Chapter 13
Traditional Forest-Related Knowledge and Climate Change

John A. Parrotta and Mauro Agnoletti

Abstract The holders and users of traditional forest-related knowledge are on the front lines of global efforts to deal with climate change and its impacts. Because of their close connection with, and high dependence on, forest ecosystems and landscapes, indigenous and local communities are among the first to witness, understand, and experience the impacts of climate change on forests and woodlands as well as on their livelihoods and cultures. The history of forest and agricultural landscape management practices of indigenous and local communities based on their traditional knowledge offer insights into principles and approaches that may be effective in coping with, and adapting to, climate change in the years ahead. Global, regional, national and local efforts to mitigate and adapt to climate change, however, have not yet given adequate attention either to the forest-related knowledge and practices of traditional communities, or to the interests, needs and rights of local and indigenous communities in the formulation of policies and programmes to combat climate change. Due consideration of, and a more prominent role for, traditional forest-related knowledge and its practitioners could lead to the development of more effective and equitable approaches for facing the challenges posed by climate change while enhancing prospects for sustainable management of forest resources.

Keywords Adaptation • Agroforestry • Biofuels • Carbon markets • Climate change • Environmental policy • Forest management • Traditional communities • Mitigation • Traditional agriculture • Traditional knowledge

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13.1 Introduction

Traditional forest-related knowledge and associated management practices have sustained local and indigenous communities throughout the world under changing environmental, social and economic conditions, long before the advent of formal forest science and 'scientific' forest management. Through long experience of inter-annual and longer-term variability in climate, many such communities have developed significant bodies of knowledge, transmitted through the generations, on how to cope with local climatic shifts and impacts of extreme weather events and other natural disasters. This includes knowledge related to weather prediction, of wild plant and animal species and their management, and agricultural techniques for managing and conserving water and soil resources.

Traditional knowledge and management practices have historically enabled these communities to adjust their agricultural calendars, crop selection and management practices, and to cope with changing abundances of preferred forest and woodland species used for food, medicine and other purposes. Management practices based on traditional knowledge have been applied over extensive closed forest areas, small woodlands, agroforestry and shifting cultivation systems, and even to the management of single trees occurring in agricultural fields and pastures.

In this chapter, we discuss how traditional forest-related knowledge and practices have helped forest-dependent and other rural communities anticipate and adapt to past and present impacts of climate change on forests and forested landscapes. We examine how this knowledge, through its application in a variety of management practices, can contribute to climate change mitigation and adaptation—by providing models for increasing resilience of forest and related agricultural resource management. These models reduce local dependency on fossil fuels and maintain or enhance terrestrial carbon stocks, while contributing to livelihoods, food security, and maintenance of ecological, social and cultural values associated with forested landscapes in the face of environmental uncertainty. Finally, we explore opportunities and risks for traditional forest-related knowledge and the holders and users of this knowledge (local and indigenous communities) associated with ongoing international climate and forest policy debates and emerging climate change mitigation measures. Examples include the expansion of biofuels production, carbon markets, and other mechanisms to enhance terrestrial carbon stocks and reduce greenhouse gas emissions from forested landscapes.

13.2 Current and Projected Impacts of Climate Change on Forest Ecosystems and Forest-Dependent Communities

The historical and projected effects of climate change on forests are influenced by ecosystem-specific factors that include human activities, natural processes, and different dimensions of climate, i.e., temperature, rainfall patterns, and wind. Climate change over the past half century has already affected forest ecosystems in a number of ways, including changing patterns of tree growth and mortality, outbreaks of damaging insects and diseases, and shifts in species distributions and seasonality of ecosystem processes. Because of the complexity of both natural and human systems, and their interactions, scientific quantification of ecological and socio-economic impacts and prediction of future impacts is fraught with difficulties and uncertainties (Lucier et al. 2009).

Nonetheless, under most scenarios outlined in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC4: Parry et al. 2007a), climate change is projected to change forest productivity (increasing in some regions, decreasing in others) and the distribution of forest types and their species composition in all biomes. Under most IPCC4 scenarios, boreal forests will be particularly affected by climate change and are expected to shift towards the poles, temperate forests are expected to be less effected than other forest types, and the effects on subtropical and tropical forests are expected to be highly variable depending on location; forest decline is considered likely in many drier tropical forest regions, and biodiversity declines are expected in wetter tropical forest regions (Seppälä et al. 2009). In regions where temperature and rainfall patterns become more favourable for agriculture and forest management purposes, traditional communities engaged in these activities could realize benefits from climate change. Many others will not, particularly where climate change effects on local ecosystems adversely affect traditional livelihoods.

The future IPPC4 scenarios suggest a number of broad regional trends that are likely to affect forests, and therefore forest-dependent communities:

- In Africa, mean annual temperature increases are likely to be larger than global increases throughout the continent and in all seasons, with drier subtropical regions warming more than moister tropical (equatorial) regions. Projections suggest decreasing rainfall in much of the African Mediterranean, northern Sahara, and southern Africa, but increasing rainfall in East Africa.
- In Asia, warming is likely to be above the global mean in central Asia, the Tibetan plateau, eastern Asia and South Asia. Winter precipitation is likely to increase in northern Asia, the Tibetan plateau, eastern Asia and in southern areas of Southeast Asia, while summer precipitation is likely to increase in northern Asia, East Asia, South Asia and most of Southeast Asia, but decrease in central Asia. Extreme rainfall events and severe winds associated with tropical cyclones are likely to increase in East Asia, Southeast Asia and South Asia.
- In Latin America, annual precipitation is likely to decrease in most of Central America and in the southern Andes, and summer rainfall is likely to decrease in the Caribbean and increase in southeastern South America.
- In the boreal regions of North America, Scandinavia and Russia, which are currently experiencing rapid and severe climate change, future temperatures are likely to rise faster than the global mean, particularly during the winter months.
- Elsewhere in North America, mean annual warming is predicted to be greater than the global mean, with notably higher winter temperatures in northern

North America and higher summer temperatures in the southwest. Mean annual precipitation is likely to increase in Canada and northeastern United States, and decrease in the Southwest, with significant changes in the seasonal distribution of precipitation throughout most of Canada and the United States.
- In the Pacific region, all North and South Pacific islands, as well as Australia and New Zealand, are considered very likely to warm. Annual precipitation is likely to increase in equatorial Pacific regions and in the west of New Zealand's South Island, and to decrease in southern Australia in winter and spring with increased risk of drought.

Indigenous and local communities in many parts of the world are already feeling the effects of current climate change on their lands in ways that jeopardize their cultures, livelihoods, food security and, in some cases, their very survival (UNPFII 2007; Macchi et al. 2008; Nilsson 2008; Collings 2009; Osman-Elasha et al. 2009). Despite our limited ability to accurately quantify and predict the magnitude of future climate change impacts of forests in specific localities, the expected or potential impacts of climate change on forest ecosystem structure and function are likely to have far-reaching consequences for the well-being of people in affected areas. At risk are such goods and services such as: timber, fuelwood and essential non-wood forest products, sufficient clean water for consumptive use, and other services required to meet people's basic nutritional, health and cultural needs (Easterling et al. 2007; Colfer et al. 2006; Osman-Elasha et al. 2009).

The observations and experiences to date of indigenous communities throughout the world have been compiled in an overview of more than 400 research studies, case studies and projects published by the United Nations University's Institute of Advanced Studies' Traditional Knowledge Initiative (Galloway-McLean 2010). Some of the major trends and examples are summarized below.

In drought-prone regions of Africa, increasing desertification threatens food security for communities who rely on rain-fed agriculture, as well as for pastoralists who struggle to sustain the fodder needs of their cattle and goats (Simel 2008). Shrinking water resources in such regions has direct implications for human health. Limited options for migration and mobility, degradation of forest and woodland resources, and increasing conflicts over natural resources limit the potential for adaptation within these communities. In tropical Asia, changing weather patterns, including increasingly severe typhoons and cyclones, are also affecting food and water security and increasing vulnerability to water- and vector-borne diseases. Indigenous peoples in some parts of Asia also report increased hardship that are the result of climate change mitigation projects that result in deforestation or loss of access to traditionally used forest resources. These projects include: biofuel plantation expansion; building of dams under the Clean Development Mechanism (established under the Kyoto Protocol); uranium mining; and inclusion of tropical forests under schemes to reduce emissions from deforestation and degradation. In the Andes, alpine warming and the shrinking of glaciers threatens water supplies, and thus food and health security, by causing shifts in populations of wild plants used for food, traditional medicine, as well as resources needed to sustain grazing animal populations and animals hunted for food.

In the Arctic boreal forest regions of North America and Eurasia, vegetation cover is changing, as are the populations and distributions of many fish, game and wild plant species that people in local and indigenous communities have traditionally relied upon for their food security needs and maintenance of their social and cultural identities. Changes in reindeer migration and foraging patterns resulting from shorter winters and increasingly unpredictable weather patterns are a particular problem for the estimated 100,000 or more reindeer herders of over 20 indigenous communities who manage an estimated 2.5 million semi-domesticated reindeer over four million km^2 of land in Alaska, Canada, Greenland, Norway, Sweden, Finland, Russia and Mongolia. Significant changes are also occurring in animal and fish populations, and in the behaviour and migration of bird, mammal and fish species that are important to indigenous (and other) communities in temperate regions of North America.

In low-lying coastal regions worldwide, but notably in many small islands in the Pacific, sea level rise caused by melting glacier ice, expansion of warmer seawater, and melting of sea ice in the Arctic and Antarctic is leading to accelerated erosion of coastal zones, increasing exposure to natural disasters such as floods and extreme weather events, and salt water intrusion into groundwater, with direct negative consequences for food security (UNPFII 2007). In the Pacific, sea level rise is already forcing migration of local and indigenous communities from low-lying islands and relocation to other communities' traditional territories, with a number of adverse social, spiritual, cultural and economic implications for affected communities (Collings 2009)

The current and potential future impacts of climate change on traditional communities who depend on forest ecosystems and landscapes are therefore cause for deep concern. Despite having contributed least to anthropogenic climate change due to their 'low carbon' lifestyles, traditional communities are disproportionately vulnerable to the effects of climate change since they generally live in ecosystems that are particularly prone to climate change impacts—polar and montane regions, small islands, tropical and subtropical forests, and deserts (Crump 2008; Macchi et al. 2008; Nilsson 2008; Rai 2008; Smallacombe 2008). Further, they are usually heavily dependent on low-input (often rain-fed) agriculture to meet their food security needs and on forest resources for other basic needs including wild foods, medicines, fuel and other non-timber forest products (Galloway-McLean 2010)

The particular vulnerabilities of many such communities to these impacts are due not only to their geographical location and greater reliance on local ecosystems to meet their livelihood and food security needs, but also to low incomes and limited institutional capacities. In many parts of Africa, for example, where communities have developed local adaptation strategies for coping with extreme weather events such as prolonged droughts, the impact of decreasing rainfall on water availability, agricultural production and human health add to existing strains on the coping capacity of communities in affected regions (Simel 2008; Galloway-McLean 2010).

