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Rural Areas

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Executive Summary

Rural areas still account for almost half the world's population, and about 70% of the developing world's poor people. {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 (*limited evidence*, *high agreement*). {9.1.3} Rural areas, viewed as a dynamic, spatial category, remain important for assessing the impacts of climate change and the prospects for adaptation. {9.1.1}

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, absolute 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 higher than overall poverty rates, but also falling more sharply, and the proportions of population in extreme poverty accounted for by rural people are also falling: in both cases with the exception of sub-Saharan Africa, where these rates are rising. {Figure 9-2} Accelerating globalization, through migration, labor linkages, regional and international trade, and new information and communication technologies, is bringing about economic transformation in rural areas of both developing and developed countries. {9.3.1}

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 and natural resource policy, and processes of environmental degradation (*very high confidence*). In developing countries, the levels and distribution of rural poverty are affected in complex and interacting ways by processes of commercialization and diversification, food policies, and policies on land tenure. In developed countries, there are important shifts toward 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 9-3}

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. {9.3.3} This increases both the uncertainty associated with detection and attribution of current impacts {9.3.2}, and with projections of specific future impacts. {9.3.3}

Structural features of farm households and communities affect their vulnerability to climate change in complex ways (*high confidence*). There is *low agreement* on some of the key factors associated with vulnerability or resilience in rural areas {9.3.5.1}, including rainfed as opposed to irrigated agriculture {9.3.5.1.1}, small-scale and family-managed farms, and integration into world markets. {9.3.5.1.2} There is *high agreement* on the importance for resilience of access to land and natural resources, flexible local institutions {9.3.5.1.3}, and knowledge and information {9.3.5.1.6}, and on the association of gender inequalities with vulnerability. {9.3.5.1.5} Specific livelihood niches such as pastoralism, mountain farming systems, and artisanal fisheries are vulnerable and at high risk of adverse impacts (*high confidence*), partly owing to neglect, misunderstanding, or inappropriate policy toward them on the part of governments. {9.3.5.2}

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 (*medium confidence*). Impacts attributable to climate change include some direct impacts of droughts, storms, and other extreme events on infrastructure and health (*low confidence* globally, but *medium confidence* in certain regions), as well as longer-term declining yields of major crops, from which impacts on income and livelihoods can be inferred with *low confidence*. There is *high confidence* in geographically specific impacts, such as glacier melt in the Andes. {9.3.2}

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*). Shifts in agricultural production, of food and non-food crops, are projected for many areas of the world (*high confidence*). {9.3.3.1} Price rises, which may be induced by climate shocks as well as 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} The time scale for impacts varies across regions and sectors, and by the nature of the specific climatic impact.

Climate change will impact international trade volumes in both physical and value terms (*limited evidence*, *medium agreement*). Importing food can help countries adjust to climate change-induced domestic productivity shocks while short-term food deficits in low-income countries may have to be met through food aid. Options exist for adaptations within international agricultural trade (*medium confidence*). Deepening agricultural markets and improving the predictability and the reliability of the world trading system through trade reform, as well as investing in additional supply capacity of small-scale farms in developing countries, could result in reduced market volatility and manage food supply shortages caused by climate change. {9.3.3.3.2}

Migration patterns will be driven by multiple factors of which climate change is only one (*high confidence*). {9.3.3.3.1} Given these multiple drivers of migration (economic, social, political, demographic, and environmental) and the complex interactions that mediate migratory decision making by individuals or households, establishment of a relation between climate change and intra-rural and rural-to-urban migration, observed or projected, remains a major challenge.

Climate policies, such as increasing energy supply from renewable resources, encouraging cultivation of biofuels, or payments under Reducing Emissions from Deforestation and Forest Degradation (REDD), will have significant secondary impacts, both positive (increasing employment opportunities) and negative (landscape changes, increasing conflicts for scarce resources), in some rural areas (*medium confidence*). {9.3.3.4} There is a need to understand how implementation of these policies will impact on rural livelihoods. These secondary impacts, and trade-offs between mitigation and adaptation in rural areas, have implications for governance, including the need to promote participation of rural stakeholders.

Most studies using valuation methodologies conclude that climate change impacts will be substantial, especially for developing countries, owing to their economic dependence on agriculture and natural resources, low adaptive capacities, and geographical locations (*very high confidence*). {9.3.4} Valuation of climate impacts needs to draw on both monetary and non-monetary indicators. The valuation of non-marketed ecosystem services {9.3.4.5} and the limitations of economic valuation models that aggregate across multiple contexts {9.3.4} pose challenges for valuing impacts in rural areas (*high confidence*).

There is a growing body of literature on adaptation practices in both developed and developing country rural areas {9.4.1}, including documentation of practical experience in agriculture, water, forestry and biodiversity, and, to a lesser extent, fisheries {9.4.3} (*very high confidence*). Public policies supporting decision making for adaptation exist in developed and, increasingly, in developing countries, and there are also examples of private adaptations led by individuals, companies, and non-governmental organizations (*high confidence*). {9.4.2} Constraints on adaptation come from lack of access to credit, land, water, technology, markets, knowledge and information, and perceptions of the need to change; and are particularly pronounced in developing countries (*high confidence*). {9.4.4} Gender and institutions affect access to adaptation options and the presence of barriers to adaptation (*very high confidence*). {9.4.4}

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9.1. Introduction

9.1.1. Rationale for the Chapter

This chapter assesses the impacts of climate change on, and the prospects for adaptation in, rural areas. Rural areas include diverse patterns of settlement, infrastructure, and livelihoods, and relate in complex ways with urban areas. The chapter shows that rural areas experience specific vulnerabilities to climate change, both through their dependence on natural resources and weather-dependent activities and their relative lack of access to information, decision making, investment, and services. Adaptation strategies will need to address these vulnerabilities. Some of the key starting points, which affect the scope and coverage of literature assessed in this chapter, are as follows:

- 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, 2013).
- 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 less developed or least developed countries (UN DESA Population Division, 2013).
- Rural dwellers also account for about 70% of the developing world's poor people. IFAD (2010) states that around 70% of the extreme poor in developing countries lived in rural areas in 2005. Ravallion et al. (2007), using 2002 data and poverty lines of US$1.08 or US$2.15, in each case with urban poverty lines adjusted upward to recognize additional non-food spending, give a figure of around 75% of people, under either poverty line, being rural.
- Rural areas are a spatial category, associated with certain patterns of human activity, but with those associations being subject to continuous change.
- Rural areas are largely defined in contradistinction to urban areas, but that distinction is increasingly seen as problematic.
- 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.

The chapter will complement the treatment of issues also dealt with in Chapters 4 and 7, 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 Chapters 12 and 13 and other sectoral and regional chapters. The important impacts of climate change on human health are covered in Chapter 11. In accordance with the proportion of the rural population found in developing countries, literature on these countries is given prominence, but issues of impact, vulnerability, and adaptation in developed countries are also assessed.

9.1.2. Definitions of the Rural

"Rural" refers generally to areas of open country and small settlements, but the definition of "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).

Frequently Asked Questions

FAQ 9.1 | What is distinctive about rural areas in the context of climate change impacts, vulnerability, and adaptation?

Nearly half of the world's population, approximately 3.3 billion people, lives in rural areas, and 90% of those people live in developing countries. Rural areas in developing countries are characterized by a dependence on agriculture and natural resources; high prevalence of poverty, isolation, and marginality; neglect by policymakers; and lower human development. These features are also present to a lesser degree in rural areas of developed countries, where there are also closer interdependencies between rural and urban areas (such as commuting), and where there are also newer forms of land use such as tourism and recreational activities (although these also generally depend on natural resources).

The distinctive characteristics of rural areas make them uniquely vulnerable to the impacts of climate change because:

- Greater dependence on agriculture and natural resources makes them highly sensitive to climate variability, extreme climate events, and climate change.
- Existing vulnerabilities caused by poverty, lower levels of education, isolation, and neglect by policymakers can all aggravate climate change impacts in many ways.

Conversely, rural people in many parts of the world have, over long time scales, adapted to climate variability, or at least learned to cope with it. They have done so through farming practices and use of wild natural resources (often referred to as indigenous knowledge or by similar terms), as well as through diversification of livelihoods and through informal institutions for risk-sharing and risk management. Similar adaptations and coping strategies can, given supportive policies and institutions, form the basis for adaptation to climate change, although the effectiveness of such approaches will depend on the severity and speed of climate change impacts.

Table 9-1 | Indicative examples of definitions of the "rural" and the "urban" in selected countries.

Country	Term	Definition	Reference
Australia	Major urban area	Population of more than 100,000	Australian Bureau of Statistics (2013)
	Other urban area	Population of 1000–99,999	
	Rural area	Includes small towns with a population of 200–999	
China	Major urban area	Population of more than 10,000	Ministry of Construction (1993)
	Medium urban area	Population of 3000–9999	
	Small urban area	Population of fewer than 3000	
	Major village	Population of 1000–3000	
	Medium village	Population of 300–1000	
	Small village	Population of fewer than 300	
India	Urban area	Population of 5000 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 km^{-2}. It is implied that all non-urban areas are rural.	Government of India (2012)
Jamaica	Urban place	Population of more than 2000 people; and provision of a certain set of amenities and facilities that are deemed to indicate "modern living". It is implied that all non-urban areas are rural.	Statistical Institute of Jamaica (2012:iv)
United States of America	Rural area	All territory outside of defined urbanized areas and urban clusters, that is, open country and settlements with fewer than 2500 residents; with population densities as high as 386 people km^{-2}.	Womach (2005)

Ultimately, 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 centers" not clearly fitting into one or the other. The variations in definitions from country to country can best be described through several examples (from both developed and developing countries of different sizes) shown in Table 9-1.

Researchers have increasingly recognized that the simple dichotomy between "rural" and "urban" is extremely problematic (Simon et al., 2006, p. 4). Additional categories such as "peri-urban areas" (Webster 2002; Bowyer-Bower, 2006; Simon et al., 2006; Simon, 2008; Lerner and Eakin, 2010) and "desakota" (McGee, 1991; Desakota Study Team, 2008; Moench and Gyawali, 2008) allow more nuanced analysis of the permeable boundaries of rural and urban areas and the diversified economic systems that exist across the urban-rural spectrum; see Box CC-UR.

While remaining aware of issues of definition, this chapter in general assesses the literature on rural areas using whatever definitions of the rural are used in that literature. Global statistics collated by international organizations and cited here are generally aggregations of national statistics compiled under each national definition.

9.2. Findings of Recent Assessments

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. Table 9-2 summarizes 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 et al., 2009). All of these sources stress uncertainty, the importance of non-climate trends, complexity, and context-specificity in any findings on rural areas and climate change.

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 that are shaping those areas. While there are major points of contact between the important trends in developing and developed 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 9-3 summarizes and compares the most important trends across the two groups of countries. Figures 9-1 and 9-2 and Table 9-4 focus on two specific trends in developing countries: demographic trends and trends in poverty indicators.

9.3.2. Observed Impacts

Documentation of observed impacts of climate change on rural areas involves major questions of detection and attribution (see Chapter 18). Whilst having potential, there are complications with using traditional knowledge and farmer perceptions to detect climate trends (Rao et al., 2011; see also Box 18-4). Implied equivalence between local perceptions of climate change, local decadal trends, extreme events, and global change is common, and often used without systematic discussion of the challenges (Paavola, 2008; Ensor and Berger, 2009; Castro et al., 2012). This is not a problem in the context of detailed social-scientific analysis of vulnerability, adaptive capacity, and their determinants, but becomes more problematic to use as evidence for observed impact. Detection and attribution of extreme events to climate change is no less challenging (Seneviratne et al., 2012). Exposure to non-climate trends and shocks further complicates the issue (Nielsen and Reenberg, 2010; see also Section 3.2.7).

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 the IPCC *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (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, and that "attribution of single extreme events to anthropogenic climate change is challenging" (p. 112). They state that it is *likely* there has been a worldwide increase in extreme high-water events during the late 20th century, with a *likely* anthropogenic influence on it. They have *medium confidence* in detecting trends toward 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. WG I AR5 Chapter 2 similarly ascribes *low confidence* in a global observed trend in drought in the later 20th century, with a *likely* increase in frequency and intensity of drought in the Mediterranean and West Africa and a *likely* decrease in central North America. 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

Table 9-2 | Relevant findings on rural areas from the IPCC Fourth Assessment Report and the International Assessment of Agricultural Science and Technology for Development.

