashgate, Aldershot, pp. 293.
Povellato, A., Bosello, F., Giupponi, C., 2007: Cost-effectiveness of greenhouse gases mitigation measures in the European agro-forestry sector: a literature survey. *Environmental Science and Policy*, 10(5), 474-490.
Power, M., 2009: Global Climate Policy and Climate Justice: A Feminist Social Provisioning Approach. *Challenge*, 52(1), 47-66.
Preston, B.L., R. Suppiah, I. Macadam, and J. Bathols, 2006: Climate Change in the Asia Pacific region. A consultancy report prepared for the Climate Change and Development Roundtable. CSIRO Marine and Atmospheric Research, Australia, pp. 93.
Preston, B.L., E.J. Yuen, and R.M. Westaway, 2011: Putting vulnerability to climate change on the map: a review of approaches, benefits, and risks. *Sustainability Science*, 6(2), 177-202.
Pretty, J., C. Toulmin, and S. Williams, 2011: Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability*, 9(1), 5-24.
Productivity Commission, 2009: Government Drought Support. In: Final Inquiry Report No. 46. [Producitivity Commission (ed.)], Melbourne, Australia, pp. 431.
Quiroga, A. and C. Gaggioli, 2011: Condiciones Para El Desarrollo De Producciones Agrícola-Ganaderas En El SO Bonaerense. Gestión Del Agua y Viabilidad De Los Sistemas Productivos 21 , Tomo LXIV, Buenos Aires, Argentina, 233-249.
Rademacher-Schulz, C. and E. Mahama, 2012: "Where the Rain falls" project. Case study: Ghana. Results from the Nadowli Distric, Upper West Region. In: Report No.3. United Nations University, Institute for Environment and Human Security (UNU-EHS), Bonn, Germany.
Raleigh, C. and H. Urdall, 2007: Climate change, environmental degradation and armed conflict. *Political Geography*, 26, 674-694.
Raleigh, C., L. Jordan, and I. Salehyan, 2008: Assessing the Impact of Climate Change on Migration and Climate. In: Social Dimensions of Climate Change Workshop March 5-6,. World Bank, Washington, pp. 49.
Ramirez-Villegas, J., A. Jarvis, and P. Läderach, 2011: Empirical approaches for assessing impacts of climate change on agriculture: The EcoCrop model and a case study with grain sorghum. *Agricultural and Forest Meteorology*, In Press, Corrected Proof.
Rao, C.H.H., 2005: Growth in Rural Non-farm Sector: Some Lessons from Asian Experience. In: *Rural Transformation in India: The Role of Non-farm Sector*. [Nayyar, R. and Sharma, A.N. (ed.)]. Institute for Human Development, New Delhi, pp. 29-34.
Ravallion, M.,G Datt, 1996: How Important to India's Poor Is the Sectoral Composition of Economic Growth? *World Bank Economic Review*, 10(1), 1-25.
Ravallion, M., S. Chen, and P. Sangraula, 2007: New Evidence on the Urbanization of Global Poverty. *Population and Development Review*, 33(4), 667-701.
Reid H., Sahlen L., Stage J., and MacGregor J., 2008: Climate change impacts on Namibia's natural resources and economy. *Climate Policy*, 8(5), 452-466.
Reid, P. and C. Vogel, 2006: Living and responding to multiple stressors in South Africa--Glimpses from KwaZulu-Natal. *Global Enivronmental Change*, 16(2), 195-206.

Reidsma, P., T. Tekelenburg, M. van den Berg, and R. Alkemade, 2006: Impacts of land-use change on biodiversity: An assessment of agricultural biodiversity in the European Union. *Agriculture Ecosystems & Environment*, 114(1), 86-102.

Reimer, J.J. and M. Li, 2009: Yield Variability and Agricultural Trade. *Agricultural and Resource Economics Review*, 38, 258-270.

Reuveny R., 2007: Ecomigration and Violent Conflict: case studies and public policy implications. *Human Ecology*, 36, 1-13.

Reynolds, J.F., D.M.S. Smith, E.F. Lambin, B.L. Turner, M. Mortimore, S.P.J. Batterbury, T.E. Downing, H. Dowlatabadi, R.J. Fernandez, J.E. Herrick, E. Huber-Sannwald, H. Jiang, R. Leemans, T. Lynam, F.T. Maestre, M. Ayarza, and B. Walker, 2007: Global Desertification: Building a Science for Dryland Development. Science *Science*, 316(5826), 847-851.

Ribas, A., J. Calbo, A. Llausas, and J.A. Lopez-Bustins, 2010: Climate Change at the local scale: trends, impacts and adaptations in a Northwestern Mediterranean Region (Costa Brava, NE Iberaian Peninsula). *International Journal of Climate Change: Impacts and Responses*, 2(1), 247-264.

Ribot, J., 2010: Vulnerability does not fall from the sky: Towards Multi-Scale Pro-Poor Climate Policy. In*: Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*. [Mearns, R. and N. Norton(eds.)]. The World Bank, Washington DC, USA, pp. 47-57.

Ringler, C., 2010: Climate Change and Hunger: Africa's Smallholder Farmers Struggle to Adapt. *Eurochoices*, 9(3), 16-21.

Rivera-Ferre, M.G. and F. López-i-Gelats, 2012: The role of small scale livestock farming in climate change and food security. Rome: . In: VSF-Europe, Rome, Italy, pp. 148.

Rivera-Ferre, M.G., M. Di Masso, M. Mailhost, F. López-i-Gelats, D. Gallar, I. Vara, and M. Cuellar, 2013: Understanding the Role of Local and Traditional Agricultural Knowledge in a Changing World Climate: The case of the Indo-Gangetic Plains. . In: CGIAR, Nepal.

Rivera-Ferre, M.G. and M. Ortega-Cerda, 2011: Recognising ignorance in decision-making strategies for a more sustainable agriculture. *EMBO Reports*, 12(5), 393-397.

Roberts, M.J. and W. Schlenker, 2010: Is Agricultural Production Becoming More or Less Sensitive to Extreme Heat? : Evidence from U.S. Corn and Soybean Yields. In: Working Paper 1630. National Bureau of Economic Research, Cambridge, MA, pp. 16.

Robledo, C., Clot, N. Hammill, A. and Riché, B., 2011, The role of forest ecosystems in community-based coping strategies to climate hazards: Three examples from rural areas in Africa, *Forest Policy and Economics*, In press.

Rochdane, S., B. Reichert, M. Messouli, A. Babqiqi, and M.Y. Khebiza, 2012: Climate Change Impacts on Water Supply and Demand in Rheraya Watershed (Morocco), with Potential Adaptation Strategies. *Water*, 4(1), 28-44.

Roncoli, C., K. Ingram, and P. Kirshen, 2001: The costs and risks of coping with drought: livelihood impacts and farmers' responses in Burkina Faso. *Climate Research*, 19(2), 119-132.