13.3 The Value of Traditional Forest-Related Knowledge for Anticipating Climate Change and Its Ecological Effects

People in many indigenous and local communities are well known for their knowledge of their natural environment, and often possess keen insights into meteorological phenomena, animal behaviour, tree phenology, and changes in ecosystem structure and dynamics. Generations of experience, particularly within indigenous communities that have been able to maintain their cultural identities and traditional lifestyles, retain rich bases of knowledge that include historical climatic data (on temperature and rainfall patterns, frequency of climatic events, etc.) and current fine-scale information relating to water and forest resources, biodiversity, agriculture, food security and human health (Salick and Byg 2007; Galloway-McLean 2010). There is a growing body of scientific literature and reports documenting the observations of local and indigenous communities regarding climate and environmental trends in many forested regions of the world (c.f. Parry et al. 2007b; Crump 2008; Galloway-McLean 2010). Vlassova (2006), for example, summarizes the results of interviews with indigenous communities on climate and environmental trends in the Russian boreal forest region.

Traditional knowledge is very commonly used in traditional communities to monitor and forecast weather and plan agricultural activities. For example, local farmers in various parts of the African Sahel have developed complex systems for gathering, predicting, interpreting observations of weather and climate that they use to make critical decisions on cropping patterns and planting dates (Ajibade and Shokemi 2003). A study in Burkina Faso found that the indicators most used for traditional weather forecasting include early dry season temperature patterns, the timing of fruiting in particular local tree species, water levels in streams and ponds, and nesting behaviour of certain bird species (Roncoli et al. 2001). Many other case studies have documented indigenous weather forecasting skills for predicting rainfall and droughts, in Gujarat, India; predicting weather through observations of sea birds and clouds, in Russia; and use of meteorological indicators and animal behaviour for weather prediction in Sri Lanka (Galloway-McLean 2010).

In a recent study conducted in the Philippines, Galacgac and Balisacan (2009) documented and critically evaluated the observations of natural phenomena, and their interpretation, of 204 traditional weather forecasters in numerous locations in Ilocos Norte Province. Traditional weather forecasters in this region use a variety of meteorological observations (e.g., temperature and wind patterns, cloud formations, sky colour, rainbow appearance, and visibility of stars and the moon), sea conditions; phenology of wild and cultivated plant species; and the behaviour of many species of birds, mammals, amphibians, and insects as the basis for prediction of rainfall patterns and specific events, including the onset of the monsoon and tropical storms (i.e., typhoons). This study found that the short- and long-term (up to 1 year) predictions made by traditional forecasters were, in general, highly reliable and often more accurate and extensive than those of national weather bureau. People in these rural communities rely heavily on this knowledge of these traditional knowledge holders (mostly elderly farmers, housewives and fisher folk) to plan their agricultural and agroforestry activities and to prepare for severe weather events. Traditional weather forecasting has been recognized by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), which considers such traditional forecasting techniques to be supplemental to scientific weather forecasting.

Several countries have indigenous knowledge-sharing programmes for weather forecasting. In Australia, for example, the Indigenous Weather Knowledge Website Project, funded by the government, displays the seasonal weather calendars of Aboriginal Australians (Bureau of Meteorology 2011).

13.4 The Value of Traditional Agricultural and Forest Management Practices for Climate Change Mitigation and Adaptation

It is increasingly recognized that agricultural and forest management strategies to deal with climate change should consider all relevant knowledge and historical experiences that have helped societies adapt to changing environmental conditions. Traditional forest-related knowledge and practices developed and utilized throughout the world for centuries have an important role to play in dealing with climate change and its social and economic impacts. In response to ongoing and anticipated climate-induced changes in forest structure and species composition, traditional knowledge of forest-dependent people about the uses of a wide range of forest plant and animal species may enhance prospects for meeting their needs for wild foods, medicinal plants and other non-timber forest products by substitution of increasingly rare species with those that may become more abundant. Land management practices that have historically helped local and indigenous communities survive in the face of extreme climatic conditions merit study as models for production systems that contribute to both climate change mitigation and adaptation (Kronik and Verner 2010).

For cultivated forest species, as for agricultural crop species and varieties, traditional knowledge and associated tree and forest management practices can play a key role in maintaining forest productivity, biodiversity, and food security, in the face of climate change. Case studies from around the world reveal a diversity of traditional ecosystem management approaches under conditions of environmental uncertainty that may increase communities' capacity to adapt to the effects of climate change (Adger et al. 2007; Roberts et al. 2009). In Italy, for example, centuries-old practices for managing chestnut orchards have enabled local communities to cultivate this important woodland food source on sites well beyond the natural climatic limits of the species (Agnoletti 2007).

In the context of climate change mitigation, it is instructive to consider the variety of traditional forest, woodland, and agricultural management practices that have been used to meet the livelihood needs of people on a sustainable, long-term basis in the face of environmental uncertainty. Of particular relevance are practices that, unlike modern energy-intensive industrial agriculture (and many forestry practices), neither depend on significant fossil fuel inputs (in the forms of inorganic fertilizers, pesticides, and mechanization) to maintain their productivity, nor result in deforestation and CO_2 emissions from both forest conversion and agricultural management activities.

In dry and semiarid regions of the world, indigenous and local societies have developed a wide variety of strategies based on traditional forest-related knowledge to cope with recurrent droughts that periodically threaten their food security. These include traditional technologies developed to manage wild and cultivated trees that provide food, fodder, and other non-timber forest products; and practices to harvest and conserve scarce water resources in traditional silvopastoral and agroforestry systems (Laureano 2005; Osman-Elasha et al. 2009). Traditional societies worldwide have devised a range of agricultural techniques designed to conserve soil fertility (and soil carbon) and maintain productivity of a range of food crops even during extended periods of drought. In the Sahel and elsewhere on the African continent where the magnitude and intensity of droughts, and their impacts on rural communities have increased over the past century (Benson and Clay 1998; Somorin 2010), local communities have survived by relying on traditional soil and water conservation practices, tree crop management innovations, use of locally developed early-maturing and drought-hardy crop varieties, and soil management techniques such as zero-tilling and mulching based on traditional knowledge (Schafer 1989; Osunade 1994; Dea and Scoones 2003; Gana 2003; Nyong et al. 2007). A number of recent projects involving indigenous communities in various parts of the world have helped to revitalize traditional practices for soil- and water-conservation methods and harvesting that have yielded important livelihood benefits within these communities (Galloway-McLean 2010).

At the other extreme, in extremely high rainfall areas such as in northeastern India, the soil and vegetation management practices developed over generations by local communities who practice shifting agriculture have been shown to enhance soil fertility and minimize erosion losses in cultivated areas (Ramakrishnan 2007). Such techniques, developed over generations by people in indigenous and local communities, may be seen as methods to 'activate' environmental resources without the use of external energy inputs derived from fossil fuels, such as chemical fertilizers and mechanization (Bertolotto and Cevasco 2000).

In the following sections we consider selected technologies, innovations, and practices developed by traditional societies that have sustained a variety of agricultural, agroforestry, and forest management systems over generations, long before dependence on fossil fuels resulted in their displacement in many parts of the world. These traditional practices, having evolved under conditions of environmental uncertainty and change, illustrate the adaptive capacity (and in some cases the vulnerabilities) of local and indigenous communities and their knowledge systems.

13.4.1 Energy Use Efficiencies of Traditional Agriculture and Forest Management Systems

While the need to reduce consumption of fossil fuels and develop renewable energy resources in industrialized and urban environments is widely recognized, rather less attention has been paid to rural landscapes—arable lands, pastures, and forests. These managed landscapes cover an increasing proportion of the earth's surface, supply the overwhelming majority of the world's food, and contribute very significantly to both carbon sequestration and carbon emissions. The development of strategies to mitigate climate change could benefit from a re-evaluation of rural development models, including those based on traditional knowledge and practices. In such evaluations, consideration should be given to energy budgets and energy use efficiencies (the ratio of energy produced to energy consumed), as well as to landscape-level impacts and trade-offs with respect to the range of environmental, economic, social, and cultural values of forests and associated agricultural landscapes (Haberl et al. 2004; Marull et al. 2010).

Several recent studies have assessed the role played by traditional knowledge and practices in sustainable forest management and conservation of cultural landscapes in (Farina 2000; Agnoletti 2006). Historical changes affecting land use were usually found to be the result of changing management of agroforestry and pastoral systems that were linked to changes in the production and consumption of energy. Landscape change can be seen as the reflection of changing metabolic relationships between a given society and the natural systems sustaining it (Tello et al. 2006). The historical process of industrialization may be viewed as a transition from a rural socio-metabolic regime, with a land-based solar-energy-controlled system, towards an industrial regime with a fossil-fuel-based energy system (Kuskova et al. 2008). Landscapes characterized by traditional activities with low mechanization tend to use energy in a more efficient way, and above all, are not highly dependent on fossil fuels, as is the case for landscapes characterized by agricultural intensification and specialization (Sieferle 2001; Krausmann et al. 2008).

Input-output analysis of the production and consumption of energy in agricultural, forestry, and pastoral systems can be used to assess the relative energy efficiencies of socio-ecological systems, and therefore of the landscape. Such analyses evaluate all variables related to the production and consumption of energy, such as agricultural and animal products, use of fuel and of mechanical, fertilizers, taking into account all the energy flows related to production activities, including inputs (animal and human labour, fertilizer, pesticides, fuels, etc.); outputs (animal and vegetable products, residues, etc.); and socio-economic stocks (humans, domesticated animals). Studies of this type can be used to quantify energy inputs from fossil fuels and from renewable sources, and to estimate the production of greenhouse gases that contribute to climate change.

Studies using input-output analysis have shown that traditional agroforestry systems, despite lower overall productivity, can make more efficient use of solar energy so that the energy produced is greater than the energy consumed. In contrast, modern agricultural landscapes consume more energy than they produce, and require higher energy inputs (particularly those based on fossil fuels, fertilizers, and pesticides) to achieve their high productivity. For example, Cussó et al. (2006) compared the rural landscape of Catalonia in 1860 with that of 1999 and found that the ratio of energy produced to energy consumed declined from 1.67 in 1860 to 0.21 in 1999. Studies of other socio-ecological systems in Europe have also shown low energy efficiencies of landscapes dominated by intensive industrialized practices. Most of the energy used today in industrialized agriculture and forestry is derived from non-renewable energy sources, and in particular from fossil fuels, making agricultural production dependent on the availability and price of oil. As a result, today's intensive agricultural landscapes are both energy inefficient and highly polluting.