	Finding	Source
Importance of non-climate trends	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, resource constraints, or inflexible land use patterns).	W 7.4.2 I 6.7.5
	Different development paths may increase or decrease vulnerabilities to climate-change impacts.	W 7.7
	Neglect by policymakers and underinvestment in infrastructure and services has negatively affected rural areas.	I 1.3.4
	Policy neglect specifically disfavors rural women.	I 1.3.4
	Assessment of climate change impacts on agriculture has to be undertaken against a background of demographic and economic trends in rural areas.	E 5.3.2
	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 5.6.5
Specific characteristics of smallholder agriculture	Subsistence and smallholder livelihood systems suffer from a number of non-climate stressors, but are also characterized by having certain resilience factors (efficiencies associated with the use of family labor, livelihood diversity to spread risks).	E 5.3.2
	Traditional knowledge of agriculture and natural resources is an important resilience factor.	I 2.1.2, 3.2.2, 3.2.3 E 5.3.2 CC4
	The combination of stressors and resilience factors gives rise to complex and locally specific impacts, resistant to modeling.	E 5.4.7 W 7.2, 7.4, 7.5
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 warming has increasingly negative impacts in all regions.	E 5.4.2
	Increases in global mean temperatures (GMTs) of 2–3°C 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 5.6.1
Forestry	Loss of forest resources through climate change may affect 1.2 billion poor and forest-dependent people, including through impacts on non-timber forest products.	E 5.4.5
Valuation	Robust valuation of climate change impact on human settlements is difficult, and social and environmental costs are poorly captured by monetary metrics: non-monetary valuation methods should be explored.	W 7.4.3, 7.5 I 8.2.5
Adaptation	The need and the capacity to adapt vary considerably from region to region, and from farmer to farmer.	I 1.3.3
	Adaptation actions can be effective in achieving their specific goals, but they may have other (positive or negative) effects, including resource competition.	I 6.7.5
	Diversification of agricultural and non-agricultural livelihood strategies is an important adaptation trend, but requires institutional support and access to resources.	E 5.5.1, 5.5.2
	The effectiveness of adaptation efforts is likely to vary significantly between and within regions, depending on geographic location, vulnerability to current climate extremes, level of economic diversification and wealth, and institutional capacity.	I 6.8
	Multi-stakeholder processes are increasingly important with respect to climate change adaptation.	I 7.5.3
Links between adaptation and mitigation	Mitigation and adaptation policies are in many cases, and certainly for agriculture, closely linked.	K 18.4.3, 18.7.1 E 5.4.1, 5.4.2, 5.6.5 W 7.1, 7.7

Sources: W = Wilbanks et al. (2007); E = Easterling et al. (2007); I = McIntyre et al. (2009); K = Klein et al. (2007); CC4 = Cross-Chapter Case Study C4 "Indigenous knowledge for adaptation to climate change" in AR4 (Parry et al., 2007).

tropical cyclone activity, as does WGI AR5 Chapter 2, and to attribution of any changes in cyclone activity to anthropogenic influence. WGI AR5 Chapter 2 states that an observed increase in the frequency and intensity of North Atlantic cyclones is *virtually certain*. It also describes varying regional trends toward heavy precipitation events, *very likely* in central North America. Section 3.2.7 ascribes *medium confidence* to observed increased likelihood of flooding at the scale of some regions.

Handmer et al. (2012) discuss both observed and projected impacts of extreme events on human systems and ecosystems, with numerous examples of diverse, widespread negative impacts (see also Chapter 18). 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 in rural areas produce severe economic stresses, including employment reduction and migration (Gray and Mueller, 2012). Agricultural livelihoods are affected by droughts. Ericksen et al. (2012) review a variety of livestock mortality rates for recent droughts in the Horn of Africa, ranging up to 80% of livestock in southern Kenya in 2009.

Climate change impacts on agriculture and ecosystems run through rising temperature and changes in rainfall variability and seasonality as well as through extreme events. Changes in temperature caused reduction in global yields of maize and wheat by 3.8 and 5.5% respectively from 1980 to 2008 relative to a counterfactual without climate change, which offset in some countries some of the gains from improved agricultural technology (Lobell et al., 2011; see also Section 7.2.1.1). 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

Table 9-3 | 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 LDCs. Rural population has already peaked in Latin America and the Caribbean, East and Southeast Asia; expected to peak around 2025 in the 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 (OECD, 2006), and less than 10% on average across developed countries; however, it 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, with social re-composition and economic restructuring taking place (Marsden, 1999; Lopez-i-Gelats et al., 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 labor-based and migration-based livelihoods increasingly existing alongside (and complementing) farm-based livelihoods. Agricultural initiatives and growth still important for adaptation and for smallholders in Africa and Asia (Collier et al., 2008; Osbahr et al., 2008; Kotir, 2011).
Poverty and inequality	Per capita gross domestic product (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 labor, low levels of public services (OECD, 2006).	Rates of poverty (percentage of population living on less than US$2 per day) and extreme poverty (percentage of population living on less than US$1.25 per 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 (World Bank, 2007; IFAD, 2010); see Figure 9-2 and Table 9-4.
Economic, policy, governance trends	Shift from agricultural (production) to leisure (consumption) activities; focus on broader amenity values of rural landscapes for recreation, tourism, forests, and ecosystem services (OECD, 2006; Rounsevell et al., 2006; Bunce, 2008). 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 help knowledge transfers (Section 9.3.3). Interlinkages between land tenure, food security, and biofuel policies impact rural poverty (see Sections 7.1 and 7.2.2 for further details). Decentralization of governance and emergence of rural civil society. Movements toward land reform in some parts of Asia (Kumar, 2010). Emergence of economies in transition, characterized in places by coexistence of leading and lagging regions; political and democratic decentralization leading to increasing complexity of policy (World Bank, 2007).
Environmental degradation	Different socioeconomic 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, exacerbating social and environmental challenges. Multiple stressors increase risk, reduce resilience, and exacerbate vulnerability among rural communities from extreme events and climate change impacts (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, D.G. 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 semiskilled and low-skilled, reducing the size of the 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 and 2008 (WTO, 2009). New initiatives of foreign direct investment (FDI) in agriculture in the form of large-scale land acquisitions in developing countries (World Bank, 2010; Anseeuw et al., 2012).

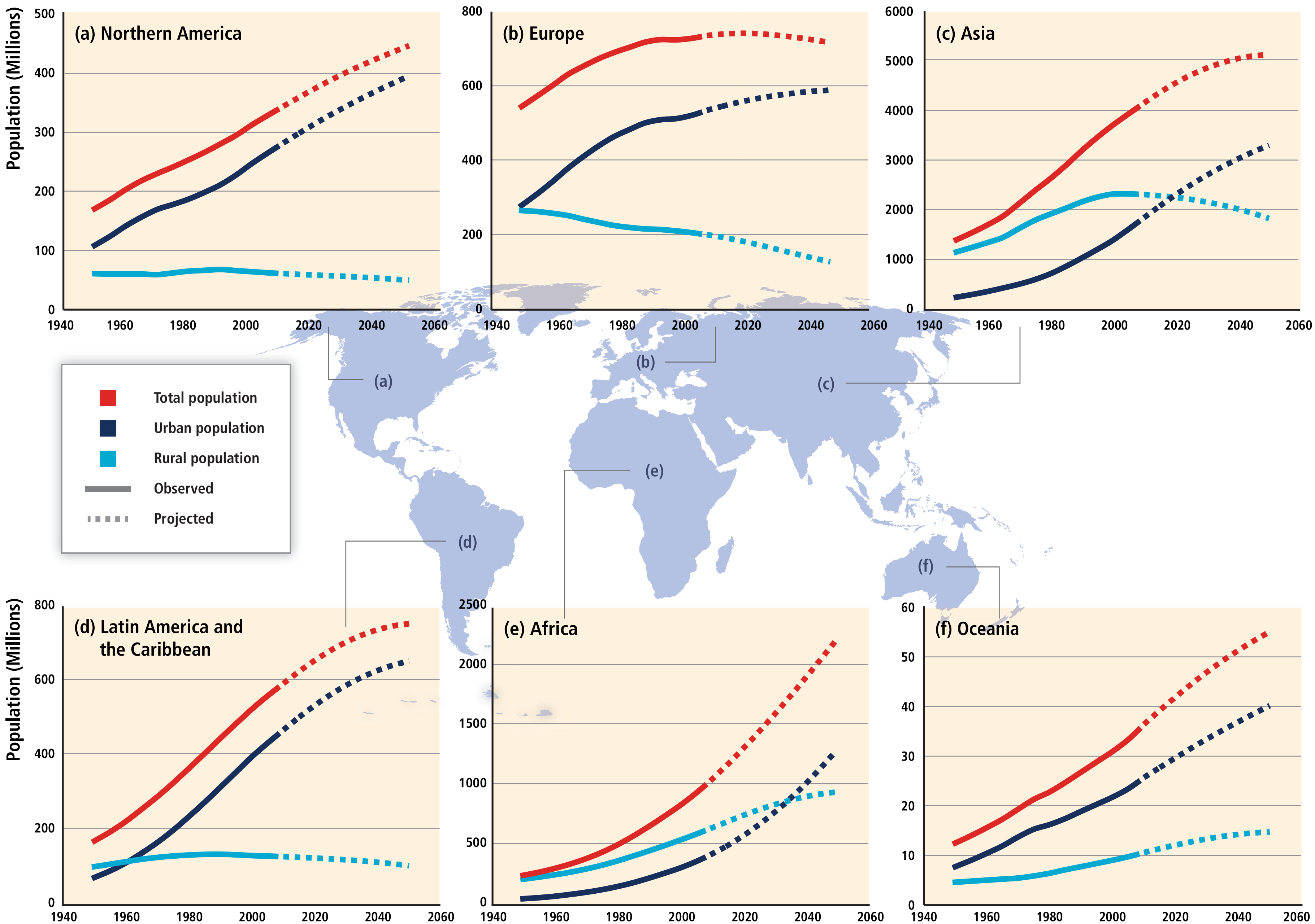

Figure 9-1 | Trends in rural, urban, and total populations by region; solid lines represent observed values and dotted lines represent projections (UN DESA Population Division, 2013). Note: Regions used in the source do not correspond with the IPCC regions covered in Chapters 22–30.

Table 9-4 | Poverty indicators for rural areas of developing countries. Source: Adapted from IFAD (2010).

	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	60.9	45.1	27.0	54.0	34.2	80.5	71.6

Note: the incidence of extreme poverty and poverty is defined as percentage of people living on less than US$1.25 per day and less than US$2 per day, respectively.

of the main crops, and that damaging dry spells during the rainy season have become more frequent.

Glacial retreat in Latin America is one of the best evidenced current impacts on rural areas (see Section 27.3.1.1). 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 (Carey, 2010; Bury et al., 2011; 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 indigenous peoples in the Arctic (Ford, 2009; Beaumier and Ford, 2010; see also Section 28.2.5.1.7).

Migration associated with weather-related extremes or longer-term climate trends is discussed in Table 12-3, with empirical examples of migrations linked to droughts, coastal storms, floods, and sea level rise. The Asian Development Bank (ADB, 2012) gives a figure of 42 million people displaced by extreme weather events in Asia and the Pacific over 2010–2011. Attribution of migration to climate change is extremely complex, as recognized by Black et al. (2011a), because life in rural areas across the world typically involves complex patterns of rural-urban and rural-rural migration, subject to economic, political, social, and demographic drivers, patterns that are modified or exacerbated by climate events and trends rather than solely caused by them (see also Section 12.4.1).

9.3.3. Future Impacts

This section examines the major impacts of climate change identified or projected for rural areas, under the headings of economic base and livelihoods; infrastructure; spatial and regional interconnections, including migration, trade, investment, and knowledge; and second-order impacts of climate policy. Section 9.3.4 assesses the literature on impact through a different and specific lens, that of economic valuation. 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 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. Lal et al. (2011) show the regional specificity of projected socioeconomic impacts across the rural USA, with different regions affected through agriculture, water stress, and energy costs. Anderson et al. (2010) discuss the complexity of projected impacts across dryland regions of developing countries. These considerations increase the uncertainty associated with any particular impact on the economic base, on land use, or on regional interconnections.

9.3.3.1. Economic Base and Livelihoods

9.3.3.1.1. General considerations

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, p. 6). Many, though by no means all, rural livelihoods are dependent on natural resources (e.g., agriculture, fishing, and forestry), and their availability will vary in a changing climate. This will have effects on human security and well-being (Kumssa and Jones, 2010; see also Chapter 12). Climate change impacts on smallholder and subsistence farmers will be compounded by 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 (Morton, 2007) and also trade and food prices (Anderson et al., 2010). Despite the growing importance of non-farm livelihoods in rural areas worldwide (Ellis, 2000; Reardon et al., 2007), and households pursuing interdependent agricultural and non-agricultural livelihoods in peri-urban areas as a risk management strategy (Lerner and Eakin, 2010; Lerner et al., 2013), there is a relative scarcity of literature on the interactions of these with climate variability and climate change.