Roncoli, C., C. Jost, P. Kirshen, M. Sanon, K. Ingram, M. Woodin, L. Somé, F. Ouattara, B. Sanfo, C. Sia, P. Yaka, and G. Hoogenboom, 2009: From accessing to assessing forecasts: an end-to-end study of participatory climate forecast dissemination in Burkina Faso (West Africa). *Climatic Change*, 92(3), 433-460.

Rossi, A. and Y. Lambrou, 2008: Gender and Equity Issues in Liquid Biofuels Production: Minimizing the Risks to Maximize the Opportunities. Food and Agriculture Organization, Rome, Italy, pp. 30.

Rounsevell, M.D., I. Reginster, M.B. Araujo, T.R. Carter, N. Dendoncker, F. Ewert, J.I. House, S. Kankaanpaa, R. Leemans, and M.J. Metzger, 2006: A coherent set of future land use change scenarios for Europe. *Agriculture, Ecosystems and Environment*, 114(1), 57-68.

Ruel, M.T., J.L. Garrett, C.R. Hawkes, and M.C. Cohen, 2010: The Food, Fuel, and Financial Crises Affect the Urban and Rural Poor Disproportionately: A Review of the Evidence. *The Journal of Nutrition*, 140(1), 170-176.

Runyuan, W., Z. Qiang, L. Hongyi, Y. Qiguo, Z. Hong, and W. Zhenguo, 2007: Impact of Climate Warming on Cotton Growth in the Hexi Corridor Area. *Advances in Climate Change Research*, 3, 57-59.

Safranyik, L. and B. Wilson, 2006: The mountain pine beetle : a synthesis of biology, management, and impacts on lodgepole pine. Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia, pp. 303.

Saldaña-Zorrilla, S., 2008: Stakeholder´s views in reducing rural vulnerability to natural disasters in Southern Mexico. *Global Environmental Change*, 18(4), 583-597.

Salema, H.B., H.C. Norman, A. Nefzaoui, D.E. Mayberry, K.L. Pearce, and D.K. Revell, 2010: Potential use of oldman saltbush (*Atriplex nummularia* Lindl.) in sheep and goat feeding. *Small Ruminant Research*, 91, 13-28.

Sall, D.M., D.S.M. Tall, D.A. Tandia, A. Samb, A.K. Sano, and S. Sylla, 2010: International migration, social change and local governance in Ourossogui and Louga, two small urban centres in Senegal. In: Human Settlements Working Paper Series Rural-Urban Interactions and Livelihood Strategies Working Paper 23. International Institute for Environment and Development (IIED), London, UK, pp. 41.
Sallu, S.M., C. Twyman, and L.C. Stringer, 2010: Resilient or vulnerable livelihoods? Assessing livelihood dynamics and trajectories in rural Botswana. *Ecology and Society*, 15(4), 3.
Sanghi A. and Mendelsohn R., 2008: The impacts of global warming on farmers in Brazil and India. *Global Environmental Change*, 18(4), 655-665.
Satterthwaite, D., 2006: Outside the Large Cities: the demographic importance of small urban centres and large villages in Africa, Asia and Latin America. In: Human Settlements Discussion Paper Series, Urban Change 3. Institute for Environment and Development (IIED), London,UK, pp. 24.
Schepp, K., 2010: How can small-scale coffee and tea producers adapt to climate change. In: AdapCC Final Report - Results & Lessons Learnt. GTZ, Eschborn, Germany, pp. 37.
Schlenker, W. and M.J. Roberts, 2009: Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. *Proceedings of the National Academy of Sciences Proceedings of the National Academy of Sciences*, 106(37), 15594-15598.
Schmidhuber, J. and I. Matuschke, 2010: Shift and swing factors and the special role of weather and climate. In: *Food Crises and the WTO*. [Karapinar, B. and C. Häberli(eds.)]. Cambridge University Press, Cambridge, New York, pp. 135-164.
Schröter D, Cramer W, Leemans R, Prentice IC, Araújo MB, Arnell NW, Bondeau A, Bugmann H, Carter TR, Gracia CA, de la Vega-Leinert AC, Erhard M, Ewert F, Glendining M, House JI, Kankaanpää S, Klein RJ, Lavorel S, Lindner M, Metzger MJ, Meyer J, Mitchell TD, Reginster I, Rounsevell M, Sabaté S, Sitch S, Smith B, Smith J, Smith P, Sykes MT, Thonicke K, Thuiller W, Tuck G, Zaehle S, and Zierl B, 2005: Ecosystem service supply and vulnerability to global change in Europe. *Science*, 310(5752), 1333-7.
Schroth, G., P. Laderach, J. Dempewolf, S. Philpott, J. Haggar, H. Eakin, T. Castillejos, J.G. Moreno, L.S. Pinto, R. Hernandez, A. Eitzinger, and J. Ramirez-Villegas, 2009: Towards a climate change adaptation strategy for coffee communities and ecosystems in the Sierra Madre de Chiapas, Mexico. *Mitigation and Adaptation Strategies for Global Change*, 14(7), 605-625.
Scott, D., 2006: Global environmental change and mountain tourism. In: *Tourism and global environmental change: Ecological, social economic and political interrelationships*. [Gösslin, S. and M. Hall(eds.)]. Routledge,Taylor & Frances Group, New York,USA, pp. 54-75.
Scott, D., B. Jones, and J. Konopek, 2007: Implications of climate and environmental change for nature-based tourism in the Canadian Rocky Mountains: A case study of Waterton Lakes National Park. *Tourism Management*, 28(2), 570-579.
Scott, D., G. McBoyle, A. Minogue, and B. Mills, 2006: Climate Change and the Sustainability of Ski-based Tourism in Eastern North America: A Reassessment. *Journal of Sustainable Tourism*, 14(4), 376-398.
Scott, D., S. Gössling, and C.M. Hall, 2012: International tourism and climate change. *Wiley Interdisciplinary Reviews: Climate Change*, 3(3), 213-232.
Seck, M., M.N.A. Mamouda, and S. Wade, 2005: Case Study 4: Senegal Adaptation and Mitigation Through "Produced Environments": The Case for Agriculture Intensification in Senegal. *IDS Bulletin*, 36(4), 71-86.
SEI, 2009: The Economics of Climate Change in Kenya: Final Report submitted in advance of COP15. SEI Oxford Office, Oxford, pp. 65.
Seneviratne, S.I., Nicholls,N., D. Easterling, C.M. Goodess, S. Kanae, J. Kossin, Y. Luo, J. Marengo, K. McInnes, M. Rahimi, M. Reichstein, A. Sorteberg, C. Vera, and X. Zhan, 2012: Changes in climate extremes and their impacts on the natural physical environment. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi et al.(eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 109-230.
Seo, S.N., 2011b: An analysis of public adaptation to climate change using agricultural water schemes in South America. *Ecological Economics*, 70(4), 825-834.
Seo, S.N. and R. Mendelsohn, 2007: Climate change adaptation in Africa: a microeconomic analysis of livestock choice. In: World Bank Policy Research Working Paper 4277. World Bank, Washington, USA, pp. 39.
Seo, S.N. and R. Mendelsohn, 2007: The impact of climate change on livestock management in Africa: a structural Ricardian analysis. In: Policy Research Working Paper 4603, Washington, USA, pp. 48-48.