Traditional fallow management practices used by shifting cultivators throughout the tropics and subtropics represent another means by which traditional knowledge has contributed, and in many regions continues to contribute, to climate change mitigation. While it usually is argued that these systems are less productive than more energy-intensive agricultural practices, traditional shifting agricultural and forest management systems are typically more energy-efficient and, in fact, may actually be more productive in terms of agricultural yields than alternative, less sustainable, higher energy-input systems—as discussed in the case of traditional agroforest landscape management in northeastern India, in Chap. 9 of this volume.

13.4.2 Agroforestry

Agroforestry—land use systems and practices in which woody perennials are deliberately integrated either in spatial mixtures or temporal sequences with crops and/or animals on the same land unit—have been developed and used by traditional communities worldwide for centuries. Agroforestry systems, both traditional and introduced, involve careful selection of species and careful management of trees and crops to optimize the production and positive effects within the system and to minimize negative competitive effects and the need for chemical fertilizers and other external energy inputs to maintain high productivity. A wide diversity of traditional and recently modified or introduced agroforestry systems are used in densely populated areas of South Asia and Southeast Asia, as well as in less densely populated tropical, subtropical and temperate regions of the world (Fig. 13.1).

While traditional agroforestry systems have evolved with changing agro-ecological, socioeconomic, and demographic conditions, many of these have been weakened, or abandoned, by communities for a variety of reasons, including population growth, land-use conflicts, deforestation, and degradation of forests, watersheds, and agricultural soils. In regions where shifting cultivation is practiced, these pressures have often led to shortened fallow periods and extension of cultivation into areas unsuited

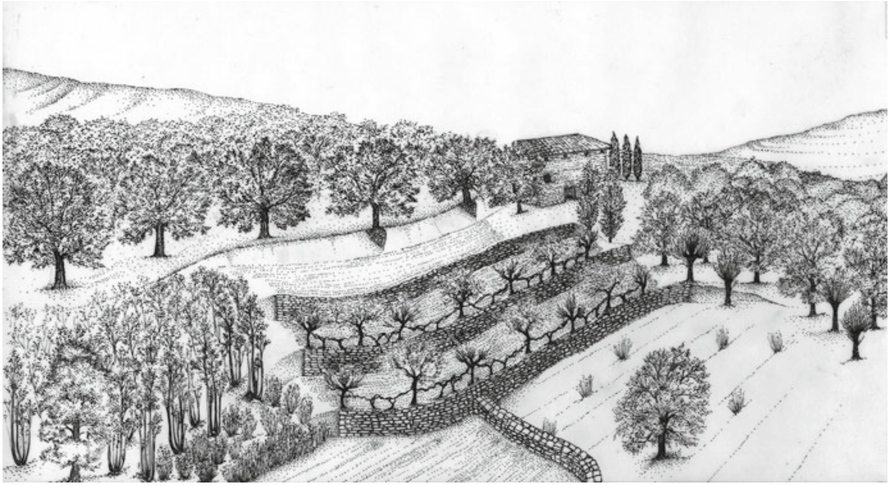

Fig. 13.1 Traditional temperate agroforestry system. Such systems, formerly common in Italy and in other Mediterranean countries, involve terracing and mixed cultivation, and accomodate multiple land uses within a limited land area

to these practices. Many communities that practice permanent agriculture face similar problems connected to their over-exploitation of natural resources to meet increasing demands for food, fodder, fuel, and water resources. This has resulted in decreased agricultural productivity, reduced incomes, poverty, overgrazing of range lands, deforestation, and forest degradation. In such situations, redevelopment of agroforestry practices may offer not only a means to improve the sustainability of agricultural production and reduce degradation of forests, soil erosion, and desertification (Tejwani and Lai 1992; Carmenza et al. 2005), but also a means to better adapt to the negative impacts of climate change and variability.

Scientific interest in tropical agroforestry can be traced to the early to mid nineteenth century, when British colonial foresters in Burma began adapting local (traditional shifting agriculture) fallow management practices for the purposes of establishing teak (*Tectona grandis*) plantations. This practice, useful for establishing plantations of a variety of high-value timber species, soon spread to nearby hill regions of northeast India and present-day Bangladesh, central and southern India, and many parts of Africa from the mid-nineteenth to early twentieth centuries (King 1987). Building on these experiences, the successes of countless generations of traditional agroforestry practitioners, and the failures of mid-twenty first century agricultural development policies and practices that were promoted to replace traditional tropical agroforest management systems, the scientific discipline of agroforestry emerged in the late 1960s and1970s with the establishment of the International Institute of Tropical Agriculture (based in Nigeria) and the International Council for Research in Agroforestry (currently the World Agroforestry Centre, based in Kenya). Over the past 40 years, agroforestry research, development, and training activities

Box 13.1 Advantages of Agroforestry Systems in Dryland Agriculture

- *Diversification of production.* Agroforestry systems yield a wide range of products, including food, fodder, fuel, fruits, green manure, etc.
- *Risk management.* By diversifying production, agroforestry systems reduce economic risk to farmers should in the case of crop failures.
- *Management flexibility.* The presence of trees in agroforestry systems expands management options for farmers. For example, tree crops can be harvested for food (in the case of fruit-yielding species), fuel, fodder, poles, or small timber according to farmers' requirements and market demands. During the fallow season, time can be effectively used for harvesting, pruning, and marketing of the tree components.
- *Utilization of off-season precipitation.* While most of the drylands are cropped during a limited season, perennial tree components can capture and use rainfall throughout the year.
- *Soil and water conservation.* The perennial component of agroforestry systems help to reduce soil and water loss.
- *Moderation of soil microclimate.* Tree components of agroforestry systems help to stabilize soil temperatures and moisture particularly during summer months, protecting soil micro-organisms. Trees also serve as shelter for cattle.
- *Soil fertility enhancement.* The deep-rooted nature of most trees results in tapping nutrients from deeper soil horizons and returning them to the plough layer through leaf litterfall and decomposition.
- *Carbon sequestration.* The presence of permanent (tree and shrub) system components enhances carbon storage above- and below-ground in biomass and soil organic matter.

have been promoted by government agencies, universities, training institutions, NGOs, and local organizations, though not with a view to their potential to address climate change issues until very recently.

Traditional and recently modified agroforestry systems can offer advantages over conventional agricultural and forest production methods. These systems both increase productivity of food crops, fodder, fruits, and other non-timber forest products, as well as provide economic and social benefits; and ecological goods and services, including biodiversity conservation and increased sequestration of carbon in biomass and soils (Box 13.1). In addition to their capacity to sequester and store carbon, sustainable agroforestry systems offer other climate-change-related benefits, through: their potential to reduce deforestation that would result should they be converted to permanent 'modern' agricultural systems; reduced degradation pressures on forest and woodlands by providing fodder and fuelwood; and increased diversity of on-farm tree crops and tree cover that may help to buffer farmers' livelihoods and food security against the effects of climate change. In regions susceptible to drought—as in most of Africa, the Mediterranean, and drier regions of the Americas, Asia, and Australia—the provision of fodder in the form of foliage from trees cultivated in agroforestry systems may be particularly important, providing a measure of insurance during seasons (or years) when fodder resources from grazing lands are scarce.

Nitrogen-fixing species cultivated in agroforestry systems that produce nutrient-rich leaf litter—such as *Sesbania sesban, Tephrosia vogelii, Gliricidia sepium,* and *Faidherbia albida*—have been shown to improve maize yields in sub-Saharan Africa. For example, a 10-year experiment in Malawi demonstrated that using trees such as *Tephrosia vogelii* and *Gliricidia sepium* increased maize yields to an average of 3.7 tonnes per hectare, compared to 1 tonne per ha in plots without these trees or application of mineral fertilizers (World Agroforestry Centre 2011a). Research with *F. albida* in Zambia showed that mature trees can sustain maize yields of 4.1 tonnes per ha over several years compared to 1.3 tonnes per ha beyond the canopy of the tree. Unlike other trees, *Faidherbia* sheds its nitrogen-rich leaves during the rainy crop growing season, precluding its competition with food crops for light, nutrients, and water. The regrowth of foliage during the dry season provides land cover and shade for crops when it is most needed (World Agroforestry Centre 2011b).

Agroforestry research in India (Bharara 2003) has documented a number of tree and shrub species that are common components of traditional agroforestry systems in the villages of arid zones, especially khejri (*Prosopis cineraria,* a tree) and ber (*Ziziphus mauritiana,* a gregarious shrub). These species, typically planted on field borders, or retained within fields, play an important role in providing high-quality fodder, fuel, and other locally used products as well as providing shade to adjacent crops. Within fields, khejri trees are lopped for fodder and fuel each year following the harvest of agricultural crops, while ber is harvested before planting of crops, allowed to re-grow with the associated crops (without competition for soil moisture and light), and again cut after the harvest of field crops. Khejri and ber grown in shelterbelts are not harvested, except for collection of twigs and small branches for fuel and thatching. In these traditional systems, fodder from both species is available every year regardless of rainfall due their deep-rooted habit and drought-tolerance, and are known as desert farmers' 'natural insurance.' During good rain years, yields of both grain crops and fodder around *P. cineraria* and *Z. mauritiana* are often higher than in other parts of the same field, attributed to their beneficial effects on soil microclimate and accumulation of humus.

One of the best examples of European agroforestry systems, known as 'mixed cultivation,' is a traditional practice found in the Mediterranean region dating back to at least 200 BC. In Italy, mixed cultivation was the most dominant land use in past centuries (Braudel 1966), representing approximately 45% of the total arable land of the country at the beginning of the twentieth century. Mixed cultivation practices allowed peasant farmers to exploit the cultivable areas of their lands and provide for their subsistence needs for both food and domestic energy. These practices also contributed significantly to the maintenance of tree cover in agricultural landscapes and meeting the energy requirements of the rural population. At the beginning of the twentieth century, the density of trees in mixed cultivation areas in northern Italy was about 160 trees ha^{-1}, higher than that of many forests, such as chestnut groves (which averaged 90–120 trees ha^{-1}). At that time, the total production of fuelwood from the Italian countryside was twice that from its forests. Those woodlands helped the country to be self-sufficient for fuelwood despite its limited forest area, which was 10% of the total land area (Agnoletti 2005, 2010a). Although mixed cultivation in Italy declined precipitously over the past 100 years with the industrialization of the agriculture sector, it is still practiced in some localities, an expression of the values expressed by these practices, which have survived despite attempts to replace them with technical and productive models that have yet to prove their historical sustainability.