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 (Reid and Vogel, 2006; Ziervogel and Taylor, 2008; O'Brien et al., 2009), Malawi (Casale et al., 2010), Kenya (Oluoko-Odingoa, 2011), Senegal (Mbow et al., 2008), and India (O'Brien et al., 2004). Economic heterogeneity of farm households within communities, in terms of farm and household size, crop choices, and input use, will be important in determining impacts (Claessens et al., 2012), as will social relations within households that affect production (Morton, 2007).

Projected impacts on yields and production of food crops are assessed in Section 7.4.1 and Figure 7-7. Local warming in excess of 1°C is projected to have negative impacts in both temperate and tropical regions without adaptation (though individual locations may benefit). There is *medium confidence* in large negative impacts of local increases of 3°C to 4°C, on productivity, production, and food security, globally and particularly

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in tropical countries, that go beyond adaptive capacity. The impacts of climate change on the agricultural sector in Africa, dominated by smallholder farming and very largely rainfed, are considered to be very significant to economies and livelihoods (Collier et al., 2008; Hassan, 2010; Kotir, 2011; Müller et al., 2011). 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 (Thurlow and Wobst, 2003; Reid et al., 2008; Molua, 2009; Thurlow et al., 2009).

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

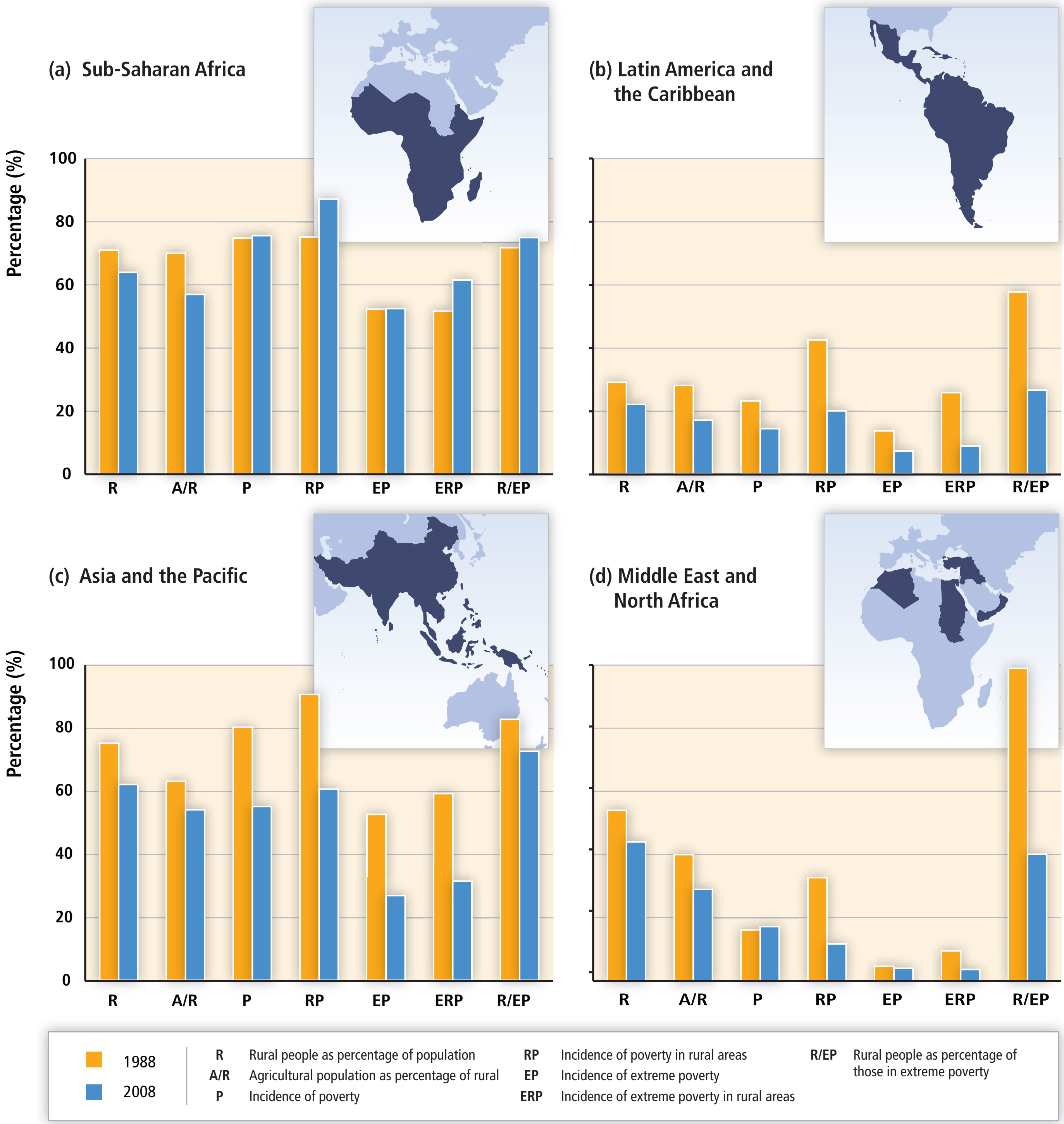

Figure 9-2 | Demographic and poverty indicators for rural areas of developing countries, by region (adapted from IFAD, 2010). Shaded countries are those for which data were available in the original source. Note: Regions used in the source do not correspond with the IPCC regions covered in Chapters 22–30.

already understood by post-harvest service providers, but getting post-harvest knowledge into use at scale is a significant challenge (Stathers et al., 2013; see also Tefera, 2012). Future impacts on production and storage will affect prices. Food crises in Africa triggered by moderate declines in agricultural production have been exacerbated by "exchange entitlement failures"—food price spikes and asset price collapses (Devereux, 2009). Rising food prices negatively affect many rural people who are net food buyers (see Table 7-1), and 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., 2010).

The remainder of this section discusses issues around climate impacts on agricultural livelihoods, other than food crop production: water as an input to agriculture, non-food crops, livestock, and fisheries.

9.3.3.1.2. Water

Water supply will be impacted through climate change (Chapter 3). In rural areas groundwater extraction and irrigation water availability is crucial for agricultural livelihoods but is typically not included in modeled projections of future crop yields, as discussed by Lobell and Field (2012). At the same time, non-climate trends including population growth and lack of adequate regulatory frameworks will greatly affect demand for water by agriculture and other competing uses, as discussed by Macdonald (2010) for the southwestern USA, by Juana et al. (2008) for South Africa, and by multiple authors for the Middle East (Iglesias et al., 2010; Chenoweth et al., 2011; Sowers et al., 2011; Hanafi et al., 2012; Rochdane et al., 2012; Verner, 2012).

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, 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 500 mm yr^{-1}, and where decreases in annual rainfall, changes in intensity, or seasonal variations may cause problems for groundwater supply (Macdonald et al., 2009). At higher resolution groundwater resources are threatened (e.g., in South Africa; Knüppe, 2011), and multiple water crises are expected to result from the increasing demand, further affecting people in rural areas (Nkem et al., 2011). Climate change is expected to impact water resources in the Asian region in a major way. Immerzeel et al. (2010), in a study of the Indus, Ganges, Brahmaputra, Yangtze, and Yellow River basins, 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. In southern Europe, declines in rainfall and meltwater from glacial ice and snow would increase the costs of production and living (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).

9.3.3.1.3. Non-food crops and high-value food crops

Non-food crops and high-value food crops, such as cotton, wine grapes, beverage crops, and other cash crops, which represent an important source of livelihood in many rural areas, have received less attention than staple food crops when assessing the impacts of climate change. 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 (e.g., 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 would decrease as changes in temperature and precipitation overcome potential benefits of increasing carbon dioxide (CO_2), have been corroborated in other findings, such as those of Haim et al. (2008, p. 433) that cotton cultivation in Israel will decline by 52% and 38% by 2070–2100 under the SRES A2 and B2 scenarios, and that the net revenue will also decrease by 240% and 173% in both scenarios. Few systematic assessments have been done on other fiber 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, and report 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 decline 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 becoming more conducive to grape growing and wine production.

Lobell and Field (2012) model impacts on 20 perennial crops in California under the A2 and B1 scenarios; of the four crops with the most reliable models cherry yields are projected to decline by nearly 20%, strawberries and table grapes to experience smaller declines, and almonds a slight positive trend. These projections do not incorporate adaptation options or possible decline in irrigation water supply, which would limit production. 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).

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 9-5.

9.3.3.1.4. Livestock

The impacts of climate change on livestock—which form a part of a variety of farming systems (Devendra et al., 2005)—are seen by Thornton et al. (2009) as a neglected research area complicated by other

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 more than 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 (Varangis et al., 2003). 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 Niño in 2005 coffee productivity fell to between a third and half of normal, similarly leading to severely reduced income for small producers (Haggar, 2009).

Gay et al. (2006), analyzing the effects of recent climate change on coffee producing areas in Veracruz, Mexico, have developed econometric models of the relationship between coffee productivity and fluctuations in temperature and precipitation, which gave an R^2 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 is *likely* to decline by 34%, and this decline in production takes producers from making net profits of on average around US$200 per acre to less than US$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 and in Table 9-5.

For Brazil, Assad et al. (2004) and Pinto et al. (2007) have mapped the changes in area suitable for coffee production in the four main coffee producing states. A 3°C increase in temperature and 15% increase in rainfall (taken from the general prediction of climate change for southern Brazil in the IPCC Third Assessment Report of 2001) would lead to major changes in the distribution of coffee producing zones. In the main coffee producing states of Minas Gerais and São Paulo the potential area for production would decline from 70 to 75% of the states to 20 to 25%, production in Gioas would be eliminated, but the area would be reduced only by 10% in Parana. New areas suitable for production in Santa Catarina and Rio Grande do Sul will only partially compensate the loss of area in other states (Pinto and Assad, 2008). The economic impacts of a rise in temperature of 3°C would cause a 60% decline in coffee production in the state of São Paulo equal to nearly US$300 million 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 General Circulation Models (GCMs) 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; Glenn et al., 2013); tea production in Kenya (CIAT, 2011a) and Uganda (CIAT, 2011b); and cocoa production in Ghana and Côte d'Ivoire (CIAT, 2011c; Laderach et al., 2013) (Table 9-5). The suitability for coffee crops in Costa Rica, Nicaragua, and El Salvador will be reduced by 40% (Glenn et al., 2013) while the loss of climatic niches in Colombia will force the migration of coffee crops toward higher altitudes by mid-21st century (Ramirez-Villegas et al., 2012). In the same way, increases in temperature will affect tea production, in particular at low altitudes (Wijeratne, et al., 2007). Only one similar study has been done for Robusta coffee (Simonett, 2006), in Uganda, which shows similarly drastic changes in both distribution and total area suitable for coffee production.

Effects are also expected on the incidence of pests and diseases in these crops. Increased generations under climate change for the coffee nematode have been predicted for Brazil (Ghini et al., 2008). Jaramillo et al. (2011) conclude that Coffee Berry Borer (*Hypothenemus hampei*) distribution in East Africa has expanded as a result of rising temperatures, and predicts, based on A2A and B2B scenarios of Met Office Hadley Centre climate prediction model 3 (HadCM3), that it will spread to affect the main coffee producing areas of Ethiopia, Kenya, Uganda, Rwanda, and Burundi by 2050.

Continued next page →

Box 9-1 (continued)

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 area suitable for production would decrease considerably with increases of temperature of only 2°C to 2.5°C. Although some local areas may experience improved conditions for coffee production, for example, high-altitude areas of Guatemala, the overall predictions are for a reduction in area suitable for coffee production by 2050 in all countries studied (Laderach et al., 2010).

drivers of change, rapid change in livestock systems, spatial heterogeneity, and social inequality between livestock keepers. They review various pathways of impact on livestock. 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). Franco et al. (2011) reveal significant declines in forage for ranching in California under SRES scenarios B1 and A2.

Pastoralists, who are dependent on livestock grazed in arid, semiarid, or mountainous areas, display very specific combinations of adaptive capacity, especially through mobility and vulnerability, as discussed in Section 9.3.5. Ericksen et al. (2012), with particular reference to East Africa, discuss possibilities of loss of rangeland productivity, changes in rangeland composition toward 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 livestock population (Verner, 2012, p. 166). Little et al. (2001) discuss impacts of floods, directly and through disease, on pastoral herds. Similarly in the Ferlo Region in northern Senegal, 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%, based on six GCMs (Hein et al., 2009).