Seo, S.N. and R. Mendelsohn, 2008: A Ricardian analysis of the impact of climate change on South American farms. *Chilean Journal of Agricultural Research*, 68(1), 69-79.
Seo, S.N. and R. Mendelsohn, 2008: Animal husbandry in Africa climate change impacts and adaptations. African *Journal of Agricultural and Resource Economics*, 2(1), 65-82.
Seo, S.N., 2011: A geographically scaled analysis of adaptation to climate change with spatial models using agricultural systems in Africa. *Journal of Agricultural Science*, 149(4), 1-13.
Seo, S.N., 2010: Is an integrated farm more resilient against climate change? A micro-econometric analysis of portfolio diversification in African agriculture. *Food Policy*, 35(1), 32-40.
Seo, S.N., 2010: A Microeconometric Analysis of Adapting Portfolios to Climate Change: Adoption of Agricultural Systems in Latin America. *Applied Economic Perspectives and Policy*, 32(3), 489-514.
Sheate, W.R., M.R. do Partidário, H. Byron, O. Bina, and S. Dagg, 2008: Sustainability Assessment of Future Scenarios: Methodology and Application to Mountain Areas of Europe. *Environmental Management*, 41(2), 282-299.
Sietz, D., M.K.B. Lüdeke, and C. Walther, 2011: Categorisation of typical vulnerability patterns in global drylands. *Global Environmental Change*, 21(2), 431-440.
Sikor, T., J. Stahl, T. Enters, J.C. Ribot, N. Singh, W.D. Sunderlin, and L. Wollenberg, 2010: REDD-plus, forest people's rights and nested climate governance. *Global Environmental Change*, 20(3), 423-425.
Simelton, E., E.D.G. Fraser, M. Termansen, P.M. Forster, and A.J. Dougill, 2009: Typologies of crop-drought vulnerability: an empirical analysis of the socio-economic factors that influence the sensitivity and resilience to drought of three major food crops in China (1961-2001). *Environmental Science & Policy*, 12(4), 438-452.
Simon, D., D. McGregor , and D. Thompson, 2006: Contemporary perspectives on the peri-urban zones of cities in developing countries. In: *The Peri-Urban Interface: approaches to sustainable natural and human resource use*. [McGregor, D., D. Simon, and D. Thompson(eds.)]. Earthscan, London, pp. 3-17.
Simon, D., 2008: Urban environments: issues on the peri-urban fringe. *Annual Review of Environmental Resources*, 33, 167-185.
Simonett, O., 2002: Potential impacts of global warming. In: Case Studies on Climate Change. GRID Geneva, Genevae, Switzerland.
Sissoko, K., H. van Keulen, J. Verhagen, V. Tekken, and A. Battaglini, 2011: Agriculture, livelihoods and climate change in the West African Sahel. *Regional Environmental Change*, 11(Suppl 1), 119-125.
Smart, R.E., 2010: A lump of coal, a bunch of grapes. *Journal of Wine Research*, 21(2), 107-111.
Smucker, T.A. and B. Wisner, 2008: Changing household responses to drought in Tharaka, Kenya: vulnerability, persistence and challenge. *Disasters*, 32(2), 190-205.
Sowers, J., A. Vengosh, and E. Weinthal, 2011: Climate change, water resources, and the politics of adaptation in the Middle East and North Africa. *Climatic Change*, 104, 599-627.
Spangenberg, J.H. and J. Settele, 2010: Precisely incorrect? Monetising the value of ecosystem services. *Ecological Complexity*, 7(3), 327-337.
Srivastava, A., S.N. Kumar, and P.K. Aggarwal, 2010: Assessment on vulnerability of sorghum to climate change in India. *Agriculture Ecosystems & Environment*, 138(3-4), 160-169.
Stage, J., 2010: Economic valuation of climate change adaptation in developing countries. *Annals of the New York Academy of Sciences*, 1185(1), 150-163.
Stathers, T., R. Lamboll, and B.M. Mvumi, submitted: Postharvest Agriculture in a Changing Climate: its importance to African smallholder farmers . *Food Policy* .
Stern, N., 2007: *The Economics of Climate Change: The Stern Review*. Cambridge University Press, Cambridge, UK, pp. 712.
Stringer, L.C., J.C. Dyer, M.S. Reed, A.J. Dougill, C. Twyman, and D. Mkwambisi, 2009: Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa. *Environmental Science and Policy*, 12, 748-765.
Stuart-Hill, S.I. and R.E. Schulze, 2010: Does South Africa's water law and policy allow for climate change adaptation? *Climate and Development*, 2(2), 128-144.
Sukhija, B.S., 2008: Adaptation to climate change: strategies for sustaining groundwater resources during droughts. In: *Climate Change and Groundwater*. [Drangoni, W. and B.S. Sukhija(eds.)]. Geological Society Special Publications, London, pp. 169-181.
Swiss Re, 2009: The effects of climate change: An increase in coastal flood damage in Northern Europe. Swiss Re, Zurich, Switzerland, pp. 4.