13.4.3 The Oasis System

Local knowledge and practices associated with the creation and management of oases and other agricultural and forest management systems in arid regions of the world offer dramatic examples of the importance and contribution of traditional forest-related knowledge for human adaptation to environmental extremes (Laureano 2005). Such knowledge and the complex agricultural and forest resource management systems that sustain communities under conditions of water scarcity, are likely to become increasingly important in the future for regions where climate change is likely to exacerbate desertification.

Oases, usually relatively small areas within large expanses of sandy deserts as in the Sahara, are not naturally occurring habitats but rather the result of human action through the application of traditional knowledge, skills, and management techniques suited to the harsh environment in which they are found and passed on from generation to generation. The date palm (*Phoenix dactylifera*), an emblematic oasis plant probably native to North Africa and southwestern Asia, is the product of centuries (or longer) of domestication and cultivation. Palm groves established in oases have been planted, tended, and watered using special techniques to capture and efficiently utilize very scarce water resources.

In other arid landscapes that occur in very diverse environments, such as the mountain regions of North Africa, people have also developed highly productive agricultural systems through careful management of scarce rainfall and other available water sources. An example of this may be found in the Telouet valley on the eastern slopes of the Atlas range in Morocco, a locale characterized by dry climate and arid soils. As shown in Fig. 13.2, the land next to the 'oued' (river, in Arabic) is intensively cultivated, while the surrounding mountain slopes are totally denuded. Farmed land in the valley includes a large number of palm and other tree species, supported by a complex system of irrigation channels that are continuously managed by farmers. In this community and others in the region, wheat, fruit, and fodder production ensure self-sufficiency and food security for the local population,

Fig. 13.2 Telouet Valley, Morocco. Traditional techniques have made it possible to live in desert areas of the world without the use of modern technologies, by developing agricultural systems based on the use of trees and characterized by low energy inputs (Photo: Mauro Agnoletti)

while maintaining the beautiful, fine-grained, landscape that preserves the cultural identity of the area.

13.4.4 Traditional Fodder Production

Adaptation to climatic change, as in the case of coping with drought, has often focused on maintaining fodder availability during even the driest years. A number of traditional techniques for this have been developed in different parts of the world. Through their long experience with recurrent drought, farmers in Ethiopia, for example, have developed their own criteria for selection and evaluation of indigenous fodder trees and shrubs, and have also perfected protocols for the propagation and effective conservation of such species (Balehegn and Eniang 2009).

Technical interventions generated by research organizations that aim to improve the quality of life of people in traditional communities, or the nutritional status of their livestock, have generally failed to realize the value of traditional knowledge and innovations such as those of these farmers in Ethiopia. It is now increasingly recognized that unlike research-generated technologies, farmers typically aim to meet a variety of sometimes conflicting objectives through the practices they use to provide feed for their animals and adapt to existing agro-climatic changes in their localities (Thorne et al. 1999), and use their traditional knowledge and experience to develop practices to balance these objectives and optimize outcomes.

While work is underway in many regions to develop varieties of staple food crops that are adapted to existing climatic changes, identification and selection of adaptable forage options remains a task for farmers. Several studies of indigenous and local communities in Africa and Asia have shown that there is a diverse array of indigenous criteria and strategies for evaluation, utilization, and conservation of such trees that are linked to the adaptation needs of each agro-ecological zone (Jimenez-Ferrer et al. 2007). In a number of instances, laboratory analyses of the nutritive value of fodder from tree species have been found to correlate positively with their value according to indigenous evaluation criteria (Roothaert and Franzel 2001). For some species, however, laboratory analyses of fodder nutritive value does not correlate or even correlates negatively with the values according to indigenous criteria, as for example *Ficus thonningii* in Ethiopia (Mekoya et al. 2008). This suggests that these farmers, in their effort to adapt their fodder production practices to severe drought, give less emphasis to conventional criteria (e.g., nutritive value), than to survival of the fodder-yielding trees. Consequently, species that are not conventionally considered (by animal husbandry professionals) to be suitable fodder species are sometimes preferred by local communities for good reason.

Given the existence of site-specific traditional knowledge-based practices used by local people for selecting adaptable fodder species, such knowledge should be considered and integrated with scientific and other conventional evaluation criteria for the selection and promotion of tree fodder species to better assist farmers in different parts of the world adapt to climate change impacts in their localities, as was done in the study of local farmers' knowledge of fodder trees in Ethiopia cited earlier (Balehegn and Eniang 2009). Research scientists concerned with the development of adaptation strategies for forest and on-farm tree management would benefit from greater exposure to, and understanding, of traditional knowledge and practices to deal with the impacts of drought and extreme weather events that have served rural communities well for generations.

An example of sustainable agroforestry practices combining fodder production and controlled use of fire is the 'alnocolture' system, used by farmers in the Italian Apennine region until the end of the nineteenth century (Bertolotto and Cevasco 2000). This system, requiring no chemical fertilizers (i.e., fossil fuel-based inputs) involved a several-stage cycle combining cereal production, fodder production, and timber production using the nitrogen-fixing species *Alnus incana*, which increased the efficiency of the system through its fertilizing effects on soils under its influence of its root system as well as its periodic burning (Daniere et al. 1986). Fragmentary descriptions of this traditional system indicate variability in the time span of the different practices involved in the cycle (Fig. 13.3), which may have been due to differences in land morphology, soil conditions, livestock carrying capacity, and individual farmer preferences. This system was used in a variety of woodland types—in alder woods, and in mixed woods with alder, beech (*Fagus sylvatica*), and Turkey oak (*Quercus cerris*). The felling of alder (stage 1 of the cycle) occurred at intervals from 3 to 12 years, the cycle length related to the time required for production of fuelwood and fodder. Alderwood is specific for the practice of ‘ronco’; its wood is also used to make ‘fornaci’ (confined fire, during stages 2 and 3), after which the ashes are spread to fertilize soils for subsequent crop production. Grazing of sheep, goats, and, rarely, cattle was allowed after harvest of the last agricultural crop, by which time grazing would not jeopardize the growth of the young trees. Controlled fire in the alnoculture cycle helped to clear the undergrowth around hawthorns and particularly brambles, which formed temporary hedges used to protect the cultivated grain crops from the surrounding grazing area. It is probable that the ‘ronco coperto’ system, in which certain trees were retained, helped to save useful fruit trees such as cherry, and fodder

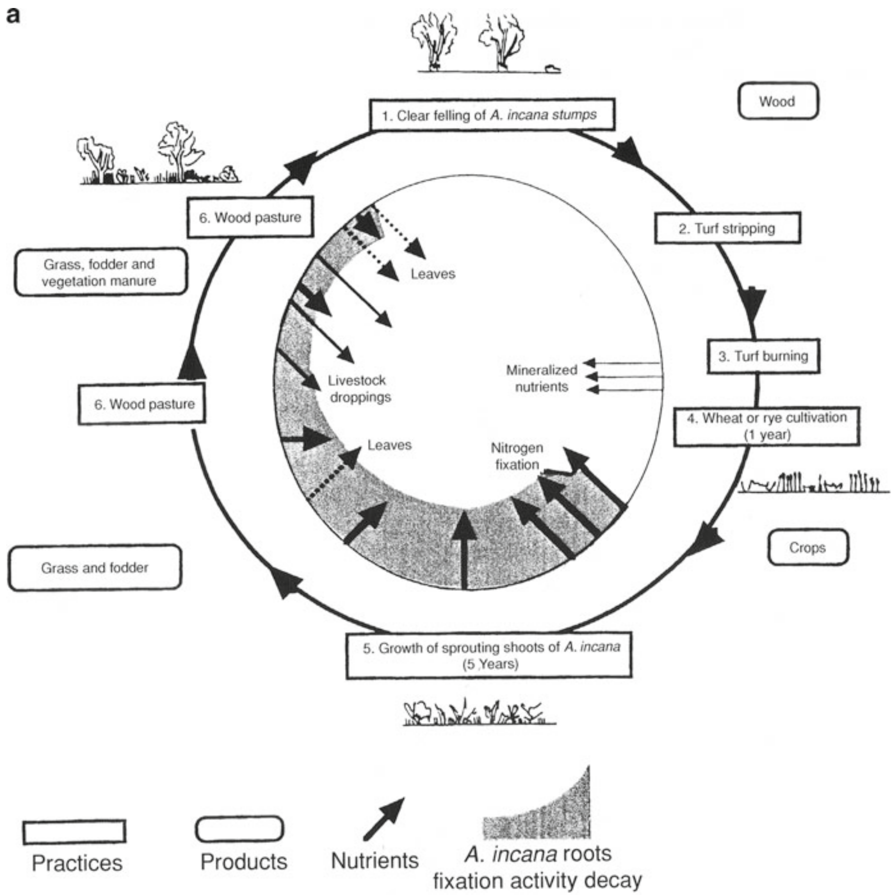

Fig. 13.3 ‘Alnocolture’, a traditional agroforestry system involving *Alnus incana* formerly used in the Italian Apennines. (**a**) schematic of the alnocolture cycle and associated nutrient inputs to soils; (**b**) Selected stages of the alnocolture cycle: (i) turf burning; (ii) cultivation of rye and oats; (iii) wood pasture

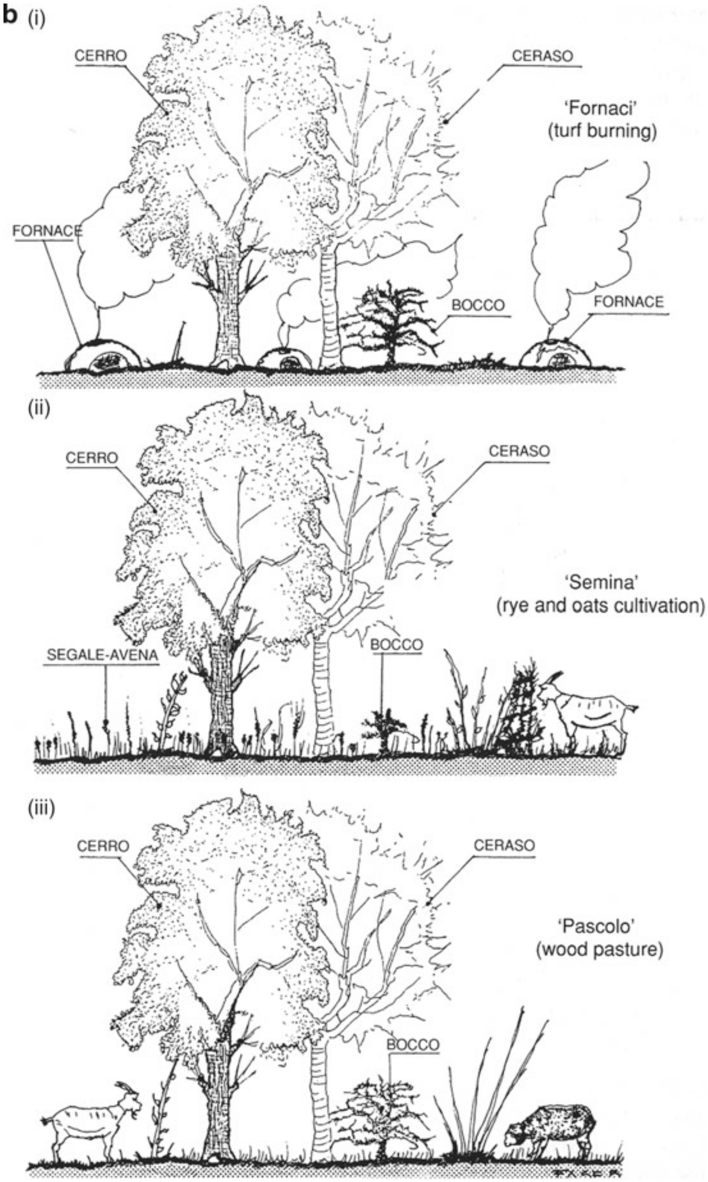

Fig. 13.3 (continued)

trees such as Turkey oak and ash (*Fraxinus* spp.). Very large, old individuals of these species survive in historical alnoculture sites to this day. What is notable about this traditional system is the fact that it did not reduce or degrade available resources over successive cycles.