As extensive livestock production is associated with semiarid areas marginal for cropping, some authors project shifts toward livestock production under climate change. Modeled data from across Africa on the net income per unit of land from crops and different livestock species show that farmers are more likely to keep livestock, compared to crop cultivation, as temperatures increase and as precipitation decreases. Within livestock production, beef production will decline and sheep and goat production increase (Seo and Mendelsohn, 2007a). Large-scale commercial beef cattle farmers are most vulnerable to climate change, particularly because they are less likely to have diversified (Seo and Mendelsohn, 2007b). Kabubo-Mariara (2009) shows for non-pastoral areas of Kenya the nonlinear relationship of livestock production to climate change, whereby increased mean precipitation of 1% could reduce revenues from livestock by 6%. Jones and Thornton (2009) identify major transition zones across Africa where increased probability of drought up to 2050 will create conditions for shifts from cropping to livestock.

9.3.3.1.5. Fisheries

Impacts of climate change on aquatic ecosystems will have adverse consequences for the world's 36 million fisherfolk, through multiple pathways including changes in fish stock distribution and abundance, and destruction of fishing gear and infrastructure in storms and severe

Table 9-5 | Projected changes in areas suitable for production of tropical beverage crops by 2050.

Crop	Countries	Change in climate by 2050	Change in total area by 2050	Change in distribution by 2050 (in meters above sea level)
Coffee	Guatemala, Costa Rica, Nicaragua, El Salvador, Honduras, Mexico[6]	2.0–2.5°C increase in temperature 5–10% decline in total rainfall	Between 38% and 89% decline in area suitable for production	Minimum altitude suitable for production rise from 600 to 1000
	Kenya[1]	2.3°C increase in temperature Rainfall increase from 1405 mm 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
Tea	Kenya[2]	2.3°C increase in temperature Rainfall increase from 1655 mm to 1732 mm	Majority of western highlands lose suitability, while losses are compensated by gains at higher altitude in eastern highlands	Optimum altitude for production change from 1500–2100 to 2000–2300
	Uganda[3]	2.3°C increase in temperature Rainfall increase from 1334 mm to 1394 mm	Considerable reduction in suitability for production across all areas	Optimal altitude change from 1450–1650 to 1550–1650
Cocoa	Ghana, Côte d'Ivoire[4,5]	2.1°C increase in temperature No change in total rainfall	Considerable reduction in area suitable for production; almost total elimination in Ivory Coast without adaptation measures	Optimal altitude change from 100–250 to 450–500

Sources: [1]CIAT (2010); [2]CIAT (2011a); [3]CIAT (2011b); [4]CIAT (2011c); [5]Laderach et al. (2013); [6]Glenn et al. (2013). Projections use the SRES A2 scenario; the projection methodology is described in Box 9-1.

weather events (Badjeck et al., 2010; see also Sections 5.4.3.3, 6.4.1.1, 7.4.2, 30.6.2.1). An indicator approach (assessing climate change impacts together with the high share of fisheries as a source of income) 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 northwestern South America, and four tropical Asian countries (Bangladesh, Cambodia, Pakistan, and Yemen) (Allison et al., 2009). In China, Japan, and South Korea, changes in climate and social systems could have a negative impact on fisheries, adversely affecting livelihoods and food security of the region (Kim, 2010).

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. River flooding and sea level rise will produce temporary loss of land and land activities, and damage to transportation infrastructure particularly on coastal areas (Kirshen et al., 2008), with specific evidence from North America (Hess et al., 2008). Flooding events may cause sediment transport and damage roads and bridges (Nearing et al., 2004) as well as affecting reservoir storing capacity. Importantly, in rural areas usually there are few alternatives once a road is blocked and that may increase vulnerability of rural areas when facing extreme hydroclimatological events that impact transportation infrastructure (NRC, 2008). Climate change will affect the operation of existing water infrastructures (Kundzewicz et al., 2008). Some documented impacts on dams, reservoirs, and irrigation infrastructure include reduction of sediment load due to reductions in flows (associated with lower precipitation), positively affecting 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).

In Arctic Canada and Alaska, infrastructure built for very cold weather will deteriorate as the air and ground warm. Larsen et al. (2008) estimate, using the Atmosphere-Ocean General Circulation Model (AOGCM) intercomparison project and an A1B scenario, increases in public infrastructure costs of 10 to 20% through 2030 and 10% through 2080 for Alaska, amounting to several billion dollars, much of it to be spent outside of urban centers. Lemmen et al. (2008) 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 (Furgal and Prowse, 2008) from a 2°C to 4°C change in ground surface temperatures, which would imply a cost of replacement with all-weather roadways of CAN$85,000 per kilometer, over several decades.

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 (see Box CC-UR).

9.3.3.3.1. Migration

It is difficult to establish a causal relationship between environmental degradation and migration (see Section 12.4.1). Many authors argue that migration will increase during times of environmental stress (e.g., Brown and Crawford, 2008; Afifi, 2011; Kniveton et al., 2011; Gray and Mueller, 2012), and will lead to an increase in abandonment of settlements (McLeman, 2011). Climate variability has been associated with rural-urban migration (Mertz et al., 2011; Parnell and Walawege, 2011). Another body of literature argues that migration rates are no higher under conditions of environmental or climate stress (Cohen, 2004; Brown, 2008; van der Geest and de Jeu, 2008; Tacoli, 2009; McLeman and Hunter, 2010; Black et al., 2011a,b; Foresight, 2011; Gemenne, 2011; van der Geest, 2011). For Tacoli (2009) the current alarmist predictions of massive flows of 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. Analogies with past migration experiences are used frequently in such studies (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—that come into play (van der Geest, 2011). Similarly, a recent survey by Mertz et al. (2010) has argued that climate factors played a limited role in past adaptation options of Sahelian farmers. Given the multiple drivers of migration (Black et al., 2011a,b) and the complex interactions that mediate migratory decision making by individual or households (McLeman and Smit, 2006; Raleigh, 2008; Black et al., 2011a,b; Kniveton et al., 2011), the projection of the effects of climate change on intra-rural and rural-to-urban migration remains a major challenge.

9.3.3.3.2. Trade

Agricultural exports accounted for around one-sixth of world agricultural production in 2012, while this proportion was higher for some commodities such as oilseeds, sugar, and fish (OECD and FAO, 2013). Global agricultural exports grew at an average annual rate of 9% in 2000–2005 and 11% in 2005–2011 (WTO, 2013, pp. 63–72). Apart from a major price hike and high price volatility since 2007–2008, several structural and cyclical factors—such as droughts in major producers, expansion of area under biofuel crop production, financial speculation, export restrictions—have led to volatility and unpredictability in the trading environment (Chapter 7; see also Abbott, 2008; FAO, 2008; Cooke and Robles, 2009; Karapinar and Haberli, 2010; Schmidhuber and Matuschke, 2010; Timmer, 2010; Headey, 2011;Wright, B.D., 2011; Anderson and Nelgen, 2012; Nazlioglu, 2013). In the absence of extensive literature and reliable data on within-country trade, this section focuses on international trade in the specific context of climate change.

There is *limited evidence* and *medium agreement* that climate change will affect trade patterns and it will increase international trade volumes in both physical and value terms by altering the comparative advantage of countries and regions, and given its potential impacts on agricultural prices (Nelson et al., 2009b, 2010, 2013; Tamiotti et al., 2009). For example, simulation based results from variants of the National Center for Atmospheric Research (NCAR) and Commonwealth Scientific and Industrial Research Organisation (CSIRO) climate models (A2 scenario) suggest that climate change might lead to increases in export volumes (of rice, wheat, maize, millet, sorghum, and other grains) from developed to developing countries by 0.9 million Mtonnes to 39.9 million Mtonnes by 2050. Higher export volumes are expected if future scenarios consider CO_2 fertilization effects, as they produce lower world prices than scenarios without CO_2 effects. Many regions including South Asia, East Asia and Pacific, Middle East, North Africa, and sub-Saharan Africa are projected to increase their imports substantially over this period (Nelson et al., 2009b, 2010).

The recent literature highlights the potential role of trade in adaptation to climate impacts on global crop yields, while cautioning policy makers about the possible negative consequences of increased trade (Verburg et al., 2009; Lotze-Campen et al., 2010; Huang et al., 2011; Schmitz et al., 2012). Importing food might help countries adjust to climate change-induced domestic productivity shocks and mitigate related welfare losses (Reimer and Li, 2009; Tamiotti et al., 2009). Countries might also 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 in neighboring countries, for example in Tanzania (Ahmed et al., 2012). Increased trade would lower the cost of food and thus help alleviate food insecurity; however, if it is driven by an expansion of agricultural areas (especially to marginal land and to forests), it would also lead to negative environmental consequences in the form of loss of biodiversity, deforestation, and additional carbon emissions (Verburg et al., 2009; Lotze-Campen et al., 2010; Schmitz et al., 2012).

If climate change affects crop yields negatively, and results in increased frequency of extreme events (IPCC, 2012; see also Chapter 3), especially in low-income developing countries, the consequent short-term food deficits might need to be supplied, fully or partly, through food aid (Alderman, 2010). Hence food aid agencies, such as the United Nations World Food Programme, might face additional operational challenges (Barrett and Maxwell, 2006; Harvey et al., 2010). Local or regional procurement of food aid, targeted distribution of food, and safety net programs through direct income transfers could be part of an overall strategy to address climate-induced shocks to food security (see also Chapter 7) (Alderman, 2010; Harvey et al., 2010).

The potential impacts of climate change on agricultural trade and the role that trade could play in adaptation will inevitably depend on countries' trade policies. There is *medium evidence* and *medium agreement* that deepening agricultural markets through trade reform, improved market access, avoiding export controls, and developing institutional mechanisms to improve the predictability and the reliability of the world trading system as well as investing in additional supply capacity of small-scale farms in developing countries could help reduce market volatility and offset supply shortages that might be caused by climate change (Reimer and Li, 2009; Tamiotti et al., 2009; UNEP, 2009; Karapinar, 2011, 2012; Tanaka and Hosoe, 2011; 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 favorable as a result of climate change are expected to see increasing inflow of investment. The recent price hikes in agricultural commodities have led to new initiatives of foreign direct investment (FDI) in large-scale crop production (World Bank, 2010b; Anseeuw et al., 2012), with capital-endowed countries with high food imports investing in large production projects in low-income countries endowed with low-cost labor forces and land and water resources. Climate change will lead to similar investment patterns. However, there is a risk that these new investments might not be integrated into local structures and that local populations will become increasingly vulnerable as they lose access to vital assets such as land and water (Anseeuw et al., 2012).

9.3.3.3.4. Knowledge

Rural areas are increasingly exposed to diffusion of knowledge through migration, trade and investment flows, technology transfers, and improved communication and transport facilities (IFAD, 2010), although differentials on knowledge access and diffusion (e.g., access to high-speed Internet) between rural and urban areas remain, even in high-income countries. Future impacts of climate change on these channels of integration will affect the pace and intensity of knowledge transfers. If trade, migration, and investment flows will be intensified as a result of climate change, this will have a positive impact on knowledge transfer both from and to rural areas.

Traditional knowledge (TK) developed to adapt to past climate variability and change can both be affected 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 TK transfer (Valdivia et al., 2010; Gilles et al., 2013). Disaster management by central government may undermine decentralization efforts, disfavoring TK transfer (Dekens, 2008).

9.3.3.4. Second-Order Impacts of Climate Policy

Policy responses for mitigation and adaptation affect rural people and their livelihoods and environments. Working toward increasing energy

Frequently Asked Questions

FAQ 9.2 | What will be the major climate change impacts in rural areas across the world?

The impacts of climate change on patterns of settlement, livelihoods, and incomes in rural areas will be complex and will depend on many intervening factors, so they are hard to project. These chains of impact may originate with extreme events such as floods and storms, some categories of which, in some areas, are projected with *high confidence* to increase under climate change. Such extreme events will directly affect rural infrastructure and may cause loss of life. Other chains of impact will run through agriculture and the other ecosystems (rangelands, fisheries, wildlife areas) on which rural people depend. Impacts on agriculture and ecosystems may themselves stem from extreme events like heat waves or droughts, from other forms of climate variability, or from changes in mean climate conditions such as generally higher temperatures. All climate-related impacts will be mediated by the vulnerability of rural people living in poverty, isolation, or with lower literacy, and so forth, but also by factors that give rural communities resilience to climate change, such as indigenous knowledge, and networks of mutual support.