Tacoli, C., 2009: Crisis or adaptation? Migration and climate change in a context of high mobility. *Environment and Urbanization*, 21(2), 513-525.
Tandon, N., 2007: Biopolitics, climate change and water security: impact, vulnerability and adaptation issues for women. *Agenda: Women for Gender Equity*, Special Issue: Biopolitics, 21(73), 4-17.
Thomas, R.J., 2008: Opportunities to reduce the vulnerability of dryland farmers in Central and West Asia and North Africa to climate change. *Agriculture, Ecosystems and Environment*, 126, 36-45.
Thomas, D.S.G., C. Twyman, H. Osbahr, and B. Hewitson, 2007: Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. *Climatic Change*, 83(3), 301-322.
Thornton, P.K., J. van de Steeg, A. Notenbaert, and M. Herrero, 2009: The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. *Agricultural Systems*, 101(3), 113-127.
Thornton, P.K., P.G. Jones, G. Alagarswamy, and J. Andresen, 2009: Spatial variation of crop yield response to climate change in East Africa. *Global Environmental Change*, 19(1), 54-65.
Thurlow, J., T. Zhu, and X. Diao, 2009: The impact of climate variability and change on economic growth and poverty in Zambia. In: IFPRI Discussion Paper 00890. International Food Policy Research Institute (IFPRI), Washington, D.C, pp. 62.
Timmer, C.P., 2010: Reflections on food crises past. *Food Policy*, 35(1), 1-11.
Tingem, M. and M. Rivington, 2009: Adaptation for crop agriculture to climate change in Cameroon: Turning on the heat. *Mitigation and Adaptation Strategies for Global Change*, 14, 153-168.
Tischbein, B., A.M. Manschadi, A.K. Hornidge, C. Conrad, J.P.A. Lamers, L. Oberkircher, G. Schorcht, and P.L.G. Vlek, 2011: Proposals for the more efficient utilization of water resources in the Province of Khorezm, Uzbekistan. *Hydrologie Und Wasserbewirtschaftung*, 55(2), 116-125.
Tol, R.S.J., T.E. Downing, O.J. Kuik, and J.B. Smith, 2004: Distributional aspects of climate change impacts. *Global Environmental Change*, 14(3), 259-272.
Tompkins, E.L., R. Few, and K. Brown, 2008: Scenario-based stakeholder engagement: Incorporating stakeholders preferences into coastal planning for climate change. *Journal of Environmental Management*, 88(4), 1580-1592.
Toth, F.L. and E. Hizsnyik, 2008: Managing the Inconceivable: Participatory Assessments of Impacts and Responses to Extreme Climate Change. *Climatic Change*, 91(1-2), 81-101-1580 (1592).
Touman, I.A. and F. Al-Ajmi, 2005: Tradition, climate: As the neglected concepts in architecture. *Building and Environment*, 40(8), 1076-1084.
Tran, P., F. Marincioni, and R. Shaw, 2010: Catastrophic flood and forest cover change in the Huong river basin, central Viet Nam: A gap between common perceptions and facts. *Journal of Environmental Management*, 91(11), 2186-2200.
Travasso, M.I., G.O. Magrin, M.O. Grondona, and G.R. Rodriguez, 2009: The use of SST and SOI anomalies as indicators of crop yield variability. *International Journal of Climatology*, 29(1), 23-28.
Tschakert, P., 2007: Views from the vulnerable: Understanding climatic and other stressors in the Sahel. *Global Environmental Change*, 17(3-4), 381-396.
Twomlow, S., F.T. Mugabe, M. Mwale, R. Delve, D. Nanja, P. Carberry, and M. Howden, 2008: Building adaptive capacity to cope with increasing vulnerability due to climatic change in Africa - A new approach. *Physics and Chemistry of the Earth*, Parts A/B/C, 33(8-13), 780-787.
Tyler, S. and L. Fajber, 2009: Land and water resource management in Asia: Challenges for climate adaptation. [International Institute for Sustainable Developmen (ed.)], Winnipeg, Canada, pp. 24.
Tyler, N.J.C., J.M. Turi, M.A. Sundset, K. Strøm Bull, M.N. Sara, E. Reinert, N. Oskal, C. Nellemann, J.J. McCarthy, S.D. Mathiesen, M.L. Martello, O.H. Magga, G.K. Hovelsrud, I. Hanssen-Bauer, N.I. Eira, I.M.G. Eira, and R.W. Corell, 2007: Saami reindeer pastoralism under climate change: Applying a generalized framework for vulnerability studies to a sub-arctic social–ecological system. *Global Environmental Change*, 17(2), 191-206.
UK Government Foresight Programme (ed.), 2004: Future flooding. Office of Science and Technology, London, .
Ulimwengu, J.M., Workneh,S. and P. Zelekawork, 2009: Impact of Soaring Food Price in Ethiopia: Does Location Matter?. In: IFPRI Discussion Paper 00846. International Food Policy Research Center (IFPRI), Washington,DC;USA, pp. 24.
UN, 2009: World population prospects. The 2008 revision, highlights. In: Working Paper No. ESA/P/WP.210. United Nations Population Division, New York, USA, pp. 87.
UN, 2010: *World Urbanization Prospects. The 2009 Revision*. United Nations, New York, USA, pp. 47.

UN, 2011: *World Urbanization Prospects, the 2011 Revision*. United Nations, http://esa.un.org/unpd/wup/index.htm
UNDP, 2005: UN Millennium Project: Halving hunger, it can be done. In: *Task Force on Hunger*. Earth Scan, London, pp. 245.
UNEP, 2009: Climate and Trade Policies in a Post-2012 World. In: United Nations Environment Programme (UNEP), Geneva, Switzerland, pp. 95.
UN-Habitat, 2008: *State of the World's Cities 2008/2009. Harmonious Cities*. United Nations, New York, USA, pp. 280.
Urcola, H.A., J.H. Elverdin, M.A. Mosciaro, C. Albaladejo, J.C. Manchado, and J.F. Giussepucci, 2010: Climate change impacts on rural societies: Stakeholders perceptions and adaptation strategies in Buenos Aires, Argentina.[Proceedings of Innovation and sustainable development in agriculture and food and ISDA(eds.)]. 28.June - 01.July 2010, Montepellier, France, pp. 10.
Vaghefi, N., M. Nasir Shamsudin, A. Makmom, and M. Bagheri, 2011: The economic impact of climate change on the rice production in Malaysia. *International Journal of Agricultural Research*, 6(1), 67-74.
Valdivia, C, Seth, A., Gillesc, J.L. , Garcíad, M., Jiméneze, E., Cusicanquid, J., Naviad, F. and Yucra, E., 2010: Adapting to Climate Change in Andean Ecosystems: Landscapes, Capitals, and Perceptions Shaping Rural Livelihood Strategies and Linking Knowledge Systems. *Annals of the Association of American Geographers*, 100(4), 818-834.
van de Giesen, N., J. Liebe, and G. Jung, 2010: Adapting to climate change in the Volta Basin, West Africa. *Current Science*, 98(8), 1033-1037.
Van der Geest, K. and R. De Jeu, 2008: Climate Change and displacement: Ghana. *Forced Migration Review*, (31), 16.
Van der Geest, K., 2011: North-South Migration in Ghana: What Role for the Environment? *International Migration*, 49(S1), e69-e94.
Van Oel, P.R., M.S. Krol, A.Y. Hoekstra, and R.R. Taddei, 2010: 2010: Feedback mechanisms between water availability and water use in a semi-arid river basin: A spatially explicit multi-agent simulation approach. , 25(4), 433-443. *Environmental Modelling & Software*, 25(4), 433-443.
Van Oostdam, J., S.G. Donaldson, M. Feeley, D. Arnold, P. Ayotte, G. Bondy, L. Chan, É. Dewaily, C.M. Furgal, H. Kuhnlein, E. Loring, G. Muckle, E. Myles, O. Receveur, B. Tracy, U. Gill, and S. Kalhok, 2005: Human health implications of environmental contaminants in Arctic Canada: A review. *Science of the Total Environment*, 351-352, 165-246.
Verner, D., 2012: Adaptation to a changing climate in the Arab countries : a case for adaptation governance and leadership in building climate resilience. World Bank, Washington DC, .
Vincent, K., T. Cull, and E. Archer, 2010: Gendered vulnerability to climate change in Limpopo province, South Africa. In: *Gender and Climate Change: An Introduction*. [Dankelman, I. (ed.)]. Earthscan, London, pp. 160-167.
Vineis, P., Q. Chan, and A. Khan, 2011: Climate change impacts on water salinity and health. *Journal of Epidemiology and Global Health*, 1(1), 5-10.
Vogel, C. and K. O'Brien, 2006: Who can eat information? Examining the effectiveness of seasonal climate forecasts and regional climate-risk management strategies. *Climate Research*, 33, 111-122.
Vogel, C., S.C. Moser, R.E. Kasperson, and G.D. Dabelko, 2007: Linking vulnerability, adaptation, and resilience science to practice: Pathways, players, and partnerships. *Global Environmental Change*, 17(3–4), 349-364.
Vohland, K. and B. Barry, 2009: A review of in situ rainwater harvesting (RWH) practices modifying landscape functions in African drylands. *Agriculture, Ecosystems and Environment*, 131, 119-127.
Walter, L.C., H.T. Rosa, and N.A. Streck, 2010: Simulação do rendimento de grãos de arroz irrigado 1 em cenários de mudanças climáticas (simulating grain yield of irrigated rice in climate change scenarios). , 45(11), 1237-1245. *Pesquisa Agropecuaria Brasileira*, 45(11), 1237-1245.
Walton, A., 2009: Provincial-level projection of the current mountain pine beetle outbreak update of the infestation projection based on the 2008 provincial aerial overview of forest health and revisions to the "model" (BCMPB.v6). Ministry of Forests and Range, Research Branch, Victoria, B.C., pp. 15.
Wang, M., Y. Li, W. Ye, J.F. Bornman, and X. Yan, 2011: Effects of climate change on maize production, and potential adaptation measures: a case study in Jilin Province, China. *Climate Research*, 46(3), 223-242.
Warner, K., Ahrhart, C., Sherbinin. A., Adamo, S. and Chai-Onn, T., 2009: In Search of Shelter: mapping the effects of climate change on human migration and displacement. Climate Change CARE International, , 1-25.