13.4.5 The Value of Terraces and Dry-Stone Structures for Climate Change Adaptation in Agriculture and Forestry

One of the most serious threats posed by climate change is sea level rise, which is expected to cause flooding and increase salt water intrusion into groundwater in many coastal areas around the world, reducing the availability of cultivated land and freshwater resources for agriculture and other uses. Throughout history, people have adapted their agricultural practices in the vicinity of low-elevation wetlands and have developed management systems to sustain agricultural production in marginal hill regions to meet increasing food needs of growing populations.

Terracing, practiced since Neolithic times, is one of the most widespread techniques used to protect soils from erosion and to capture and channel water. These are self-regulating systems characterized by high aesthetic quality that model the landscape while integrating with its natural features. In the Mediterranean region, terraces have been used since ancient times for the cultivation of a variety of agricultural, horticultural, and other tree crops (Ron 1966; Rackham and Moody 1992; Grove and Rackham 2001). Never an isolated landscape element, terraces are rather part of a system of land-shaping works that are the product of traditional knowledge of construction techniques. They demonstrate an exquisite understanding of local hydrogeology and climate that allow local populations to make the most of their environmental resources (Fig. 13.4).

Terracing is used throughout the world today in agriculture as well as forestry. These systems are characteristic of rice civilization in Southeast Asia, exemplified

Fig. 13.4 Terracing in the Gargano massif, southern Italy. Terracing is commonly used to cultivate trees on mountain slopes in many parts of the world, and are an effective means to manage scarce water resources, particularly in drier regions. Sea level rise resulting in the loss of low-elevation agricultural lands may require restoration or extension of traditional terracing practices in upland areas to cope with such losses (Photo: Mauro Agnoletti)

in the Philippines' Banaue rice terraces of the Ifugao, a UNESCO World Heritage Site in Ifugao Province in Luzon (see Chap. 10, Box 10.3), or those in the Sapa region of northern Vietnam.

In Italy there is a prevalence of terraces that originated in the Middle Ages, when the abandonment of water control structures after the fall of the Roman Empire created vast flooded areas in the lowlands that forced the population to develop agriculture on hill slopes (Sereni 1997). Terracing, in the form of grass-covered contour terraces and terraces supported by dry-stone walls, is thus one of the main forms of adaptation to difficult environmental conditions. Terraces are used to produce not only agricultural crops but also trees of economic importance. Chestnut groves, in particular, are often grown on terraces of various designs in southern Europe (Pitte 1986), including structures held by dry-stone walls to 'lunettes'—semi-circular walls surrounding each individual tree. Terracing was also widely used in the reforestation and watershed restoration in mountain regions, as in most of the Alpine countries of Europe during the latter half of the nineteenth century.

Terraces provide a number of important services, notably land stabilization, by reducing soil erosion and loss (Llorens et al. 1992). In many areas, terrace construction required enormous human effort—cutting into the rocky matrix with sledgehammers and pickaxes, and carrying soil up from valleys on people's shoulders or mules' backs to fill the terraces. They are sometimes Cyclopean works of monumental character, both for their size and work forces required to build them. Many terraces, especially in farmed areas, have been replaced over the years with 'rittochino' arrangements, with planted crop rows following the maximum acclivity lines (i.e., directly upslope), since modern machines are powerful enough to work on steep slopes. Mechanization has also favoured larger agricultural fields, which has led to the total or partial removal of many terrace structures to increase field sizes, without replacement of equally effective structures to prevent soil loss. As a result, erosion on such farms is often extremely high, as documented in a study conducted in Tuscany which found that erosion rates increased 900% between 1954 and 1976 (Zanchi and Zanchi 2008). Chemical fertilizers are increasingly required to compensate for soil fertility losses.

Today, to ensure sustainability and landscape protection, it is necessary to minimize or reverse soil erosion and hydrogeological deterioration both by using conservative agronomic techniques that are adapted to specific local situations, and by restoring and maintaining traditional structures with high landscape value such as terraces (Zanchi and Zanchi 2008). Dry-stone walls used in traditional terrace construction in the Mediterranean as in other regions offer additional advantages to crops by absorbing heat during the hot hours of the day and releasing it during the cooler hours. Although the maintenance costs of terraces are higher, they guarantee the conservation of agriculture's most important resource—soil. In Italy, the Ministry of Food Agriculture and Forestry supported a survey of terracing as part of its research for a National Catalogue of Historical Rural Landscapes (Agnoletti 2010b), and made the conservation of terraces a pre-requisite for farmers requesting subsides in the framework of the EU Common Agricultural Policy.

Fig. 13.5 A ‘pantesco garden,’ on the Mediterranean island of Pantelleria (Ben Ryé) between Sicily and Tunisia. The traditional practice of constructing dry-stone walls, which protect trees within them from strong winds, allows the cultivation of trees without irrigation under semiarid conditions (Photo courtesy of Giuseppe Barbera)

Dry stone is used for purposes other than terraces in the traditional management of trees in different parts of the world. In regions where water shortages and high winds have created difficult conditions for cultivation of forest and horticultural tree species, a number of traditional techniques have been developed using locally available materials to overcome these limitations. Examples can be found in many Mediterranean islands as well as in the Canary Islands.

On the volcanic island of Pantelleria (also known as Ben Ryé, from the Arabic *Bent El Riah*), located between Sicily and Tunisia, the *orti panteschi* (pantesco gardens) are currently under study by Italy’s National Council of Research as an adaptation to dry climate. Rounded dry-stone structures, up to 4 m tall with walls about 1 m thick, are used to shelter fruit (usually citrus) trees that could not otherwise be grown due to their vulnerability to high winds and high water requirements (Fig. 13.5). The shade, wind protection, and condenzation of dew on the surface of the lava stones used to construct these shelters, create a microclimate that allows the trees to grow and bear fruit even without supplemental irrigation. Local farmers here have also traditionally cultivated drought-tolerant, wind-resistant species using techniques to maximize soil water retention and reduce surface runoff by improving soil drainage. Specific tree management practices—for example, the pruning of olive trees to create collapsed canopies with their branches resting on the ground—are also used to maximize the protection from wind and sea air afforded by dry-stone walls.

On the volcanic island of Lanzarote (in the Canary Islands), high winds present a major challenge for management of tree crops on young soils. Farmers there have developed ingenious methods for cultivating citrus and fig trees, as well as grapes, under these difficult conditions. These include creation of depressions in which these crops are planted, and construction dry-stone walls on their windward edges to provide additional protection from strong winds. These traditional techniques both reduce wind exposure and take advantage of the heat storage capacity of these soils to create a microclimate highly favourable for the growth of planted trees. These farmers have created a unique landscape based on traditional knowledge, with clear social and economic benefits. Wine-making is an important industry on the island, challenging a common opinion that traditional knowledge and practices are not compatible with current agricultural production standards (Fig. 13.6).

13.4.6 Coppice Woods Management

Of the traditional forest management techniques that are relevant to climate change mitigation and adaptation, one of the more useful is coppice management. This short-rotation system is particularly suited to CO_2 sequestration because of its focus on repeated harvesting of wood on rotations of 5–25 years. Coppice systems typically provide higher, and more frequent, yields of fuelwood compared to high forest stands (Agnoletti 2005), and allow grazing within stands when pollarding methods are used. Coppice woods have been documented in Europe during the Roman period (750 BC–450 AD) or even earlier (as discussed in Sect. 6.3), and have been widely distributed in the Mediterranean landscape for the past 150 years (Agnoletti 2005, 2010a). They are usually low woods, managed with variable cutting regimes, found on mountains, hills, and along the coast. The spread of coppice management practices is due to their great capacity for integration with agricultural activities, and their high yield of fuelwood (one of their main products), which was usually converted into charcoal on the spot.

A broad array of coniferous and broadleaved tree and shrub species have traditionally been managed in coppice systems in Europe as well as in many other parts of the world (Ciancio and Nocentini 2004). These highly developed traditional systems involve a variety of management practices depending on the species used, local soil and climatic conditions, the products desired, and the integration of coppice management with other production activities (such as grazing or crop production).

Among the many existing traditional forms of coppice management in Europe is one applied to scrub woods (such as heathland and maquis formations), which were once managed throughout the Italian peninsula to Sicily. Heaths are evergreen species that thrive on dry, acidic, and siliceous soils that are highly inflammable (pyrophytic), and whose reproduction by seed and vegetative regrowth are favoured by fire. These species are often found on very degraded and arid soils, and can rapidly

Fig. 13.6 Horticultural applications of traditional dry-stone structures under extreme environmental conditions in Lanzarote, Canary Islands (Photos: Mauro Agnoletti)

colonize areas otherwise unsuitable for tall vegetation, including bare hill slopes that are protected from landslides and erosion by heath growth .