Given the strong dependence in rural areas on natural resources, the impacts of climate change on agriculture, forestry, and fishing, and thus on rural livelihoods and incomes, are *likely* to be especially serious. Secondary (manufacturing) industries in these areas, and the livelihoods and incomes that are based on them, will in turn be substantially affected. Infrastructure (e.g., roads, buildings, dams, and irrigation systems) will be affected by extreme events associated with climate change. These climate impacts may contribute to migration away from rural areas, though rural migration already exists in many different forms for many non-climate-related reasons. Some rural areas will also experience secondary impacts of climate policies—the ways in which governments and others try to reduce net greenhouse gas emissions such as encouraging the cultivation of biofuels or discouraging deforestation. These secondary impacts may be either positive (increasing employment opportunities) or negative (landscape changes, increasing conflicts for scarce resources).

supply from renewable resources may result in landscape changes (Dockerty et al., 2006; Prados 2010); increasing employment opportunities (del Río and Burguillo, 2008); or increasing conflicts for scarce resources, such as water (Gold and Bass, 2010; Blair et al., 2011; McIntyre and Duane, 2011; Phadke, 2011). Planning applications for wind energy schemes in the UK have been subject to local opposition when they are perceived as having negative impacts on rural landscape qualities (van der Horst, 2007; Wolsink, 2007; Jones and Eiser, 2010). Governance of energy distribution is thus an important issue (Vermeylen, 2010; Devine-Wright, 2011). Steps toward energy self-sufficiency can reinforce rural autonomy in isolated rural communities, including indigenous groups (Love and Garwood, 2011).

Social responses to such changes are expected (Molnar, 2010). The promotion of biofuel crops has been an extremely controversial issue during 2000–2010, as they have potential socioeconomic impacts related to their asserted ability to act as stimulus for rural economies, promote changes in land ownership, and affect food security (German et al., 2011). Delucchi (2010) concludes that biofuels produced from intensive agriculture will aggravate stresses on water supplies, water quality, and land use, and impact rural areas (through land use change) and agriculture (see also Box CC-WE). Concerns about the impact of biofuel production on food security relates to increases in food prices, land concentration (and landgrabs), and competition for water (Eide, 2008; Müller et al., 2008; German et al., 2011). Gurgel et al. (2007), who modeled potential production and implications of a global biofuels industry by the end of the century under a reference scenario and a high-mitigation scenario, recognized the need for a high land conversion rate to achieve moderate objectives. Delucchi (2010) suggests developing biofuels programs with low inputs of fossil fuels and chemicals, that do not require irrigation, and on land with little or no economic or ecological opportunity cost (Plevin et al., 2010). This implies analyzing each case in its context, including production for both local and global markets, and factoring in concerns for social, cultural, and economic costs of biofuel production (i.e., impact of biofuel production on indigenous livelihoods and culture).

International mechanisms for emission reduction through forest and land management have been developed under the global initiative Reducing Emissions from Deforestation and Forest Degradation (REDD), now REDD+. These mechanisms are designed to use market tools (e.g., payment for ecosystem services) to reduce emissions, while providing social co-benefits following the principles of effectiveness, efficiency, and equity (Brown, D. et al., 2008; Hall, 2012; Hoang et al., 2013). However, there have been many criticisms that the rural poor are excluded from participation (Campbell, 2009; Sikor et al., 2010; van Noordwijk et al., 2010; Hall, 2012); and that lack of community participation can undermine a general decentralization of forest management (Phelps et al., 2010).

9.3.4. Valuation of Climate Impacts

This section assesses studies that have adopted various economic methods for valuation of impacts of climate change on rural areas. This 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 individual or communal levels (Farber et al., 2006) and often involve complexities with regard to the use of social discount rates for comparing intergenerational effects over varying time horizons (Dasgupta, 2011). Different understandings of value, and different philosophical approaches to address it, may exist (Weisbach and Sunstein, 2008; Kosoy and Corbera, 2010; Spangenberg and Settele, 2010), which makes it 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 (Collier et al., 2008; World Bank, 2010a). 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 the valuation of impacts with reference to agriculture, fisheries and livestock, water resources, mining, extreme weather events and sea level rise, recreation, tourism, and forestry. 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. Because rural areas are included, but not exclusively dealt with in calculations of economy-wide gross domestic product (GDP) losses due to climate change impacts, these are not dealt with separately in this chapter. Studies on the health impacts of climate change for the most part do not distinguish between rural and urban areas, although there are specific vulnerabilities that communities in rural areas face arising from a variety of factors such as remoteness, lack of access to services, and dependence on certain occupations such as farming which are dealt with in Section 11.3. The impact on availability of freshwater resources is another major area of concern for the developing regions in particular. Climate change can adversely impact poverty through multiple channels (Sections 10.9, 13.2).

Viewing impacts regionally, despite the ongoing debates around the uncertainty and limitations of valuation studies, scholars generally agree that some African countries could experience relatively high losses compared to countries in other regions (Collier et al., 2008; Watkiss et al., 2010; World Bank, 2010a). 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 scenario of mitigation to 450 ppm and 2°C global mean temperature increase as generated by the PAGE2002 model, while the World Bank uses a range of country specific models for calculating costs. Global costs including adaptation costs are calculated for an approximately 2°C warmer world by 2050 for Mozambique, Ethiopia, Ghana, Bolivia, Vietnam, Samoa, and Bangladesh. 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; see also Chapter 3) and for droughts in particular for Australia (Meinke and Stone, 2005; Nelson et al., 2007). In Latin American and Caribbean countries, higher temperatures and changes in precipitation patterns associated with climate change affect the process of land degradation, compromising extensive agricultural areas. Research on climate change impacts in rural North America has largely focused on the effects on agricultural production and on indigenous populations, 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 draw 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 GDP (Stage, 2010; Watkiss, 2011). Values that are aggregated across sectors generalize 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, 2009; Stage, 2010; Watkiss, 2011). Würtenberger et al. (2006) developed a methodology to estimate environmental and socioeconomic impacts of agricultural trade regarding virtual land use, and Adger et al. (2011) use qualitative methodologies to consider non-market metrics of risk, focusing on place- and identity-based principles of justice, which recognize individual and community identity in decision making.

Integrated assessment models and cost-benefit tools have been criticized: for being inadequate to assess intergenerational events, or processes with high levels of uncertainty and irreversibility; for not considering equity concerns and power structures; for assigning monetary values on the basis of incomplete information or assuming speculative judgments regarding the monetary value of, for example, natural resources (Kuik et al., 2008; Ackerman et al., 2009); and for not recognizing 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 behavioral economics-based (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 interdisciplinarity, 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 agricultural and non-agricultural impacts of climate change, as available in the literature, are presented here.

9.3.4.1. Agriculture

Changes in agricultural production will have corresponding impacts on incomes and well-being of rural peoples. The largest known economic impact of climate change is on 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

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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 socioeconomic 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 (with adaptation inbuilt) in agriculture. However, often such analysis does not incorporate features like technological progress, relative price changes, agricultural policy, and other dynamic characteristics. Similarly on the biophysical 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 9-6.

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, 3.8). 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), which measures human utilization of water by a nation, and the concept of virtual water have been suggested for informing policy makers in water-scarce countries, such as Egypt.

Analysis of intergenerational valuation has provided 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.,

Table 9-6 | Illustrative sample of studies on economic value and changes in value from climate change impacts in the agriculture sector.

Findings and estimates	Country/region and model/scenario	Study
Annual economic loss in rice production: $54.17 million	Malaysia (2°C rise in temperature)	Vaghefi et al. (2011)
GDP reduction from loss of agricultural productivity by 2080: 1.4%; welfare loss: 1.7%	Southeast Asian countries: Thailand, Vietnam, Philippines, Singapore, Malaysia, Indonesia (dynamic CGE)	Zhai and Zhuang (2009)
Decline in food grain production between 2030 and 2050 by up to 18%	India (SRES A1B scenario)	Dasgupta et al. (2013)
Annual spending for coping with adverse agricultural impacts between 2010 and 2050: US$4.2–5 billion	Asia (various scenario based estimates)	ADB and IFPRI (2009)
Decline in farmland values for each degree Celsius of warming: 4–6000 pesos	Mexico (Ricardian analysis)	Mendelsohn et al. (2010)
Fall in crop land values for rural communities: 13%	USA (10% average increase in temperature)	Mendelsohn et al. (2007)
Mixed effects with some improved profits	Canada (increasing precipitation)	Mendelsohn and Reinsborough (2007)
Adverse impacts on farming	USA (increasing temperature)	Mendelsohn and Reinsborough (2007)
Crop losses under drought: CAN$7–171 per hectare	Canada (Canadian Global Model 2)	Wittrock et al. (2011)
Annual agricultural losses up to $3 billion Flooding increases losses	California (SRES B1 (low emissions) and SRES A2 (medium emissions) scenarios)	Franco et al. (2011)
Damages to agriculture, hydropower, and infrastructure (including coastal areas) by 2050: US$7.6 billion	Mozambique (dynamic CGE model)	World Bank (2010a)
Decline in gross domestic product (GDP) from agriculture and linked sectors: 10% from benchmark levels	Ethiopia (Cline, CGCM2, and PCM)	Mideksa (2010)
By 2100: total losses of US$48.2 billion to gains of US$90 billion In 2020 for 1.6% warmer and 3.7% drier climate: net farm revenues decline by up to 25%	11 African countries (Ricardian analysis; various climate scenarios)	Dinar et al. (2008)
Decline in daily per capita calorie availability by up to 10% in 2050	Developing countries (SRES A2 scenario; CSIRO and NCAR models)	Nelson et al. (2009)
Losses in gross value of production up to 25% (Guatemala, followed by other countries)	Guatemala, Belize, Costa Rica, Honduras (SRES A2 and B2; Regional climate models)	UN ECLAC (2010a,b)
Loss in incomes of farmers by 2020: 14%; by 2060: 20%	South America (SRES A1; Canadian Climate Centre)	Seo and Mendelsohn (2008)
Annual damages between 1% and 39% in farm property values	Brazil (climate predictions from 14 GCMs)	Sanghi and Mendelsohn (2008)
Varying impacts across regions; declining agricultural crop productivity in some	Southern Europe (IPCC AR4 climate projections; qualitative assessment)	Falloon and Betts (2010)
Large variation in impacts on crops in Europe by 2050, mostly negative	Most affected: Hungary, Serbia, Bulgaria, Romania (expert evaluation; climate predictions from RCMs)	Olesen et al. (2011)

Notes: CGCM2 = Coupled General Circulation Model 2; CGE = Computable General Equilibrium; CSIRO = Commonwealth Scientific and Industrial Research Organisation; GCM = General Circulation Model; NCAR = National Center for Atmospheric Research; RCM = Regional Climate Model; SRES = Special Report on Emission Scenarios.

2011). Climate change can also have significant impacts on livestock production (Section 9.3.3.1).

A relatively less researched area which may impact the livelihoods of rural communities is mining (Section 26.11.1.2). Economic viability of mining enterprises as well as communities dependent on them is vulnerable to climate change. Pearce et al. (2011) highlight concerns for Canada, where mining is a rural activity with few other available economic activities while Damigos (2012) finds economic losses for mining in the Mediterranean region and Greece in particular. 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. There is little research on impacts in mining sectors in the USA and Mexico. Changes in the energy and water sector present a complex mix of risks and opportunities for primary extraction and processing industries. Site management, transport of supplies and resources to and from mines, exploration activities, and their associated costs would determine the extent of loss, along with the importance of the sector in the local economy (Backus et al., 2012).

9.3.4.3. 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; see also Section 3.4.9). 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 ecosystem services lost (for discussion on the methodologies for valuing costs refer to Handmer et al., 2012; see also Section 4.5.3).

Damage costs of floods and droughts (Section 10.3.1) and from sea level rise in Europe (Swiss Re, 2009) demonstrate the cost implications for rural communities in the developed regions of the world. Studies mapping the adverse impacts in UK and elsewhere in Europe show a range of sectors that are impacted in rural areas particularly due to drought in Europe and flooding in UK, with the worst effect being on summer crops in Mediterranean regions (Giannakopoulos 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 (Foresight, 2004) estimates that global warming of 3°C to 4°C could increase flood damage costs from 0.1% up to 0.4% of GDP. Much of the investment in flood defenses 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). 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 (Dasgupta, S. et al., 2009; SEI, 2009). Ahmed et al. (2009) suggest that climate volatility from increase in extreme events increases poverty in developing countries, particularly Bangladesh, Mexico, Indonesia, and countries in Africa. They also find that on simulating the effect of climate extremes on poverty in Mexico using the A2 scenario as generated by a Coupled Model Intercomparison Project Phase 3 (CMIP3) multi-model data set, rural poverty increases by 43 to 52% following a single climate shock due to climate extremes. Studying extreme events, Boyd and Ibarrarán (2009) use a CGE model to simulate the effects of persistent droughts on the Mexican economy and find declines in production of 10 to 20% across a variety of agricultural sectors between 2005 and 2026. 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).