Warren, R., N. Arnell, R.J. Nicholls, P. Levy, and J. Price, 2006: Understanding the regional impacts of climate change: research report prepared for the Stern review on the economics of climate change. In: Tyndall Centre Working Paper 90. Tyndall Centre,The University of East Anglia, Norwich, Uk, pp. 223.
Watkiss, P., T.E. Downing, and J. Dyszynski, 2010: ADAPTCost Project: Analysis of the Economic Costs of Climate Change Adaptation in Africa. United Nations Environment Programme (UNEP), Nairobi, pp. 33.
Watkiss, P., 2011: Aggregate economic measures of climate change damages: explaining the differences and implications. *Wiley Interdisciplinary Reviews: Climate Change*, 2(3), 356-372.
WDI, 2010: People. In: *World Development Indicators*. World Bank, Washington DC, USA, pp. 53-147.
WDI, 2012: *World Development Indicators* 2012. World Bank, Washington DC, USA, pp. 463.
Webster, D., 2002: On the edge : shaping the future of Peri-urban East Asia. Asia/Pacific Research Center, Stanford, USA, pp. 53.
Weisbach, D. and C. Sunstein, 2008: Climate Change and Discounting the Future: A Guide for the Perplexed. Rochester, NY: Social Science Research Network.SSRN Scholarly Paper, 26.02.2013.
Wellard, K., D. Kambewa, and S. Snapp, 2012: Farmers on the Frontline: adaptation and change in Malawi. In: *Climate Change and Threatened Communities: Vulnerability, capacity and action*. [A.P. Castro, D. Taylor and D.W.Brokensha (ed.)]. Practical Action Publications, Rugby, UK., .
Westerhoff, L. and B. Smit, 2009: The rains are disappointing us: dynamic vulnerability and adaptation to multiple stressors in the Afram Plains, Ghana. *Mitigation and Adaptation Strategies for Global Change*, 14(4), 317-337.
Westhoek, H., M. van den Berg, and J. Bakkes, 2006: Scenario development to explore the future of Europe's rural areas. *Agriculture Ecosystems & Environment*, 114(1), 7-20.
Wilbanks T.J., P. Romero Lankao, M. Bao, F. Berkhout, S. Cairncross, J.-P. Ceron, M. Kapshe, R. Muir-Wood, and R. Zapata-Marti, 2007: Industry, settlement and society. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [Parry M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson(eds.)]. Cambridge University Press, Cambridge, UK, pp. 357-390-390.
Williams, J., 2012: The impact of climate change on indigenous people – the implications for the cultural, spiritual, economic and legal rights of indigenous people. *The International Journal of Human Rights*, 16(4), 648-688.
Wittrock, V., S.N. Kulreshtha, and E. Wheaton, 2011: Canadian prairie rural communities: their vulnerabilities and adaptive capacities to drought. *Mitigation and Adaptation Strategies for Global Change*, 16(3), 267-290.
Wolfe, D., L. Ziska, C. Petzoldt, A. Seaman, L. Chase, and K. Hayhoe, 2008: Projected change in climate thresholds in the Northeastern U.S.: implications for crops, pests, livestock, and farmers. *Mitigation and Adaptation Strategies for Global Change*, 13(5), 555-575.
Womach, J., 2005: *Agriculture : terms, programs, and laws*. Nova Science Publishers, New York, pp. 234.
World Bank, 2003: Nicaragua Poverty Assessment. In: Report No. 26128-NI. World Bank, Washington DC, USA, pp. 51.
World Bank, 2007: *World Development Report 2008. Agriculture for Development*. World Bank ; Oxford University Press, Washington, D.C.; New York, .
World Bank, 2008: *World Development report 2009 : Reshaping Economic Geography*. World Bank, Washington, DC .
World Bank, 2010: Economics of Adaptation to Climate Change: Synthesis Report. World Bank, Washington, DC.
World Bank, 2010: Rising Global Interest in Farmland. Can It Yield Sustainable and Equitable Benefits. World Bank, Washington DC, USA, pp. 214.
WTO, 2009: *International Trade Statistics 2009*. World Trade Organization, Geneva, Switzerland.
WTO, 2009: Trade and Climate Change. World Trade Organization (WTO), United Nations Environment Programme (UNEP), Geneva, Switzerland, pp. 160.
Würtenberger, L., T. Koellner, and C.R. Binder, 2006: Virtual land use and agricultural trade: Estimating environmental and socio-economic impacts. *Ecological Economics*, 57(4), 679-697.
Wutich, A., A.B. York, A. Brewis, R. Stotts, and C.M. Roberts, 2012: Shared cultural norms for justice in water institutions: Results from Fiji, Ecuador, Paraguay, New Zealand, and the U.S. *Journal of Environmental Management*, 113, 370-367.
Xiong, W., C. Declan, J. Jinhe, Y. Li, L. Erda, Y. Xu, H. Ju, and Y. Li, 2009: Future cereal production in China: The interaction of climate change, water availability and socio-economic scenarios. *Global Environmental Change*, 19, 34-44.

