The Trend of Land Use and Land Cover Change and its Impacts on Biodiversity in the Himalayas

Xu Jianchu, PhD
Senior Scientist, Country Representative
World Agroforestry Centre (ICRAF), China Program
Tel: +86 10 62119430 (Beijing) +86 871 5223014 (Kunming)
Email: J.C.Xu@cgiar.org or: jxu@mail.kib.ac.cn
www.worldagroforestry.org

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The pace, magnitude and spatial reach of human alterations of the Himalayan region are unprecedented (Ives and Messerli 1989). Changes in land cover (biophysical attributes of the earth's surface) and land use (human purpose or intent applied to these attributes) are among the most important (Lambin et al., 2001). Land-use and land-cover changes directly impact biodiversity in mountain ecosystem (Körner 2004); contribute to local and regional climate change as well as feedback to global climate warming (Houghton et al. 1999); By altering ecosystem services, Himalayan environmental change affects the ability of biological systems to support 1.3 billion people in the ten river basins in the region (Xu et al 2007). Such changes also determine, in part, the vulnerability of places and people to climatic, economic or socio-political perturbations (Kasperson et al., 1995).

The theory of Himalayan environmental degradation, which involves a paper published in ‘Science’ in 1975, is enormously influential: a wake-up call concerning land use issues in the high mountains and a stimulus to research in the Himalayan region. Many studies focused in causes of land use and land cover changes. Among the most powerful contemporary forces that drive land use and land cover change are increasing human activities (anthropogenic drivers) and climate change (climatic driver). These forces are positive in some cases and not in others. Despite both magnitude of land use/cover change and advance in spatial technology by earth observing satellites, our understandings of land use trend and its impacts on biodiversity in the Himalayas are insufficient. Scientists recognize, however, the overall forest transition including plantation and forest recovery (Rudel et al., 2005, FAO 2007) and rangeland degradation (Wilkes 2008) in most Himalayan countries. Better data alone are insufficient for improved understandings and projections of future land use trend. They must be matched by enhanced understanding of the causes of change and interactions among different drivers, inter-linkage of land use systems along elevation gradients for environmental services, as well as feedback to coupled ecological-social systems. I try to synthesize major land use/cover trend along elevation gradients, i.e., highland rangeland, upland forest and agriculture, lowland plantation economy, and urbanization.

Land use/cover change in the Himalayas

Land use in the Himalayas is a function of altitudinal gradients, latitudinal variation, and the local political economy. Land cover of the Himalayas was first described in its longitude and its altitudinal variation by Schweinfurth (1957). In general a variation of species along the Himalayas arc can be observed as well as an extreme vertical zonation. From east to west vegetation becomes sparse with tropical rain forest in Assam to sub-tropical thorn-steppe in the Punjab. The forests of the humid regions in the eastern Himalayas are composed of broad-leaved species, in the central Himalayas of oak and coniferous, and in the western part mainly of coniferous species. Land use/cover varies from east to west and according to elevation. In the west of the Himalayas, in Balochistan, desert prevails followed by shrub land in the remaining of Pakistan. The middle mountains of the Himalayas are mainly under cropland. North of the main cropping areas in higher altitudes there are extensive pasture areas. In the east of the Himalayas large forest areas cover large parts of Yunnan province and the parts of Myanmar falling within the boundaries of Himalayas. In northeast India and parts of Myanmar shifting cultivation is largely being practiced. The land use in Tibetan Plateau varies from nomadic pasture to agropasture to sedentary agriculture. The prevailing farming systems are rice-wheat integrating irrigated rice, wheat, vegetables and livestock on the southern boundary of the Himalayas and inner valleys of the middle mountains, followed by highland mixed farming systems incorporating a range of cereals, legumes, tubers, fodder and livestock. Large areas of Afghanistan and Balochistan are pastoral and sparsely farmed. In the upper slopes of the Himalayan ranges above about 3000m farming depends on potatoes, wheat, barley and buckwheat, plus cattle and yak.

In the Himalayas over 80% of the population depends either on full or part time farming for their livelihoods. Most farmers are subsistence and mainly producing grain. This grain production has remained stable of the last 10 to 15 years according. However, with the population increase the per capita grain availability is decreasing. Climate change has deteriorated food production particularly during extreme climatic year.