9.3.4.4. 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). Both sensitivity to climate variability and climate change have been considered in the literature. While some studies locate an increase in values for certain regions others estimate shifts in tourism and losses (Hamilton et al., 2005; Bigano et al., 2007; 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). 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 (Scott et al., 2007; Collins, 2008; Wolfsegger et al., 2008; Hein et al., 2009; Nyaupane and Poulde, 2011).

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

9.3.5. Key Vulnerabilities and Risks

9.3.5.1. Drivers of Vulnerability and Risk

Discussions on climate vulnerability in rural areas must recognize competing conceptualizations and terminologies of vulnerability, particularly those of "starting point" and "end-point" vulnerability (O'Brien et al., 2007). The focus here is on starting point vulnerability, or contextual vulnerability (see Glossary and Chapter 19), while we consider risk to be the probability of adverse impact resulting from exposure and vulnerability (see Chapter 19). These distinctions are important because they can result in contradictory findings regarding vulnerability in rural areas, and the policy prescriptions derived therefrom are also different.

There is *low agreement*, but *medium evidence*, 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, and diversification. 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. 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 *robust evidence* and *high 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 and vulnerability (see Box CC-GC and Chapter 13).

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, as well as their adaptive capacity to hazards and stressors. Although vulnerability is experienced locally, its causes and solutions occur at different social, geographic, and temporal scales, and are seen as context dependent (Ribot, 2010). Non-climate factors affecting vulnerability in rural areas at both individual and community levels (Eakin and Wehbe, 2009) include the following:

- Physical geography, for example, desert or semi-desert conditions (Lioubimtseva and Henebry, 2009), remoteness (Horton et al., 2010), level of dependence on climate conditions (Brondizio and Moran, 2008; Sietz et al., 2011)
- Economic constraints and poverty (Macdonald et al., 2009; Mertz et al., 2009a; Ahmed et al., 2011; Sietz et al., 2011)
- Gender inequalities (Nelson et al., 2002)
- Social, economic, and institutional shocks/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 to and availability of food, density of social networks, memories of past climate variations, knowledge, and long-term residence in the region (Parks and Roberts, 2006; Brondizio and Moran, 2008; Cooper et al., 2008; Macdonald et al., 2009; Mertz et al., 2009a; Simelton et al., 2009; Gbetibouo et al., 2010b; Ruel et al., 2010; Sallu et al., 2010; Ahmed et al., 2011; Mougou et al., 2011; Seto 2011).

This section focuses on the following drivers of vulnerability to climate change: water, market orientation and farm scale, institutions and access to resources, gender, migration, and access to information and knowledge.

9.3.5.1.1. Access to water

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

9.3.5.1.2. Market orientation and farm scale

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 is seen as reducing the capacity of indigenous or smallholder systems for dealing with climate risk in Bolivia (Valdivia et al., 2010), Honduras (McSweeney and Coomes, 2011), Mexico (Eakin, 2005), Mozambique (Eriksen and Silva, 2009; Silva et al., 2010), and in the Sahel (Fraser et al., 2011) by variously accelerating socioeconomic stratification and reducing crop diversity. On the other hand, distance from large markets is seen as increasing vulnerability of rainfed mixed crop/livestock areas in sub-Saharan Africa (Jones and Thornton, 2009) and the Peruvian Altiplano (Sietz et al., 2011). Each case needs to be analyzed within its complexity, considering interactions among all the factors that can affect vulnerability (Rivera-Ferre et al., 2013a).

Regarding the scale of farms, some authors suggest that small-scale farming increases the vulnerability of communities in rural areas (Gbetibouo et al., 2010b; Bellon et al., 2011) although their resilience (stemming from factors such as indigenous knowledge, family labor, livelihood diversification) should not be underestimated. Brondizio and Moran (2008) indicate that small farmers are less vulnerable than large, monocrop farmers when climatic variations make an area inappropriate for a particular crop, because they tend to cultivate multiple crops and work with on-farm biodiversity. However, they recognize that small farmers tend to suffer from technological limitations, low access to extension services, and market disadvantages.

9.3.5.1.3. Institutions, access to resources, and governance

Institutions and networks can affect vulnerability to climate change: through distribution of climate risks between social groups; by determining the incentive structures for adaptation responses; and by mediating external interventions (e.g., finances, knowledge and information, skills training) into local contexts (Agrawal and Perrin, 2008; Ribot, 2010). Institutions can decrease vulnerability (Anderson et al., 2010) or increase it (Eakin, 2005). Governance structures and communication flows as shown in a Swiss mountain region vulnerable to climate change (Ingold et al., 2010) and the knowledge and perceptions of decision makers are also important. Romsdahl et al. (2013) show that local government decision makers in the U.S. 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.

Lack of access to assets, of which land is an important one, is accepted to be an important factor increasing vulnerability in rural people (McSweeney and Coomes, 2011). The breakdown of traditional land tenure systems increases vulnerability, particularly for those who experience poorer land access as a result (Brouwer et al., 2007; Dougill et al., 2010; Fraser et al., 2011). Those who benefit, for example, wealthier farmers who increased their landholding after privatization in Botswana, remain less vulnerable (Dougill et al., 2010).

9.3.5.1.4. Migration

The relationship of vulnerability to migration is complex. 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. The decline in transmission of traditional knowledge through social networks can also increase vulnerability (Valdivia et al., 2010). Furthermore, those places receiving migrants can experience an excessive demographic growth, which increases pressure over scarce resources, as is being experienced in the semiarid tropics (Cooper et al., 2008; 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 (see Section 12.4).

9.3.5.1.5. Gender

Box CC-GC sets out the general issues on climate change and gender-related inequalities. These are of special relevance to rural areas, particularly but not solely in the developing world (Nelson and Stathers, 2009; Vincent et al., 2010; Alston, 2011) (*robust evidence*, *high agreement*). Access to land shows strong differences between men and women, as do labor markets (FAO, 2010), and access to non-farm entrepreneurship (Rijkers and Costa, 2012). Fewer 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 labor force in developing countries; in South Asia almost 70% of employed women work in agriculture, and more than 60% in sub-Saharan Africa (FAO, 2010, 2011). Climate change also increases vulnerability through male out-migration that increases the work to women (Chindarkar, 2012); cropping and livestock changes that affect gender division of labor (Lambrou and Paina, 2006); increased difficulty in accessing resources (fuelwood and water) (Tandon, 2007); and increased conflicts over natural resources (Omolo, 2011).

Women are generally, though not in every context, more vulnerable to the impacts of extreme events, such as floods and tropical cyclones (Neumayer and Plümper, 2007).

9.3.5.1.6. Knowledge and information

Lack of access to information and knowledge of rural people can also interact with all the above mentioned drivers to mediate vulnerability. Shared knowledge and lessons learned from previous climatic stresses provide vital entry points for social learning and enhanced adaptive capacity (Tschakert, 2007). But while some authors emphasize 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; Brugger and Crimmins, 2012), Bellon et al. (2011) state that local knowledge is too local, and in some contexts gathering information from further away is important.

Access to information alone is not 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 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 cooperation between local sector organizations, lack of local coordination, and an absence of methods and traditions to build institutional knowledge present barriers to manage vulnerability (Glaas et al., 2010). In Benin, as elsewhere in Africa, there is a lack of coordination between climate policies and the policies and practices that govern agricultural research and extension, while good practice at project level has been insufficiently harnessed to foster collective learning of farmers and other agricultural stakeholders, and thus adaptation to climate change (Moumouni and Idrissou, 2013a,b). For institutional learning, knowledge transfer, and more reliable assessments of local vulnerabilities, local institutional structure must be flexible, establishing communication mechanisms among public authorities, other knowledge producers, and civil society (Glaas et al., 2010).

9.3.5.2. Outcomes

The outcome of vulnerability is the result of, and interaction of, the driving forces that determine vulnerability in a given sector, social group, and so forth. This section analyzes how different drivers may affect specific vulnerable groups in rural areas, particularly pastoralists, mountain farmers, and artisanal fisherfolk. Box 9-2 takes a specific economic sector important in rural areas and demonstrates the interplay of vulnerability and exposure.

Box 9-2 | Tourism and Rural Areas

The three major market segments of tourism most liable 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 land use 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% of their GDP from this industry (Meyer, 2006). Coastal environments elsewhere in the world are also characterized by dependence on rural tourism, and are known to be vulnerable to cyclones and sea level rise (Payet, 2007; Klint et al., 2012a).

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 to 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, may affect trekking in the Nepali Himalayas (Nyaupane 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), and dive tourism in Vanuatu (Klint et al., 2012b). 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 resource use by tourists is much higher than that of locals (e.g., in Nepal; Nepal, 2008).

Despite the potential impacts of climate change on rural tourism, there is *low 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 (Hall, 2006; Brouder and Landmark, 2011).

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 are 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 has also necessitated reassessment of the extent of the potential impacts of climate change on the tourism industry in rural areas. With the availability of snowmaking as a (costly and uncertain) adaptation in the eastern North American ski industry, only 4 out of 14 ski areas are at risk before 2029, but 10 out of 14 in the period 2070–2099 (Scott et al., 2006).

9.3.5.2.1. Pastoralists

Pastoralists have developed successful strategies for responding to climate variability, especially "strategic mobility" in pursuit of high-quality grazing (Krätli et al., 2013), in combination with shorter-term coping strategies (Morton, 2006), for example, in sub-Saharan Africa (Davies and Bennett, 2007; Kristjanson et al., 2010) or Inner Mongolia (Wang and Zhang, 2012). However, mobility, a key component for community resilience, is declining , increasing the vulnerability of people in arid and semiarid regions (Lioubimtseva and Henebry, 2009; Fraser et al., 2011). 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).

This is "induced vulnerability" (Krätli et al., 2013), arising from a range of social, economic, environmental, and political pressures external to pastoralism that bring about 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 liberalization; concentration of political power in national centers; and perceptions that pastoralists are backward (Smucker and Wisner, 2008; Dougill et al., 2010; Dong et al., 2011; Rivera-Ferre and López-i-Gelats, 2012). These in turn can be seen as results of what Reynolds et al. (2007) conceptualize as two key features of dryland populations: remoteness, and distance from the centers 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).

9.3.5.2.2. Mountain farmers

Mountain ecosystems have been identified as extremely vulnerable to climate change (Fischlin et al., 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.

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 (Gehrig-Fasel et al., 2007; Gellrich et al., 2007; López-i-Gelats, 2013) given the extreme climatic conditions and their remoteness and subsequent isolation, while in developing countries (e.g., tropical mountain areas) there is a trend toward increasing population (Huber et al., 2005; Lama and Devkota, 2009). 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 mountain grasslands tend to suffer from conversion to agriculture, and land abandonment where livestock raising is less feasible (Gellrich et al., 2008), in tropical mountain 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).

9.3.5.2.3. 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 potential 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; and 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; and 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 focused on industrial fishing than artisanal fishing (Mills et al., 2011).

9.4. Adaptation and Managing Risks

9.4.1. Framing Adaptation

AR4 stated with *very high confidence* that adaptation to climate change was already taking place, but on a limited basis, and more so in developed than developing countries. Since then, the documentation of adaptation in developing countries has grown (*high confidence*). Adaptation is progressive, and is distinguished from coping as it reduces vulnerability in the case of re-exposure to the same hazard (Vincent et al., 2013): it can therefore be identified even without *high confidence* that a local hazard or climate trend is attributable to global climate change—indeed many cases of adaptation are driven primarily by other stressors, but have the result of aiding adaptation to climate change (Berrang-Ford et al., 2011).