Xu, Jianchu,Yang,Y., Z. Li, N. Tashi, R. Sharma, and J. Fang, 2008: Understanding Land Use, Livelihoods, and Health Transitions Among Tibetan Nomads: A Case from Gangga Township, Dingri County, Tibetan Autonomous Region of China. *Ecohealth*, 5(2), 104-114.

Zagonari, F., 2010: Sustainable, just, equal, and optimal groundwater management strategies to cope with climate change: Insights from Brazil. *Water Resources Management*, 24(12), 3731-3756.

Zepeda, C., M. Salman, and R. Ruppanner, 2001: International trade, animal health and veterinary epidemiology: challenges and opportunities. *Preventive Veterinary Medicine*, 48(4), 261-271.

Zhao, J., Jin, and Y., 2010: Effects of climate change on environment and human health. *Journal of Health*, 27(5), 463-464.

Ziervogel, G. and F. Zermoglio, 2009: Climate change scenarios and the development of adaptation strategies in Africa: challenges and opportunities. *Climate Research*, 40(2-3), 133-146.

Ziervogel, G., A. Opere, I. Chagonda, J. Churi, A. Dieye, B. Houenou, S. Hounkponou, E. Kisiangani, E. Kituyi, C. Lukorito, A. Macharia, H. Mahoo, A. Majule, P. Mapfumo, F. Mtambanengwe, F. Mugabe, L. Ogallo, G. Ouma, A. Sall, and G. Wanda, 2010: Integrating meteorological and indigenous knowledge-based seasonal climate forecasts for the agricultural sector. Lessons from participatory action research in sub-Saharan Africa IDRC, Ottawa, pp. 24.

Ziervogel, G., 2004: Targeting seasonal climate forecasts for integration into household level decisions: the case of smallholder farmers in Lesotho. *The Geographical Journal*, 170(1), 6-21.

Ziervogel, G. and T.E. Downing, 2004: Stakeholder networks: improving seasonal climate forecasts. *Climatic Change*, 65(1-2), 73-101.

Ziervogel, G., M. Bithell, R. Washington, and T. Downing, 2005: Agent-based social simulation: a method for assessing the impact of seasonal climate forecast applications among smallholder farmers. *Agricultural Systems*, 83(1), 1-26.

Ziervogel, G. and A. Taylor, 2008: Feeling stressed: Integrating climate adaptation with other priorities in South Africa. *Environment*, 50(2), 32-41.

Zografos, C. and R.B. Howarth, 2010: Deliberative Ecological Economics for Sustainability Governance. *Sustainability*, no. 11: 3399-3417. Sustainability, 2(11), 3388-3417.

XADB, 2009: *Climate change in the Pacific: Stepping up responses in the face of rising impacts*. Asian Development Bank, Philippines, pp. 33.

XADB, 2009: Understanding and Responding to Climate Change in Developing Asia, Asian Development Bank, Philippines, 223 pp.

Table 9-1: Major findings of the IPCC Fourth Assessment Report and the International Assessment of Agricultural Science and Technology for Development.

Importance of non-climate trends	Source
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 (e.g. water scarcity, governance structures, institutional and jurisdictional fragmentation, limited revenue streams for public sector roles, or inflexible land use patterns)	W
Different development paths may increase or decrease vulnerabilities to climate-change impacts	W
Neglect by policy-makers and under-investment in infrastructure and services has negatively affected rural areas	I
Policy neglect specifically disfavours rural women	I
Assessment of climate change impacts on agriculture has to be undertaken against a background of demographic and economic trends in rural areas	E
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	E
Specific characteristics of smallholder agriculture	
Subsistence and smallholder livelihood systems suffer from a number of non-climate stressors, but are also characterized for having certain resilience factors (efficiencies associated with the use of family labour, livelihood diversity to spread risks)	E
Traditional knowledge on agriculture and natural resources is an important resilience factor	I, E
The combination of stressors and resilience factors gives rise to complex and locally specific impacts, resistant to modelling	E, W
Impacts on agriculture and agricultural trade	
In low-latitude regions, temperature increases of 1-2°C are likely to have negative impacts on yields of major cereals. Further arming has increasingly negative impacts in all regions	E
Increases in global mean temperatures (GMTs) of 2-3 might lead to a small rise or decline (10-15%) 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%	E
Forestry	
Loss of forest resources through climate change may affect 1.1 billion poor and forest-dependent people, including through impacts on Non-Timber Forest Products.	E
Valuation	
Robust valuations of climate change impact on human settlements are rare	W
Social and environmental costs are poorly captured by monetary metrics: non-monetary valuation methods should be explored	W, I
Adaptation	
Prospects for adaptation depend on the magnitude and rate of climate change	I
Adaptation actions can be effective in achieving their specific goals, but they may have other (positive or negative) effects, including resource competition	I
Diversification of agricultural and non-agricultural livelihood strategies is an important adaptation trend, but requires institutional support and access to resources	E
Links between adaptation and mitigation	
Mitigation and adaptation policies are in many cases, and certainly for agriculture, closely linked	K, E, W

Sources: W = Wilbanks *et al*. 2007; E = Easterling *et al*. 2007; I = McIntyre *et al*. 2009; K = Klein *et al*. 2007

Table 9-2: Major demographic, poverty-related, economic, governance, and environmental trends in rural areas of developed and developing countries.

	Developed countries	**Developing countries**
Demographic Trends	Rural population accounts for 22.3% of the total population (or about 276 million people) (UN-DESA Population Division, 2012). Rural areas account for 75% of land area in OECD countries (OECD 2006). Rural population has peaked (absolute numbers) in Europe and North America. Rural depopulation in some places, but also counter-urbanization with people moving from urban to rural areas elsewhere.	Rural population accounts for 50.3% of the total population (or about 2.5 billion people) in less developed countries (excluding LDCs), 71.5% (or about 608 million people) in the LDCs (UN-DESA Population Division, 2012) 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.
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-i-Gelats, 2009)	Proportion of rural population engaged in agriculture declining in all regions(Figure 9-2).. 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)
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. Recent price hikes and volatility exacerbated hunger and malnutrition among rural households many of which are net-food buyers (FAOSTATS, 2013). Hunger and malnutrition prevalent among rural children in South Asia and Sub-Saharan Africa (UN, 2010; IFAD, 2010; World Bank, 2007). Figure 9-2 and Table 9-3

Table 9-2 (continued)

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; Rounsevell *et. al.,* 2007) Agricultural subsidies under pressure from international trade negotiations and domestic budgetary constraints. As a result of recent price hikes, domestic price support has been lowered in OECD countries. New policy approach in OECD countries that focuses on investments and targets a range of rural economic sectors and environmental services.	Interconnectedness and economic openness in rural areas have encouraged shifts to commercial agriculture, livelihoods diversification and aid knowledge transfers (section 9.3.3). Interlinkages between land tenure, food security and biofuel policies impact rural poverty (see Chapter 7, section 7.1 and 7.3.2 for further details) Decentralization of governance and emergence of rural civil society. 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 (Chapter 13, Section 13.2.6) .
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).	Stronger rural-urban linkages through migration, 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). Continued out-migration to urban areas by the semi-skilled and low-skilled, reducing the size of rural workforce (IFAD, 2010). Trend for migration to small and medium-sized towns (Sall *et al*., 2010). Increased volumes of agricultural trade, growing by 5% on average (annually) between 2000-2008 (WTO, 2009). New initiatives of foreign direct investment (FDI) in agriculture in the form of large-scale land acquisitions in developing countries (Anseeuw *et al*., 2012; World Bank, 2010).