Traditionally managed scrub woods, typically associated with grazing and agriculture, involve the heath species *Erica scoparia* and *E. arborea,* which occur in many scrublands along with a variety of other shrub species and in the understory of oak (e.g., cork oak—*Quercus suber*, holm oak—*Q. ilex*) and pine forests. Both above- and below-ground parts of these species are used for a variety of purposes. Traditional managed *Erica* coppice systems in Italy yield vineyard poles at cutting intervals of about 8–10 years; foliage for silkworm raising and hut roofs; firewood for bread ovens, brick furnaces, charcoal, and other purposes; branches used for brooms; and high-quality wood from roots for carving pipe bowls. The extent of heath formations has been greatly reduced during the past century because of their declining utility to farmers, abandonment of the practice of land burning, the shrinking of pasture areas, and reforestation of scrublands to 'improve' them (since they were regarded as a degradation of high forest stands, and formal forestry regards *Erica* and associated shrub species as weeds because they compete with trees). Heath management was never dealt with systematically in official silviculture texts, and the traditional knowledge regarding their management is unfortunately being progressively lost with the decline of traditional rural livelihoods (La Mantia et al. 2006, 2007)

13.5 Traditional Forest-Related Knowledge in International Climate Change Assessments, Policy Forums and Programmes

13.5.1 Traditional Knowledge and Scientific Assessments of Climate Change

The forest-related knowledge, experience, and practices of local and indigenous communities have a critical role to play in the assessment of climate change trends and impacts, as well as in the development of viable and effective strategies for climate change mitigation and adaptation (Salick and Byg 2007). Although the translation of traditional forest-related knowledge into the language of formal forest science can be a helpful step towards adapting and applying traditional forest-related knowledge, often such translation fails to include the full depth of traditional knowledge. Collaborative efforts are often need to apply both traditional knowledge and formal science to new or changing environmental, social and economic contexts. Traditional forest-related knowledge may find important applications in forest rehabilitation, restoration, and adaptive management in the face of climate change (Berkes et al. 2000; Parrotta and Agnoletti 2007).

Understanding traditional knowledge and associated forest landscape management practices may also further the development of policies that help to close the existing gap between global environmental paradigms and related strategies with the local level, where they often fail. The need to incorporate these views in sustainable forest management has also been recognized by important political bodies, such as the Ministerial Conference on the Protection on Forest in Europe, through specific resolutions and scientific guidelines for implementing them (IUFRO 2007). The Arctic Climate Impact Assessment (ACIA),[1] which includes assessments of climate change and its impacts on boreal forests, is held in high regard by both the scientific community and indigenous peoples and is a good model for integration of traditional and scientific knowledge in climate change assessments.

Of particular relevance to climate change policy and mitigation and adaptation programmes is the work of the Intergovernmental Panel on Climate Change (IPPC), established by the United Nations Environmental Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to assess the scientific, technical, and socioeconomic information relevant for the understanding of human induced climate change, and its potential impacts and options for mitigation and adaptation. The importance of traditional knowledge has been recognized in the work of the IPPC (specifically within Working Group II, which deals with climate change impacts, adaptation, and vulnerabilities). The IPCC recognizes that traditional and local knowledge has been an important missing element in its previous assessments, and intends to remedy this gap to focus on the knowledge and experience of local and indigenous communities in its 5th Assessment Report (scheduled for completion in 2013–2014), which will place greater emphasis on assessing the socioeconomic aspects of climate change and implications for sustainable development, risk management, and the framing of a response through both adaptation and mitigation.[2]

13.5.2 Traditional Knowledge in Global Climate Change Mitigation and Adaptation Policy

Governments, international organizations, and the private sector have undertaken or are developing a number of measures aimed at reducing emissions of greenhouse gases arising from fossil fuel use. These include: increased production and use of (theoretically less polluting) biomass-based energy sources; mitigating schemes aimed at offsetting fossil fuel-related emissions by increasing CO_2 capture and storage (sequestration) in forest biomass and soils; and development of mechanisms for reducing emissions from terrestrial sources (i.e., agricultural and forest lands). Although mitigation measures are needed to minimize future impacts on forest and agricultural landscapes, and the people who most directly depend on them for their livelihoods, these mitigation approaches have implications (both opportunities and

[1]The ACIA is a project of the Arctic Council and the International Arctic Science Committee: http://www.acia.uaf.edu/

[2]http://www.ipcc.ch/activities/activities.shtml

threats) for the holders and users of traditional forest-related knowledge, i.e., the local and indigenous communities who are at the receiving end of the impacts of problems that were not their creation.

As discussed earlier, these communities, and the knowledge possessed by their elders, could make significant contributions towards the development of policies as well as the design and implementation of sustainable climate change mitigation measures that involve carbon sequestration, forest conservation, renewable energy production, low-energy agricultural systems and agroforestry systems, and rehabilitation of degraded agricultural and forested landscapes. Traditional lifestyles and livelihoods present approaches and specific practices and technological innovations that serve as examples for development of more widely applicable models for reducing dependency on fossil fuels (and other environmentally damaging energy sources such as uranium). These include, among others, production practices involving low (or no) consumption of fossil fuels, efficient and sustainable utilization of forest resources (biomass for energy and animal fodder), agricultural practices that conserve water and soils (including maintenance or enhancement of soil carbon storage), and local technological innovations for energy production and conservation from solar energy, biomass, and small-scale hydro-power (Galloway-McLean 2010).

Philips and Titilola (1995) note that it is widely recognized that the key to sustainable social and economic development is knowledge, not financial capital. Building on proven traditional knowledge and land management practices, the local institutions in which they have developed and evolved can thus facilitate the design and implementation of climate change mitigation and adaptation strategies that serve the broader social and economic development needs of communities who must contend with the impacts of climate change (Nyong et al. 2007).

Unfortunately, in the climate change policy arena, the rights, interests, and knowledge of local and indigenous communities are, on the whole, greatly undervalued (Macchi et al. 2008). As discussed in Chap. 1 of this book, traditional societies face an uphill struggle to make their voices heard within the countries in which they live, particularly in the international environmental policy forums including the climate change arena. Despite their knowledge, experience, and wisdom, such communities (with a few exceptions) are typically at a distinct economic and political disadvantage in influencing sectoral policies, strategies, laws, programmes, institutional arrangements, and investments related to climate change mitigation and adaptation and questions related to forests and land use (Garcia-Alix 2008; Gerrard 2008; Nilsson 2008).

13.5.3 Global Forest-Related Climate Change Mitigation Strategies: Carbon Markets and REDD

Carbon emissions trading, a system designed to offset carbon emissions from one activity (such as burning fossil fuels to generate electricity) with another more efficient or less polluting activity remains a much-debated topic in the international community. It is also a contentious issue among organizations representing the rights and interests of indigenous peoples in forest and climate change policy arenas.

Market-based systems for climate change mitigation measures such as carbon trading and agro-fuels (or biofuels) production have generated considerable mistrust among traditional forest communities given the number of cases in which the implementation of projects has violated the rights of indigenous communities (Bailey 2007; CBD 2007; UNPFII 2007; Collings 2009). For example, certain Clean Development Mechanism[3] projects initiated over the past decade have created serious conflicts involving communities who refused to give up territories on which such projects were planned. One example can be seen with the Benet people, an indigenous community living on Mt. Elgon in Uganda, who have struggled to regain their rights to live in their ancestral forest lands following implementation of a tree-planting carbon offset project initiated in the early 1990s (UNPFII 2007). Other communities have been seriously affected by the construction of hydro-power facilities that flooded their lands (as in Burma and Thailand), geothermal plants displacing sacred sites (in the Philippines), and nuclear power plants that have jeopardized human health in Native American communities in the United States (Galloway-McLean 2010).

Other local and indigenous communities in various parts of the world, however, have seen or are anticipating benefits from carbon trading projects (Galloway-McLean 2010; Collings 2009). An example of traditional knowledge holders' collaboration with the private sector is the West Arnhem Land Fire Abatement Project in Australia.[4] In this climate change mitigation programme, Aboriginal communities are receiving significant funds from a private energy firm (Darwin Liquefied Natural Gas) for carrying out their traditional fire management practices, which have been shown to reduce greenhouse gas emissions as compared to naturally recurring wildfires. Also in Australia, the oil company ConocoPhillips agreed in 2007 to pay a group of indigenous communities (practicing traditional fire management) in northern Australia AUD $1million per year for a 17-year period to offset their refinery's greenhouse gas emissions (Collings 2009).

In many countries, local and indigenous communities are preparing for engagement in carbon trading markets in hopes of benefiting financially from their traditional forest management practices that help to maintain forest carbon stores. This often involves collaboration and assistance from NGOs and international research organizations, such as the World Agroforestry Center (ICRAF) through its RUPES programme.[5] In the Philippines, for example, the Ikalahan community, which manages their traditional forest areas for both conservation and various utilization

[3]The Clean Development Mechanism is one of three mechanisms (the others being Emissions Trading and Joint Implementation, created under the Kyoto Protocol; the Protocol was established under the United Nations Framework Convention on Climate Change (UNFCC) in 1997 and entered into force in 2005 http://unfccc.int/kyoto_protocol/items/2830.php).

[4]http://www.savanna.org.au/al/fire_abatement.html

[5]RUPES: Rewards for, Use of and shared investment in Pro-poor Environmental Services http://rupes.worldagroforestry.org/overview

purposes, have received support and technical assistance from ICRAF to prepare for possible Clean Development Mechanism funding, and have reportedly engaged with Mitsubishi UFJ Securities for this purpose.

REDD (Reduced Emissions from Deforestation and Forest Degradation) is among the more controversial approaches for climate change mitigation involving forests and forest-dependent communities. REDD is a strategy that seeks to address the perceived shortcomings of the Kyoto Protocol, in which mitigation policies related to deforestation and forest degradation were excluded due to the complexity of measurements and monitoring for such diverse ecosystems and land use changes. REDD expands the scope of carbon offset activities for which carbon credits could be earned to include forests. It is an evolving approach that aims to use market and financial incentives to reduce emissions of greenhouse gases from deforestation and forest degradation—estimated to contribute between 15% and 25% of total CO_2 emissions worldwide (Kindermann et al. 2008; Van der Werf et al. 2009)—while also delivering 'co-benefits' such as biodiversity conservation and poverty alleviation.

In 2005, at the 11th Conference of the Parties (COP-11), the Coalition of Rainforest Nations[6] proposed inclusion of greenhouse gas emissions from deforestation in climate negotiations. Discussions on this evolved to REDD+, which was included in the 'Bali Action Plan' that emerged from the UNFCCC COP-13 meeting in 2007. REDD+ includes "policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries" (UNFCCC Decision 1/CP.13, Bali Action Plan).

A deadline for agreement on the specifics of an international REDD mechanism was set for 15th Conference of the Parties to the UNFCCC (COP-15), held in Copenhagen in December 2009. The Copenhagen Accord of 18 December 2009 included recognition of the crucial role of REDD and REDD+ and the need to provide positive incentives for such actions by enabling the mobilization of financial resources from developed countries. While REDD and REDD+ mechanisms are still under discussion, it is likely that future climate agreements will allow for offsetting carbon emissions through 'savings' from avoided deforestation.