Many adaptations do 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 prioritizing short-term resource availability (Adepetu and Berthe, 2007; O'Brien et al., 2007). In Malawi, for example, forest resources are used for coping (gathering wild food and firewood to sell), but this process reduces the natural resource base and increases vulnerability to future flooding through reduced land cover and increased overland flow (Fisher et al., 2010). 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 (Eriksen and O'Brien, 2007; Hassan, 2010; Nielsen et al., 2012; see also Section 13.4). For more information on the integration of adaptation and development in climate-resilient development pathways, see Chapter 20. 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. Decision Making for Adaptation

Decision making for adaptation takes place at a variety of levels, and can be public or private. International mechanisms variously support adaptation decision making at all levels (see Sections 14.4, 15.2). At the national and local levels, law and policies can enable planned adaptation (Stuart-Hill and Schulze, 2010). A longer history of evidence for public policies to support adaptation exists for developed countries, although increasingly developing countries are also introducing such policies (for more information, see Section 15.2, Box 25-2 on Australia's water policy and management, and Section 26.9.1 on federal adaptation policies in the USA and Canada). At local levels, some progress toward adaptation planning has been observed, particularly in developed countries. In Australia, for example, western Australia, South Australia, and Victoria have mandatory State planning benchmarks for 2100 (see Box 25-1) and, in the Great Plains of the USA, some jurisdictions have developed plans on either climate adaptation or climate mitigation, although so far fewer than 20% have done so (Romsdahl et al., 2013). At the local level, many adaptations are examples of private decisions for adaptation, undertaken by NGOs (primarily in developing countries, often in the form of community-based adaptation), and companies and individuals. Public and private decision making for adaptation is not always mutually exclusive: one example of where policy can support private adaptation is in the provision of index-based insurance schemes (Linnerooth-Bayer and Mechler, 2007; Suarez and Linnerooth-Bayer, 2010), which have variously been trialed in India, Africa, and South America (Patt et al., 2009, 2010; for a case study on index-based weather insurance in Africa, see Box 22-1). However, national policies and laws are not always mutually supportive of private actions (Stringer et al., 2009).

There is now *high confidence* that public decision making for adaptation can be strengthened by understanding the decision making of rural people in context, and in particular considering examples of autonomous adaptation and the interplay between informal and formal institutions (Bryan et al., 2009; Eakin and Patt, 2011; Adhikari and Taylor, 2012; Naess, 2012). Adaptation can also build upon local and indigenous knowledge for responding to weather events and a changing climate as has been observed in Samoa (Lefale, 2010; see Chapter 29), the Solomon Islands (Rasmussen et al., 2009; see Chapter 29), Namibia (Newsham and Thomas, 2011), Canada (Nakashima et al., 2011; see Chapter 24), the Indo-Gangetic Plains (Rivera-Ferre et al., 2013b), and Australia (Green et al., 2010).

9.4.3. Practical Experiences of Adaptation in Rural Areas

In AR4, examples of adaptation in rural areas exhibited a bias toward developed countries (WGII AR4 Chapter 17), but since then practical examples of adaptation in rural areas have increased substantially in developing countries (*very high confidence*). 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., 2009a). 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; and implementing management practices such as shading and conservation agriculture. Table 9-7 gives some examples; Box 9-3 describes adaptation initiatives in the beverage crop sector. More information on agricultural adaptation is available in Sections 23.8.2 (Europe), 24.4.3.5 (Asia), 25.7.2 (Australasia), 26.5.4 (North America), and 27.3.4.2 (Central and South America).

Conservation agriculture shows promising results and can be used as an adaptation (Speranza, 2013) 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). See Box 22-2 for a case study on integrating trees into annual cropping systems. Water management for agriculture is also critical in rural areas under climate change, for example, the use of rainwater harvesting (Vohland and Barry, 2009; Kahinda et al., 2010; Rivera-Ferre et al., 2013b), and more efficient irrigation, particularly in rural drylands (Thomas, 2008).

Adaptations are also evident among small-scale livestock farmers (Kabubo-Mariara, 2008, 2009; Rivera-Ferre and López-i-Gelats, 2012), 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). According to Chapter 7, adaptation leads to lower reductions in food production with more effective adaptation (of around 15 to 20% compared with no adaptation), and adaptations are more successful at higher latitudes (for maize, wheat, and rice) than in tropical regions. Figure 7-8 shows the varying efficiency of different crop adaptation measures, with cultivar adjustment leading to the largest percentage difference from the baseline, compared with irrigation optimization and planting date adjustment (although this shows the largest variation).

9.4.3.2. Water

As well as being an important input to agriculture, adaptation in water resources through improved management is critical in rural areas, not only at basin level but also for human settlements (Mukheibir, 2008). The extent to which adaptation measures have been implemented to date varies: in a study from Europe, Africa, and Asia, European basins were most advanced (Krysanova et al., 2010). In the cases of transboundary basins additional barriers exist to adaptive management measures, particularly in Africa (Goulden et al., 2009), although examination of potential institutional designs has been undertaken

Table 9-7 | Examples of adaptations in the agricultural sector in different regions.

Agricultural adaptations	Examples	Where observed	Source
Modifying planting, harvesting, and fertilizing practices for crops	Maize and wheat crops	Central and South America (Bolivia, Argentina, Chile); South Africa (including North West, Limpopo, and KwaZulu-Natal provinces)	PNCC (2007), Thomas et al. (2007), Magrin et al. (2009), Meza and Silva (2009)
	Composting and coralling of livestock to collect waste	Africa (South Africa, including North West, Limpopo, and KwaZulu-Natal provinces; northern Burkina Faso; Sahelian region of Mali)	Adepetu and Berthe (2007), Thomas et al. (2007), Barbier et al. (2009), Bryan et al. (2009)
Changing amount or area of land under cultivation		South Africa	Bryan et al. (2009)
	Moving winter wheat northwards	China	Lin et al. (2005)
	Expansion of fields	Northern Burkina Faso	Barbier et al. (2009)
	Increase in the size of plots	Sahelian region of Mali	Adepetu and Berthe (2007)
Using different varieties (e.g., early maturing, drought-resistant)	Early maturing cultivars	South Brazil	Walter et al. (2010)
		North America	Coles and Scott (2009)
	Drought-tolerant cultivars	Asia	Thomas (2008), Zhao et al. (2010)
		South Africa and Ethiopia	Bryan et al. (2009)
		Ghana	Gyampoh et al. (2008)
		Northern Burkina Faso	Barbier et al. (2009)
		Sahelian region of Mali and Nigeria	Adepetu and Berthe (2007)
		North West, Limpopo, and KwaZulu-Natal provinces of South Africa	Thomas et al. (2007)
Diversifying crops and/or animal species	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)
		KwaZulu-Natal, South Africa	Thomas et al. (2007)
	Replacing cattle with hardier goats and camels	Kenya	Rivera-Ferre and López-i-Gelats (2012)
Commercialization of agriculture		Ghana	Gyampoh et al. (2008)
		Limpopo Province, South Africa	Thomas et al. (2007)
	Income generation from natural resources (e.g., fuelwood)	Limpopo River Basin, Botswana	Dube and Sekhela (2007)
Water control mechanisms (including irrigation and water allocation rights)	Improved rice harvests	Monsoonal Asia	Hatcho et al. (2010)
	Adaptation for quinoa	Bolivian Altiplano	Geerts and Raes (2009)
	Adaptation for tomatoes	Central Brazil	
	Adaptation for cotton	Northern Argentina	
	Adaptation for rice	Northeast China	Lin et al. (2005)
	Small water harvesting pits in improved yields and incomes due to improved soil moisture	Ethiopia	Bryan et al. (2009), Amede et al. (2011)
		Burkina Faso	Barbier et al. (2009), Hertsgaard (2011)
		South Africa	Bryan et al. (2009)
		Ghana	Gyampoh et al. (2008)
	Dry season vegetable production through irrigation to enable two crop cycles	Northern Burkina Faso	Barbier et al. (2009)
		Sahelian region of Mali and Nigeria	Adepetu and Berthe (2007)
		Limpopo Province, South Africa	Thomas et al. (2007)
Shading and wind breaks	For coffee	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	Barbier et al. (2009), Hertsgaard (2011)
		Ethiopia	Bryan et al. (2009)
		Sahelian region of Mali	Adepetu and Berthe (2007)

Continued next page →

Table 9-7 (continued)

Agricultural adaptations	Examples	Where observed	Source
Modifying grazing patterns for herds	Utilizing spatial variability in resources	Arctic	Bartsch et al. (2010)
		East Africa	Eriksen and Lind (2009)
		Southern Africa	O'Farrell et al. (2009)
		Northern Burkina Faso	Barbier et al. (2009)
		Sahelian region of Mali and Nigeria	Adepetu and Berthe (2007)
		North West, Limpopo, and KwaZulu-Natal provinces, South Africa	Thomas et al. (2007)
Providing supplemental feeding for herds/storage of animal feed		Arctic	Forbes and Kumpula (2009)
		South Africa	Bryan et al. (2009)
	Use of sorghum and hay residue for feeding livestock	Northern Burkina Faso	Barbier et al. (2009)
		Sahelian region of Mali and Nigeria	Adepetu and Berthe (2007)
	Cutting fodder for livestock	Limpopo Province, South Africa	Thomas et al. (2007)
Ensuring optimal herd size	Changing size of European reindeer herds to match pasture availability	Northern areas of Norway, Sweden, Finland, and Russia	Rees et al. (2008)
	Culling of livestock	Northern Nigeria	Adepetu and Berthe (2007)
	Selling of livestock	Northern Burkina Faso	Barbier et al. (2009)
		Sahelian region of Mali and Nigeria	Adepetu and Berthe (2007)
Developing new crop and livestock varieties	Biotechnology and breeding	Brazil and Argentina	Urcola et al. (2010), Marshall (2012)
		Northern Nigeria	Adepetu and Berthe (2007)

(Huntjens et al., 2012). In the Middle East and North Africa, while 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., 2011).

While the majority of focus on adaptation concerning water relates to its availability, many rural areas in both developed and developing countries 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 (Deltacommissie, 2008; Kabat et al., 2009), and small-scale containment of flood risks through increasing compartmentalization (Klijn et al., 2009). In the Mekong Delta in Vietnam, 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). See Table 9-8 for further examples.

More information on adaptation in the water sector is available in Sections 24.4.1.5 and 24.4.2.5 (Asia), 26.3.3 (North America), and 27.3.1.2 and 27.3.2.2 (Central and South America).

9.4.3.3. Forestry and Biodiversity

Effective management is also essential for adaptation of forests and biodiversity to climate change, particularly involving (where appropriate) communities (Porter-Bolland et al., 2012). Forest resources have been shown to play a role in enabling livelihood adaptation during extreme events in Zambia, Mali, and Tanzania, although it should take place

Table 9-8 | 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 (Döll, 2009; Kundzewicz and Döll, 2009; Zagonari, 2010; Burte et al., 2011)
	Groundwater recharge	Potential identified in India (Sukhija, 2008)
	Irrigation (often using water-saving technology)	Asia (Ngoundo et al., 2007; Tischbein et al., 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 (Geerts et al., 2010; Montenegro and Ragab, 2010; Van Oel et al., 2010; Bell et al., 2011); Argentine Pampas (Quiroga and Gaggioli, 2010)
	Policies	Murray-Darling Basin Authority (MDBA) established to address over-allocation of water resources (Connell and Grafton, 2011; MDBA, 2011). See also Box 25-3 on Australia's water policies.
	Reviewing allocation rights	Indogangetic Plains (Rivera-Ferre et al., 2013b); Australia's MDBA reviewed the "exceptional circumstances" concept in drought policy (Productivity Commission, 2009)

Box 9-3 | 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. Facilitating processes of adaptation in the context of strong variability in vulnerability between different communities in the same region and even families within the same community (Baca Gómez, 2010) 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 (Schroth et al., 2009; Laderach et al., 2010; Schepp, 2010; Eakin et al., 2011) have prioritized the following 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 and financial support, and to 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 greenhouse gas emissions from agricultural practices and to increase sequestration of carbon in soils and trees, but also to prepare producers for adapting to climate change (Linne, 2011; SAN, 2011). The latter consists of improved understanding of climate impacts and promoting sustainable production practices to increase resilience in the production systems.

within a managed context to ensure sustainability (Robledo et al., 2011). 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 that enhances biodiversity and environmental services (Benayas et al., 2009), increases the potential for carbon sequestration, and promotes economic livelihoods in rural areas (Chazdon, 2008), as seen in examples of the Brazilian Atlantic Forest (Calmon et al., 2011; Rodrigues et al., 2011). 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).