Table 9-3: 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 9-4: Projected changes in areas suitable for production of tropical beverage crops by 2050.

Crop	**Countries**	**Change in climate to 2050**	**Change in total area by 2050**	**Change in distribution by 2050**
Coffee	Guatemala, Costa Rica, Nicaragua, El Salvador, Honduras, Mexico	2.0-2.5ºC increase in temperature 5-10% decline in total rainfall	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	2.3ºC increase in temperature Rainfall increase from 1405mm to 1575 mm	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	2.3ºC increase in temperature Rainfall increase from 1655mm to 1732 mm	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	2.3ºC increase in temperature Rainfall increase from 1334mm to 1394 mm	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	2.1ºC increase in temperature No change in total rainfall	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 9-5: 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

Table 9-6: Examples of adaptations in the agricultural sector in different regions.

Agricultural adaptations	**Where it has been observed and source**
Modifying planting, harvesting and fertilising practices for crops	Anchioreta in Brazil (Bonatti et al., 2012), semi-arid mountain regions of Bolivia (PNCC, 2007), Chile (Meza and Silva, 2009), maize and wheat crops in Argentina (Magrin et al., 2009; Travasso et al., 2009b), South Africa and Ethiopia (Bryan *et al*, 2009), composting and coraaling of livestock to collect waste in northern Burkino Faso (Barbier et al, 2009), Sahelian region of Mali (Adepetu and Berthe, 2007), in North West Province, Limpopo Province and KwaZulu Natal, South Africa (Thomas *et al*, 2007)
Changing amount or area of land under cultivation	Moving winter wheat northwards and expanding rice crops (Lin et al., 2005), South Africa (Bryan et al, 2009), expansion of fields in northern Burkino Faso (Barbier et al, 2009), increase in the size of plots in the Sahelian region of Mali (Adepetu and Berthe, 2007)
Using different varieties (e.g. early maturing, drought-resistant)	Early maturing cultivars in South Brazil (Walter et al, 2010), North America (Coles and Scott, 2009), drought-tolerant in Asia (Thomas, 2008; Zhao et al., 2010), South Africa and Ethiopia (Bryan *et al,* 2009), Ghana (Gyampoh et al, 2008), northern Burkino Faso (Barbier et al, 2009), Sahelian region of Mali and Nigeria (Adepetu and Berthe, 2007), in North West Province, Limpopo Province and KwaZulu Natal, South Africa (Thomas *et al*, 2007)
Diversifying crops	Peruvian Andes (Lin, 2011), South America (Montenegro and Ragrab, 2010), northeastern Mexico (Eakin and Appendini, 2008; Eakin and Bojorquez-Tapia, 2008), Tasmania, Australia (Smart, 2010), in KwaZulu Natal, South Africa (Thomas et al, 2007)
Commercialisation of agriculture	Income generation from natural resources (e.g. fuelwood) in the Limpopo River Basin, Botswana (Dube and Sekhela, 2007), Ghana (Gyampoh *et al*, 2008), Limpopo Province, South Africa (Thomas et al, 2007)
Water control mechanisms (including irrigation and water allocation rights)	Improved rice harvests in monsoonal Asia (Hatcho et al., 2010); adaptation for quinoa (Bolivian Altiplano), tomatoes (central Brazil) and cotton (northern Argentina (Geerts and Raes, 2009); for rice in northeast China (Lin et al, 2005); small water harvesting pits (known as zai) in improved yields and incomes due to improved soil moisture in Ethiopia (Amede *et al*., 2011; Bryan *et al*, 2009) and Burkina Faso (Hertsgaard, 2011, Barbier *et al*, 2009), in South Africa (Bryan et al, 2009), amongst rural women farmers in the Eastern Cape, South Africa (Bryan *et al*, 2009), Ghana (Gyampoh et al, 2008), dry season vegetable production through irrigation in northern Burkino Faso to enable two crop cycles (Barbier et al, 2009), Sahelian region of Mali and Nigeria (Adepetu and Berthe, 2007), in Limpopo Province, South Africa (Thomas et al, 2007)
Shading and wind breaks	For coffee in Brazil, Costa Rica and Colombia (Camargo, 2010), Ethiopia (Bryan *et al,* 2009)
Conservation agriculture (e.g. soil protection, agroforestry)	Honduras, Nicaragua and Guatemala (Holt-Gimenez, 2002), Burkina Faso (Hertsgaard, 2011, Barbier *et al*, 2009), Ethiopia (Bryan *et al*, 2009), Sahelian region of Mali (Adepetu and Berthe, 2007)
Modifying grazing patterns for herds	Arctic (Bartsch et al, 2010), East Africa (Eriksen and Lind, 2009) and southern Africa (O'Farrell *et al*., 2009), moving livestock to less densely populated pastures in northern Burkino Faso (Barbier et al, 2009) and the Sahelian region of Mali and Nigeria (Adepetu and Berthe, 2007), in North West Province, Limpopo Province and KwaZulu Natal, South Africa (Thomas *et al*, 2007)
Providing supplemental feeding for herds/ storage of animal feed	Arctic (P. and M., 2008; Forbes and Kumpula, 2009), South Africa (Bryan *et al*, 2009), use of sorghum and hay residue for feeding livestock in northern Burkino Faso (Barbier et al, 2009), Sahelian region of Mali and Nigeria (Adepetu and Berthe, 2007), cutting fodder for livestock in Limpopo Province, South Africa (Thomas *et al*, 2007)
Ensuring optimal herd size	Arctic (Forbes et al, 2009), culling of livestock in Northern Nigeria (Adepetu and Berthe, 2007), selling of livestock northern Burkino Faso (Barbier et al, 2009) and the Sahelian region of Mali and Nigeria (Adepetu and Berthe, 2007)
Developing new crop and livestock varieties (e.g. biotechnology and breeding)	Brazil and Argentina (Marshall, 2012; Urcola et al, 2010), Northern Nigeria (Adepetu and Berthe, 2007)

Table 9-7: Examples of adaptations in the water sector observed in different regions.