REDD activities are undertaken by national or local governments, large NGOs, the private sector, or a combination of these. The World Bank, other International Financial Institutions and the UN support REDD by setting up the bases for the carbon market and the legal and governance frameworks of countries receiving REDD support. A number of governments of industrialized countries,[7] NGOs

[6] http://www.rainforestcoalition.org/

[7] At the 2007 UNFCCC Conference in Bali in 2007, for example, the Norwegian government announced their International Climate and Forests Initiative, which provided $500 million towards the creation and implementation of national-based, REDD activities in Tanzania. Since then a number of other industrialized countries' governments including Australia, Denmark and Spain have followed with major financial commitments to UN-REDD and other international as well as national REDD/REDD+programmes.

(particularly some larger conservation organizations), development agencies, research institutes and international organizations provide support to countries that wish to engage in REDD activities. These include the World Bank's Forest Carbon Partnership Facility, the UN-REDD Programme, and Norway's International Climate and Forest Initiative.

The World Bank presently plays a leading role in the facilitation of REDD activities. As one of the financial contributors for the REDD programme, the World Bank has created a $300 million fund, the Forest Carbon Partnership Facility (FCPF), for initiation of REDD activities in developing countries. The UN-REDD Programme[8] was established in 2008 by UNDP, UNEP, and FAO to help developing countries address measures needed to effectively participate in the REDD mechanism, including development, governance, engagement of indigenous peoples, and technical support. The Programme also supports global activities on measuring, verifying, and reporting systems, engagement of indigenous peoples and other forest-dependent communities, and governance. In 2010, eight countries—Bolivia, Democratic Republic of Congo, Zambia, Cambodia, Papua New Guinea, Paraguay, the Philippines, and the Solomon Islands—received funding totaling US$51 million from the Programme for development of full or initial national programmes for REDD+ readiness and implementation (UN-REDD 2011).

The success of REDD activities will largely depend on the effective engagement of people in local and indigenous communities whose livelihoods are derived from forests. In the climate change policy arena, many groups are actively promoting 'safeguards' and other means to ensure this. The Accra Caucus on Forests and Climate Change, for example, works to place the rights of indigenous and forest communities at the centre of REDD negotiations and to ensure that efforts to reduce deforestation promote good governance and are not a substitute for emission reductions in industrialized countries.[9] Many grassroots organizations are working to develop REDD activities with communities that include benefit-sharing mechanisms to help ensure that REDD funds reach rural communities as well as governments.

Critics of REDD, such as the International Indigenous Peoples Forum on Climate Change (IIPFCC), argue that REDD mechanisms could facilitate logging operations in primary forests, increase violations of indigenous peoples' rights, displace local populations in the interest of 'conservation,' threaten indigenous agricultural practices, destroy biodiversity and cultural diversity, cause social conflicts, and increase expansion of tree plantations at the expense of native forests. Deficiencies in current major REDD programmes cited by critics include: weak consultation processes with local communities, the lack of criteria to determine when a country is ready to implement REDD projects, the potential negative impacts on forest ecosystems and their biodiversity due to insufficient planning; the lack of safeguards to protect indigenous peoples' rights, and the lack of regional policies to stop

[8]http://www.un-redd.org/

[9]The Accra Caucus is a network of NGOs representing approximately 100 civil society and indigenous peoples' organizations from 38 countries. It was formed at the UNFCCC meeting in Accra, Ghana, in 2008 (http://www.rainforestfoundationuk.org/Accra_Caucus).

deforestation; and current operational definitions of ‘forests’ that do not distinguish between natural forests and plantations, which could result in expansion of plantation forests at the expense of natural forest ecosystems and the communities who depend upon them (Butler 2009). The World Bank’s declared commitment to fight against climate change, and its role in promoting REDD, is also viewed with caution by many civil society organizations and grassroots movements who consider the processes being developed under the FCP to be problematic (Dooley et al. 2011).

A number of technical, scientific, economic, political, and social questions likely to affect the success or failure of REDD/REDD+ programmes and activities remain unresolved. Optimizing carbon sequestration and environmental and socioeconomic ‘co-benefits’ such as biodiversity conservation envisioned under REDD+ schemes will be a challenge given the current state of knowledge regarding the relationships between forest carbon storage, biodiversity and ecosystem services, and how these relationships are affected by forest management activities, including forest restoration (White et al. 2010; Nasi et al. 2011; Sasaki et al. 2011). These topics are receiving increasing attention within the scientific community, as well in policy forums including the Convention on Biological Diversity (SCBD 2006, 2009).

For local and indigenous communities who manage forested landscapes using practices based on their traditional knowledge, these uncertainties revolve around several key issues (Peskett et al. 2008):

- Accountability, particularly under conditions of poor governance, and the fair and equitable distribution of REDD benefits to forest communities that minimizes capture of these benefits by national governments or local elites;
- Full and effective participation of indigenous peoples and forest-dependent communities in the design, implementation, and monitoring of REDD activities, and respect for their human rights;
- Prevention of ‘carbon leakage,’ caused by the displacement of deforestation to other areas;
- Achieving and balancing multiple benefits (conservation of biodiversity, ecosystem services, and social benefits, e.g., income and improved forest governance);
- Concern that by putting a monetary value on forests, the spiritual value they hold for indigenous peoples and local communities will be neglected; and
- The need in many countries for prior reform in forest governance and more secure tenure systems, without which fair distribution of REDD benefits will not be achieved.

Pirard and Treyer (2010) argue that in order for REDD+ mechanisms to be effective, supportive agricultural policies will be required. These policies should (1) foster changes in agricultural technologies that may contribute to forest conservation objectives; (2) harmonize sectoral public policies that have a direct or indirect impact on forest cover (e.g., agriculture, transportation, etc.); and (3) adopt the principle of payments for environmental services (PES) to promote measures that condition support for the adoption of sound agricultural technologies on the absence of excessive forest clearing on nearby lands.

Proponents of UN-REDD and other REDD schemes are optimistic that such arrangements could present huge financial opportunities for both biodiversity conservation and for local and indigenous forest communities who could be paid to preserve these forests as carbon sinks. Supporters suggest that the funding promised through REDD programmes to governments and communities will help to overcome the obstacles that have severely hampered efforts to reduce forest loss and degradation over the past century.

Others are more sceptical, pointing out that the underlying causes of tropical deforestation and degradation are complex and multi-faceted, related to a number of political, social, economic, and environmental problems—such as poverty; population growth and increasing scarcity of land and other natural resources; human rights; governance issues; national policies in finance, energy, transportation, agricultural, and other non-forest sector; and the like. Large infusions of money into these contexts is unlikely to produce intended forest conservation results without creating social conflict and other unintended negative outcomes until these pre-existing, often recalcitrant, issues are resolved. Critics further suggest that REDD schemes could also directly threaten these same communities if currently intractable issues related to land rights are not properly addressed to recognize their collective and individual rights and customary laws regarding these forests and the livelihoods they support (UNPFII 2007; Gerrard 2008; Collings 2009; Lyster 2010). Unless these and other governance issues are resolved satisfactorily, these communities may not receive adequate (or any) financial benefits, and could face limitations on their traditional uses of forests (or eviction), which would have serious consequences for their livelihoods, cultures, and the future of their traditional forest-related knowledge.

An analysis of past research on tropical deforestation by Kanninen et al. (2007) suggests that the design and implementation of effective REDD policies will be highly problematic, given the complexity of social, economic, environmental, and political dimensions of deforestation and forest degradation. This study reiterates the findings of many others over the past 20 years that underlying causes of deforestation are generated outside the forestry sector, that alternative land uses tend to be more profitable than conserving forests, and that institutions (local, national, and global) for harmonizing the interests and actions of diverse economic actors with the public interest are generally weak.

The uneven playing field on which local and indigenous communities engage with local elites, national governments, investors, and international organizations, discussed above and in Chap. 12 of this book (Sect. 12.3.4), suggests that there is reason for concern that REDD programmes, and carbon markets generally, may not produce positive outcomes from the point of view of traditional communities or their forests, and could exacerbate ongoing conflicts between local forest communities and the state.

13.5.4 Global Forest-Related Climate Change Mitigation Strategies: Biofuels

Biofuels, which include a wide range of fuels derived from biomass, are gaining increased importance and attention from the public, policy-makers, and the scientific community as an alternative to fossil fuels and their potential to help mitigate climate change. Although traditional biomass resources (fuelwood, charcoal, and agricultural residues) are the primary source of domestic energy for cooking and heating used by an estimated 500 million households worldwide (Bringezu et al. 2009), the demand for energy derived directly or indirectly (i.e., liquid biofuels) from biomass is rising steeply. Transport biofuels include ethanol produced from maize and sugar cane, and biodiesel from rapeseed, palm oil, and soya, which collectively accounted for 1.8% of the world's transport fuel in 2008. The world's largest producers at present are the United States, Brazil, and the European Union, although biodiesel production is expanding rapidly in Southeast Asia (principally in Malaysia, Indonesia, China, and Singapore); Latin America (Argentina and Brazil); and in southeast Europe (in Romania and Serbia). Global investment (both private and public) into biofuel production capacity is increasing, and exceeded US$4 billion in 2007 (Bringezu et al. 2009).

Biofuel production and use raise a variety of technical, environmental, economic, and social issues that have been the subject of considerable study and debate within the scientific community, international policy forms, and the media. Many of these issues have, or could have, important implications for forest-dependent indigenous and local communities. These include effects on: global fossil fuel prices; energy balances and efficiencies; greenhouse gas emissions (and thus climate change); land use change and its implications for food security, agricultural productivity, forest loss, and biodiversity; poverty reduction potential; the sustainability of biofuel production systems; and water resources (Laurance 2007, Persson and Azar 2010). A global assessment of these issues associated with biomass energy is provided by Bringezu et al. (2009). This study covers trends and drivers of biofuels production, life-cycle-wide environmental impacts, impacts associated with increased demand for biofuels and land use change, options for more efficient and sustainable production and use of biomass, strategies and measures to enhance resource productivity, and research and development needs.

The production of biofuels requires energy for growing biomass crops, including agricultural inputs (fertilizers and biocides) required for their production, as well as for transport and conversion into usable fuel products—all of which have environmental consequences, including production of greenhouse gases. The energy balance of biofuels—i.e., the ratio of the energy released from the fuel when it is burned to the energy required for its production—is highly variable, depending in part on the feedstock used, the final product, and the energy inputs involved in the processes of production, transportation, and conversion. According to a study by Pimentel and Patzek (2005), energy outputs from ethanol produced by using corn, switchgrass, and wood biomass were each less than the respective fossil energy inputs. Similar results were obtained for biodiesel using soybeans and sunflower, although the energy cost for producing soybean biodiesel was only slightly negative compared with ethanol production.