As the climate changes, part of adaptive management may entail modification of existing biodiversity management practices. Manipulating vegetation composition and stand structure, for example, has been proposed as an adaptation option to wildfires in Canada (Girardin et al., 2013; Terrier et al., 2013); for more information on wildfires see Box 26-2. In Central and South America, protected areas of restricted use reduced fire substantially, but multi-use protected areas are even more effective; and 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). The PES literature is more developed for carbon payments, CDM and REDD+, but some research suggests potential for adaptation as well (see Section 13.3.1.2 for an assessment of the relationship between REDD+ and poverty alleviation). Particularly developed in Central and South America (see Table 27-7 for examples of PES schemes), 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, which may improve adaptive capacity in the longer term, bearing in mind with reforestation there is a time delay before payments are received (Locatelli et al., 2008). More indirectly, there are opportunities for PES to contribute to adaptation indirectly through natural adaptation co-benefits (e.g., water regulation and soil protection for reduced climate impacts in watersheds) (Pramova et al., 2012) and through the creation of institutional structures that may support adaptive capacity (Wertz-Kanounnikof et al., 2012). For further case studies on ecosystem-based adaptation, see Figure 22-8 (Africa), Box CC-EA, and Section 14.3.2; and for a diagrammatic representation see Figure CC-EA-1. More information on adaptation for forestry and biodiversity is available in Sections 23.8.2 and 23.8.4 (Europe), 24.5.1 (Asia), and 25.7.1.2 (Australasia).

9.4.3.4. Fisheries

Adaptation in marine ecosystems is also of relevance to rural areas. As with terrestrial natural resources, evidence from the marine resources sphere shows that a transformative approach to fisheries co-management, introducing ecosystem rights, and participation principles is essential for adaptation (Andrew and Evans, 2011; Charles, 2011). Such an approach, involving local fishermen and allowing limited extraction of resources, favors a balance between resource conservation and livelihoods, for example, in Brazil (Francini-Filho and Moura, 2008), and the improvement of livelihoods, as well as the cultural survival of traditional populations (Moura et al., 2009; Hastings, 2011) (see also Section 30.6.2.1). 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). According to Section 6.4.1.1, appropriate management will have a greater impact on biological and economic conditions than climate change. Table 30-2 outlines potential adaptation options and supporting policies for fisheries and aquaculture in the Pacific Islands considering a variety of time scales. Section 7.5 gives additional examples on adaptation for aquaculture.

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). Limits are typically defined (Dow et al., 2013) as hard, that is, they will not change over time, and are particularly applicable to biophysical systems (where, e.g., there are critical thresholds to species and ecosystem tolerances of climate parameters and regimes). Constraints, on the other hand, are typically soft, and are more relevant to social systems, where changes in factors such as financial and physical resources, technology and infrastructure, knowledge and information, and human resources may change over time. For further information, see Figure 16-1 and Sections 16.3.2 and 16.4.1. Here we focus on the soft constraints in social systems that act as barriers to implementation of practical adaptation options in rural areas.

As with risks and vulnerabilities, the literature emphasizes constraints to adaptation in rural areas in developing regions, although adaptation bottlenecks exist also in developed countries (where there has been an increase in awareness and planning for adaptation, but that has not necessarily translated into implementation; see Chapter 14). Constraints to adaptation in developed regions have been observed in North America (Section 26.8.4.2) and Australasia (Section 25.4.2; Boxes 25-1, 25-2, 25-9). Another key bottleneck comes from the fact that the need for adaptation to climate change is not the only pressing issue in rural areas in developed countries (Kiem and Austin, 2013).

There is *very high confidence* that lack of financial resources (in the form of credit) and physical resources (such as water and land) are major factors inhibiting adaptation for farmers in Africa and Asia (e.g., Hassan and Nhemachena, 2008; Bryan et al., 2009; Deressa et al., 2009; Ringler, 2010). 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).

Rural households' lack of access to technologies and infrastructure (e.g., markets) is also a major barrier to adaptation for certain production systems (*medium evidence*, *high agreement*). 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 households with a larger resources base took 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

Frequently Asked Questions

FAQ 9.3 | What will be the major ways in which rural people adapt to climate change?

Rural people will in some cases adapt to climate change using their own knowledge, resources, and networks. In other cases governments and other outside actors will have to assist rural people, or plan and execute adaptation on a scale that individual rural households and communities cannot. Examples of rural adaptations will include modifying farming and fishing practices; introducing new species, varieties, and production techniques; managing water in different ways; diversifying livelihoods; modifying infrastructure; and using or establishing risk-sharing mechanisms, both formal and informal. Adaptation will also include changes in institutional and governance structures for rural areas.

Box 9-4 | Factors Influencing Uptake and Utility of Climate Forecasts in Rural Africa

The IPCC *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX) identified the use of forecasts as a risk management measure (IPCC, 2012). So far the uptake of weather and climate information has been suboptimal (Vogel and O'Brien, 2006). In Africa annual climate information (e.g., seasonal forecasts) is more used than climate change scenarios for agricultural development (Ziervogel and Zermoglio, 2009), although attempts to use longer-term climate projections for crop forecasting and livestock farming have been examined (Boone et al., 2004; Challinor, 2009). The potential for improved prediction and effective timely dissemination of such information has been noted in different sectors, including water managers (Ziervogel et al., 2010a) and disaster planners (Tall et al., 2012), as well as farmers (both arable and pastoral) (Klopper et al., 2006; Archer et al., 2007; Bryan et al., 2009).

Extensive research has taken place to assess factors influencing uptake and utility of climate forecasts, including mapping of dissemination through stakeholder networks (Ziervogel and Downing, 2004), and user needs (Ziervogel, 2004). Such studies have shown that various factors affect dissemination and use, including stakeholder involvement in the process (usually higher when participatory processes had taken place) (Roncoli et al., 2009; Peterson et al., 2010); effects of user wealth, risk aversion, and presentational parameters, such as the position of forecast parameter categories, and the size of probability categories (Millner and Washington, 2011); and the legitimacy, salience, access, understanding, and capacity to respond (Hansen et al., 2011). Gender differences have been observed in preferred dissemination channels (Archer, 2003; Naab and Korenteng, 2012).

There are promising signs for the integration of scientific-based seasonal forecasts with indigenous knowledge systems (Speranza et al., 2010; Ziervogel et al., 2010b). 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). For more information on climate information and services, and the history, politics, and practice of this area, see Section 2.4.1.

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 that had better market access had significantly higher income (Cunguara and Darnhofer, 2011). A multinomial choice model fitted to data from a cross-sectional survey of more than 8000 farms from 11 African countries showed that better access to markets, extension and credit services, technology, and farm assets (labor, 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).

Although access to credit, water, technologies, and markets are barriers, more fundamental is access to knowledge and information (*very high confidence*). Because 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 (Dockerty et al., 2006; Sheate et al., 2008; Patt and Schröter, 2008; Bryan et al., 2009; Deressa et al., 2009; Ringer, 2010). 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 (2013a) for Benin. There is now an important literature on dissemination of short-term or seasonal weather forecasts to farmers in developing countries (see Box 9-4).

Access to information is affected by human resources, or social characteristics (*medium evidence*, *high agreement*). These include culture, gender, age, governance, and institutions (Deressa et al., 2009; Goulden et al., 2009; Nielsen and Reenberg, 2010; Jones and Boyd, 2011). A growing body of literature investigates the socio-cognitive, psychological, and cultural barriers to adaptation. Section 2.2.1.2 explains how culture and psychology affect decision making; Section 16.2 also discusses how the framing of adaptation depends on perception of risk and values. For planned adaptation to be successful, or autonomous adaptation to occur, actors need to be convinced of the magnitude of risks of climate change (Patt and Schröter, 2008).

9.5. Key Conclusions and Research Gaps

9.5.1. Key Conclusions

This chapter has assessed impacts of climate change, vulnerability to climate change, and prospects for adaptation to climate change in the rural areas of the world. Rural areas are distinctive and important in the context of climate change because:

- They account for nearly half of the world's population, even with rapid urbanization.
- They account for well over half of the world's poor and extremely poor people.
- Economic activity and livelihoods in rural areas are closely linked to natural resources and thus particularly sensitive to climate variability and climate change.
- Conversely, it is in rural areas that long-established adaptations to climate variability exist and can form a basis under certain conditions for adaptations to climate change.

Rural areas are hard to define—there is no internationally valid definition, and definitions that do exist depend on definitions of the urban (see Table 9-1). They are also extremely diverse, existing in nearly every country of the world, across low-, middle-, and high-income countries, although 90% of the world's rural population lives in low- and middle-income countries, which receive particular attention in this chapter. Rural areas are undergoing important and rapid changes in terms of their demography, economic profile, and governance (see Table 9-3)—some specific to developing countries, some to high-income countries, and some generic. Many of these changes are in the direction of economic and livelihood diversification away from agriculture and natural resources. Others are in the direction of increased rural-urban interdependencies and less well-defined boundaries between the rural and the urban.

Many of the non-climate factors characterizing rural areas and populations within them, especially in low- and middle-income countries, are cited as factors increasing vulnerability to climate change. There is *high agreement* on the importance for resilience of access to land and natural resources, flexible local institutions, and knowledge and information, and the association of gender inequalities with vulnerability. There 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. Specific livelihood niches such as pastoralism and artisanal fisheries are vulnerable and at high risk of adverse impacts (*high confidence*), partly due to neglect, misunderstanding, or inappropriate policy toward them on the part of governments (Section 9.3.5).

Against this background, discussion of impacts of climate change will be complex. 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, starting either with increased frequency of extreme events or with more gradual manifestations of climate change, and working through impacts on agriculture, ecosystems, or infrastructure. This increases the uncertainty associated with any particular projected impact. Biophysical impacts on food production are discussed in Chapter 7: this is supplemented here by an assessment of impacts on the production of non-food crops on which many millions of rural people depend, illustrated in particular by coffee, tea, and cocoa (Box 9-1). Literature on the downstream impacts on incomes and livelihoods of changes in agricultural production (including livestock and fisheries) is also assessed.

Despite methodological problems in attribution, around the difficulties of attributing extreme events to climate change, the status of local knowledge, and the action of non-climate shocks and trends, evidence for observed impacts, both of extreme events and other categories, is increasing. Impacts on income and livelihoods can be inferred from biophysical impacts, but with *low confidence*. There is *high confidence* in geographically specific impacts such as glacier melt in the Andes (Section 9.3.2).

Major impacts of climate change in rural areas will be felt through impacts on agricultural production and therefore through agricultural incomes. In some regions shifts in agricultural production, of food and non-food crops, are *likely* to take place, not only as a result of changes in temperature and rainfall, but also through changes in availability of irrigation water, which are not necessarily factored into crop yield projections based on crop models (Section 9.3.3.1). There are also *likely* to be impacts on rural infrastructure both in developing and developed countries (Section 9.3.3.2).

The interconnections between rural and urban areas will be affected in complex ways. Climate change will impact international trade volumes in both volume and value terms (*limited evidence*, *medium agreement*). Options exist for adaptations within international agricultural trade (*medium confidence*) to reduce market volatility and manage food supply shortages caused by climate change. Migration patterns will be driven by multiple factors of which climate change is only one (*high confidence*) and establishment of a relation between climate change and intra-rural and rural-to-urban migration, observed or projected, remains a major challenge (Section 9.3.3.3).

Climate policies, such as increasing energy supply from renewable resources, encouraging cultivation of biofuels, or payments under REDD, will have significant secondary impacts, both positive (increasing employment opportunities) and negative (landscape changes, increasing conflicts for scarce resources), in some rural areas (*medium confidence*). These secondary impacts, and trade-offs between mitigation and adaptation in rural areas, have implications for governance, including the need to promote participation of rural stakeholders (Section 9.3.3.4).

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 (*very high confidence*). In rural areas especially, valuation of climate impacts needs to draw upon both monetary and non-monetary indicators.The valuation of non-marketed ecosystem services and the limitations of economic valuation models that aggregate across multiple contexts pose challenges for valuing impacts in rural areas and require interdisciplinarity and innovative approaches (Section 9.3.4).

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 (Section 9.3.4). 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 constraints, such as low levels of educational attainment, environmental degradation, gender inequalities, and isolation from decision making, create additional vulnerabilities which undermine rural societies' ability to cope with climate risks (*high confidence*). The supply of information and opportunities for learning will be a key issue.

9.5.2. Research Gaps

There is a major continuing need for research on climate change in rural areas, which 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. Such research will need to be developed, and extended to rural areas and diverse categories of rural people throughout the world.

Integrated research is needed on changes in land use and trade-offs between land uses under climate change, including non-agricultural land uses such as conservation and tourism. It should examine the trade-offs and synergies between adaptation and mitigation in rural areas, the impact of climate policies on rural livelihoods, and the appropriate structures for governance of natural resources at a landscape level for both developed and developing countries.

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

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

A relevant area will be that of improving understanding of rural-urban linkages, their evolution, and their management under climate change, including the respective roles of climate and other factors in rural-urban migration.

Research is needed on practical adaptation options, not only for agriculture but also 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 must be open to participatory and action-research approaches that build on both local and scientific knowledge, and foster learning for adaptation and resilience among rural people.

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