Type	Example	Where it has been observed and source
Supply-side mechanisms	Dams	Proposed in the Volta River in Ghana (van de Giesen *et al*., 2010).
	Reservoirs	Asia (Tyler and Fajber, 2009), particularly in areas where water stress is an issue of distribution rather than absolute shortage (Biemans et al, 2011; Rivera-Ferre et al 2013)
	Groundwater pumping	Arid and semi-arid South America (Burte et al., 2011; Döll, 2009; Kundzewicz and Döll, 2009; Zagonari, 2010)
	Groundwater recharge	Potential identified in India (Sukhija, 2008)
	Irrigation (often using water-saving technology)	Asia (Ngoundo et al., 2007; Tischbein etal., 2011)
	Fog interception practices	South America (Holder, 2006; Klemm et al., 2012)
	Water capture	Bolivia (PNCC, 2007)
Demand-side mechanisms	Improved management, e.g. through efficiency	Asia (Kranz et al, 2010), South America (Bell et al., 2011; Geerts et al., 2010; Montenegro and Ragab, 2010; Van Oel et al., 2010); Pampas Argentina (Quiroga and Gaggioli, 2011)
	Policies	Murray-Darling Basin Authority (MDBA) established to address over-allocation of water resources (Connell and Grafton, 2011; MDBA, 2011) See also box 26-3 on Australia's water policies;
	Reviewing allocation rights	Indogangetic Plains (Rivera-Ferre et al., 2013); Australia's MDBA reviewed the "exceptional circumstances" concept in drought policy (Productivity Commission, 2009);

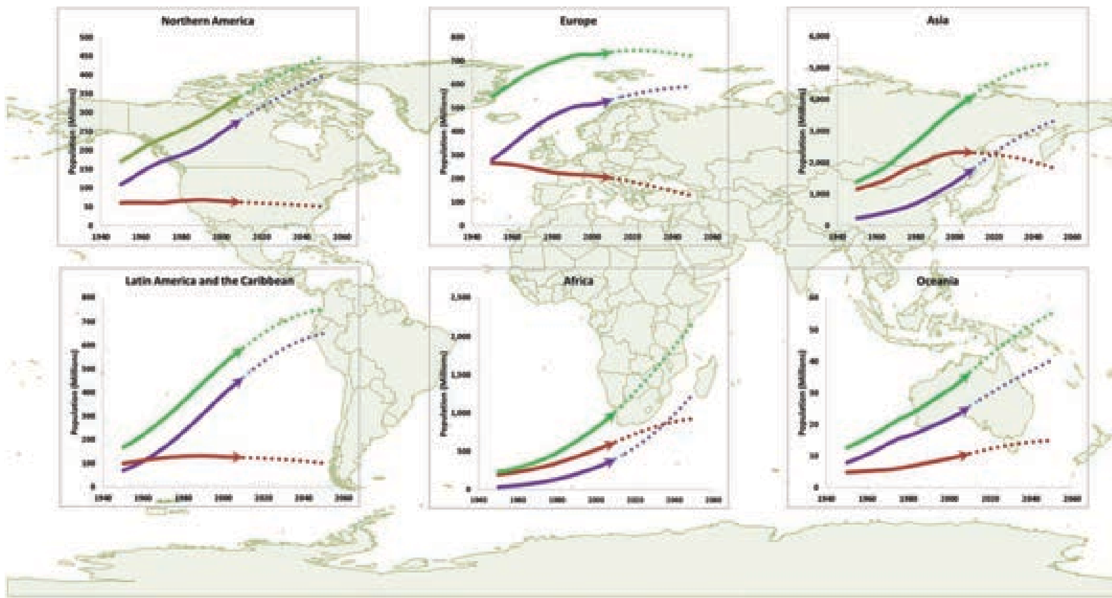

Figure 9-1: Trends in rural (red), urban (purple), and total (green) populations by region. Solid lines represent observed values and dotted lines represent projections. Source: United Nations, Department of Economic and Social Affairs/Population Division (2012).

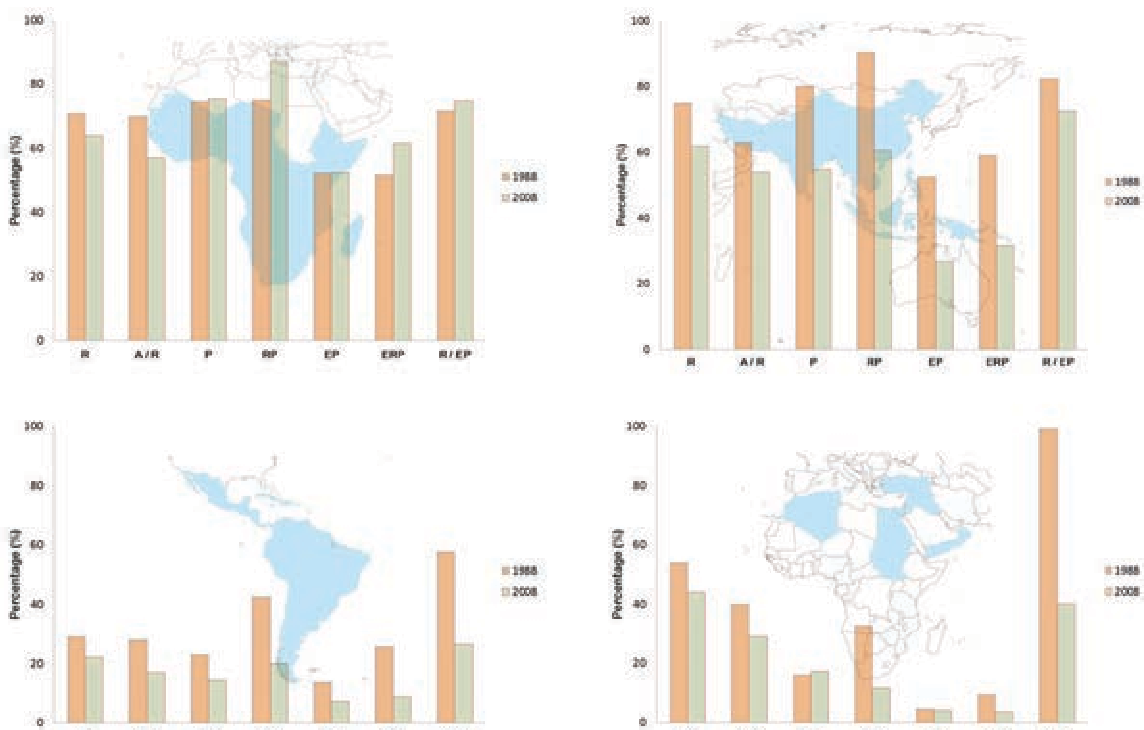

Figure 9-2: Demographic and poverty indicators for rural areas of developing countries, by region. R: percentage of rural population; A/R: agriculture as percentage of rural; P: incidence of poverty; RP: incidence of rural poverty; EP: incidence of extreme poverty; ERP: incidence of extreme rural poverty; R/EP : rural as percentage of those in extreme poverty. Source: Adapted from IFAD (2011).