The scientific literature on 'life cycle analyses' that calculate production of CO_2 and other greenhouse gas costs through the full cycle of biofuel production from planting to final use of the fuel have yielded highly variable results, depending on the feedstock (crop used), conversion technologies, and other factors. Such studies suggest that under the right circumstances, substitution of fossil fuels by biofuels can result in net savings of greenhouse gas emissions (Bringezu et al. 2009). However, such studies do not take into consideration increases in greenhouse gas emissions that may result from indirect land use changes (as in cases of conversion of forests). Consideration of the broader land use dynamics in the context of biofuel production is therefore very important for the assessment of the climate change mitigation potential of biofuels. Life cycle assessments that have taken this broader landscape view provide support for the assertion that biofuel production under many, perhaps most, circumstances, will result in net increases in greenhouse gas emissions and thus exacerbate global climate change (Bringezu et al. 2009; Searchinger et al. 2009).

More immediate concerns for local and indigenous communities living in forested regions where large-scale production of biofuel crops are either underway or planned are that land and livelihood security will decrease and poverty worsen. Depending on location, large-scale expansion of biofuel feedstock production can involve major diversion of land and water resources that are currently used for production of food crops or for animal husbandry; conversion (i.e., clearing) of non-agricultural land (forests and woodlands, for example); and/or the displacement of farmers (practicing permanent or shifting cultivation) or pastoralists from their traditionally used lands (Degawan 2008). While these issues are important to traditional communities in many parts of the world, they are of particular concern to rural communities in Africa, where food security is a paramount interest (Molony and Smith 2010). In Brazil, rapid expansion of soybean production (used increasingly for biodiesel) is expected to focus on conversion of pasture land and savannah (cerrado) ecosystems. In Southeast Asia, palm oil plantation expansion (for both food and biofuel purposes) is a leading cause deforestation. In Indonesia, for example, where approximately 30% of total palm oil is produced by smallholders, two-thirds of current production expansion is based on conversion of rainforests,[10] the remainder being produced on previously cultivated or fallow lands. Palm oil production in Indonesia, which currently uses approximately six million ha of land, is planned to increase to 20 million ha in the not-distant future (Bringezu et al. 2009). This growing industry supports as many as 4.5 million households, most drawn

[10] Approximately 25% of this converted forest land is on peat soils, which when drained for oil palm production result in particularly high greenhouse gas emissions. By 2030, oil palm plantations on peat soils are expected to constitute 50% of the total, by which time the total rainforest area of Indonesia is expected to be reduced by 29% (compared to 2005) or 49% of the county's rainforest area in 1990 (Bringezu et al. 2009).

from local and indigenous communities who lost their lands to expansion of palm oil plantations (Bailey 2007).

According to a study undertaken by the Overseas Development Institute [UK], biofuels could help relieve poverty in some developing countries through increased employment, economic growth multipliers, and lower prices for imported fossil fuels used for transportation, agriculture, and domestic needs (Leturque 2009). However, this study also points out that the impacts with respect to poverty reduction may be quite different in situations where biofuel feedstock production is undertaken on a large scale; or creates pressure on limited agricultural resources such as capital, land, and water, or ultimately increases the price of food. The authors note that production of biofuels is subject to the same policy, regulatory, or investment shortcomings that influence the potential of agriculture to improve rural incomes. Since these limitations require *national* policy solutions, a country-by-country analysis of the potential poverty impacts of biofuels is more appropriate than global analyses.

As discussed earlier in the context of REDD programmes, large-scale biofuel production has a high potential to threaten the livelihoods of local and indigenous communities if issues related to land rights are not properly addressed to recognize their collective and individual rights and customary laws regarding agricultural lands, forests, and water resources (Tauli-Corpuz and Tamang 2007; Degawan 2008). As noted above, these problems are already arising in countries where rising demand for palm oil (and other biofuel crops) has resulted in large-scale plantation establishment on sites recently occupied by forests, as discussed also in Sect. 12.3.4. In Indonesia, for example, an estimated 38,000 km^2 have been converted to palm oil plantations since 1996 (Bailey 2007). Worldwide, several millions of indigenous people have been affected by the deforestation of their lands to make way for biofuel plantations (Bailey 2007).

Rising concerns about the negative environmental and social side effects of biofuels' production have prompted some governments and international organizations to promote the development of criteria for sustainable bioenergy production. However, as pointed out by Bringezu et al. (2009) and many others, these standards and certification schemes rely on life-cycle analysis methods that often fail to take into account impacts (specifically greenhouse gas emissions) along the full biofuel production chain, including landscape-level impacts related to land-use changes (Dale et al. 2010). A recent review by van Dam et al. (2010) evaluated 67 ongoing certification initiatives to safeguard the sustainability of bioenergy, most focusing on sustainability of liquid biofuels. Their analysis confirmed concerns that while environmental impacts are generally considered in standards developed by these initiatives, indirect land-use change and socio-economic impacts of bioenergy production generally are not. An exception to this is an initiative in Brazil known as the 'social fuel label,' which aims to protect small-scale farmers in areas of large-scale biofuel production. They suggest that certification schemes have the potential to influence direct, local impacts related to environmental and social effects of direct bioenergy production provided that unwanted land-use changes and governance issues are properly addressed.

13.6 Conclusions and Recommendations

Traditional forest-related knowledge, innovations, practices, and associated social institutions have supported the livelihoods and cultures of local and indigenous communities for generations. Such communities have often been very successful in adapting to environmental change. Their traditional knowledge—an important component of their cultural capital—represents an important community asset that can enhance the adaptive capacity of indigenous and local communities and reduce their vulnerability to climate change (Salick and Byg 2007; Osman-Elasha et al. 2009).

Although traditional forest-related knowledge represents an important element of adaptive capacity for local and indigenous communities to cope with climate change, it is important to recognize their limitations for adaptation to changing environmental conditions (Eastaugh 2008; FAO 2005, 2009; Collings 2009). While traditional knowledge, practices, and associated social institutions have historically been dynamic, their capacity to adapt quickly enough to the more dramatic climate-change impacts on forests envisaged for some regions cannot be assumed (Adger 1999; Adger et al. 2003, Macchi et al. 2008). This may be particularly problematic in cases where these impacts exceed the limits of applicability of this knowledge, as for example in traditional hunting and fishing communities when climate change impacts create major changes in wildlife ranges and habitat structure. Exacerbating this is the fact that traditional knowledge is already disappearing from local and indigenous communities in many parts of the world for a number of reasons (c.f., Newing et al. 2005; Galloway-McLean 2010), as discussed in earlier chapters of this volume. Because such knowledge is rarely codified and often restricted to a few members (usually the elders) of local, particularly indigenous, communities, its vulnerability to inter-generational loss is increased.

For traditional societies that have maintained their systems of reciprocity (sharing knowledge among communities), coping with change may be easier and may not create conflict within and among communities. As Nuttall (2008) pointed out with reference to indigenous peoples, the adaptive capacity and resilience of communities in the face of significant environmental change depends on several factors: the strength of relationships between people and the environment; community cohesiveness and cultural identity; strong social relations; and the existence of enabling policies and governance that support traditional livelihood practices, food security, and other economic, social and cultural needs.

Opportunities exist to preserve and/or revitalize traditional forest-related knowledge and to develop appropriate strategies for adaptation of forest resource management to climate change that combine traditional and scientific forest-related knowledge (Kruger 2005). Traditional knowledge can complement formal science in various ways, for example in monitoring the effects of climate change (Vlassova 2002). The scientific community has an important role to play in this through collaborative and participatory research with the holders and users of traditional forest-related knowledge to build on existing knowledge (both traditional and formal scientific) to better understand and deal with uncertainties that climate change presents. Such research collaboration could encompass a wide range of topics and objectives. Examples include: monitoring and modelling of climate change impacts on forest ecosystem structure and processes; development of improved practices for increasing resilience in managed forest ecosystems; and addressing threats to productivity in traditional agricultural systems such as shifting cultivation and agroforestry affected by climate change (e.g., shifting rainfall and temperature patterns, inadequate surface and groundwater resources, and salt water intrusion in coastal groundwater supplies due to rising sea levels).

Studies carried out in a manner consistent with ethical principles using research methodologies appropriate for the study of traditional forest-related knowledge (discussed in Chap. 14) can help elucidate underlying ecological principles that could enable wider application and further development of traditional knowledge and practices. Knowledge gained from such research could be translated into innovative forest and agricultural management practices to help a broader spectrum of rural communities adapt to the impacts of climate change (Roberts et al. 2009).

In recent years, indigenous communities have been among the first to react to the impacts of climate change and measures taken at the international level towards its mitigation. Traditional communities have raised the awareness of the global public and policy-makers by recording and publicizing their observations of changes in climate and its effects on the natural environments in which they live. They are also reacting to climate change mitigation approaches that involve significant changes in land use and forest management regimes affecting their livelihoods and cultures. By doing so they are helping to inform the ecological, socio-economic, legal, and human rights dimensions of climate change and policies being developed to combat and/or adapt to its impacts.

Policy makers and other decision makers should give greater attention to the experience and insights that have developed effective practices and related social institutions for coping with environmental change to ensure their food- and forest-based livelihood security (Nilsson 2008; Roberts et al. 2009). Rural communities are more likely to adopt mitigation and adaptation strategies based on principles derived from traditional knowledge that are cost-effective, participatory, and compatible with existing social and governance structures (Robinson and Herbert 2001; Hunn 1993). A study in Zimbabwe, for example, found a greater willingness of farmers to use seasonal weather forecasts based on scientific (meteorological) predictions when such information was presented and compared with local indigenous climate forecasts (Patt and Gwata 2002).

The importance of traditional forest-related knowledge to local and indigenous communities for climate change adaption needs to be recognized, even though TFRK has declined in most regions of the world. Supportive policies and actions should be implemented to facilitate its preservation and further development. (Roberts et al. 2009). Both this knowledge, and the rights, interests, and traditional practices and social institutions of those communities who are responsible for its development and preservation need to be respected in the development of policies and emerging global mechanisms for climate change mitigation and adaptation.

Recent experiences of local and, particularly, indigenous communities with global policy-making bodies, international financial institutions, and others involved in the creation and promotion of climate change mitigation mechanisms (such as carbon markets, Clean Development Mechanism projects, and biofuels development in particular) have been mixed but generally unfavourable to the interests of these local communities (Degawan 2008; Garcia-Alix 2008). It remains to be seen whether emerging mitigation mechanisms such as REDD+ will be an improvement from the point of view of traditional forest-dependent communities. Much will depend on the extent to which the playing field in national and international climate change and forest policy debates can be levelled. At present, the cultural capital of traditional societies is presently no match for the financial capital of the interests that dominate these policy debates worldwide (i.e., investors, international financial institutions, and large international conservation organizations, among others). Greater appreciation of alternative approaches to mitigating and adapting to climate change by policy makers, the scientific community, and the general public could change this equation, however, with potential benefits for all societies.

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