Land use/cover in the key basins shows the differences between the rivers of the Western part of the Himalayas, the Eastern Himalaya and the Chinese rivers (Table 1). The Southeast Asian rivers have still high forest cover in their basins, while the South Asian rivers have high percentage of crop land, mainly irrigated land. All the basins however have lost large parts of their original forest cover. The industrial and urban areas are in all basins quite limited, however is expected to further increase in the coming future.

Table 1: Landuse/cover in the 8 key river basins (source: IUCN, IWMI, Rasmar Convention Bureau and WRI, 2004)

River	Forest	Grassland, savanna, shrubland	Wetlands	Cropland	Irrigated cropland	Dryland	Urban and industrial areas	Loss of original forest cover
Indus	0.4	46.4	4.2	30.0	24.1	63.1	4.6	90.1
Ganges	4.2	13.4	17.7	72.4	22.7	58.0	6.3	84.5
Brahmaputra	18.5	44.7	20.7	29.4	3.7	0.0	2.4	73.3
Irrawaddy	56.2	9.7	6.3	30.5	3.4	4.4	1.9	60.9
Salween	43.4	48.3	9.5	5.5	0.4	0.1	0.5	72.3
Mekong	41.5	17.2	8.7	37.8	2.9	0.8	2.1	69.2
Yangtse	6.3	28.2	3.0	47.6	7.1	2.0	3.0	84.9
Huang He	1.5	60.0	1.1	29.5	7.2	79.4	5.9	78.0
Tarim	0.0	35.3	16.3	2.3	0.6	38.6	0.3	69..3
Amu Darya	0.1	57.3	0.0	22.4	7.5	77.8	3.7	98.6

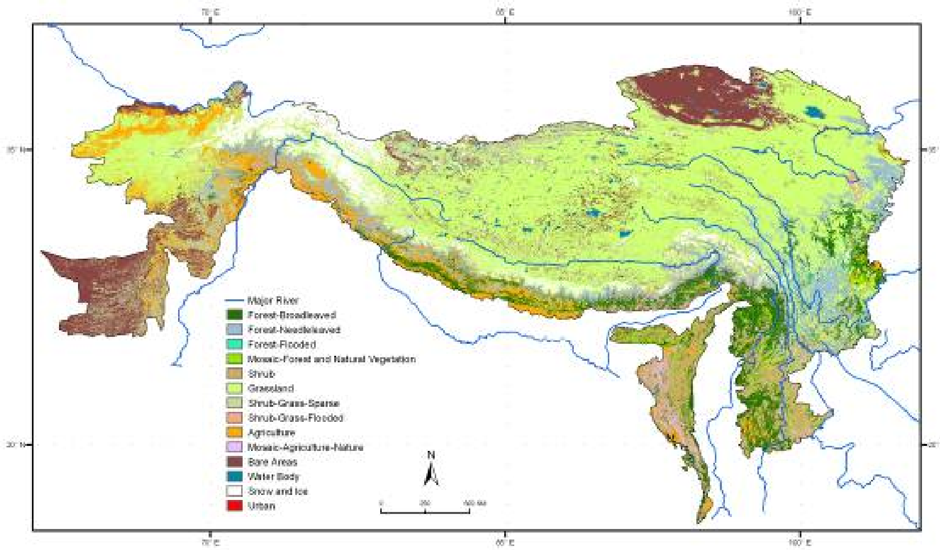

Figure 1: Land use and land cover map of ICIMOD defined working areas in the Himalayas

The Himalayan highlands show different land use picture, covering 22.6% forestland, 50.5% grassland, 9% agriculture, less than 0.1% for urban, 17.8% for others including bare areas, water, snow and ice (See Figure 1).

Rangeland degradation in the highland

<u>Significance</u>

Rangeland is predominant land use in the Himalayas, accounting for more than half in the Himalayas. Highland rangelands provide ecosystem goods and services locally and downstream. Driven by a combination of climate change impacts and unsustainable management practices, half of the highland's grasslands are estimated to be degraded or desertified. The Himalayan rangelands also provide the livelihood basis nearly for ten million pastoralists, many of whom live in poverty. Rangeland degradation – due either to unsustainable management practices or to the impacts of climate change – undermines the basis of pastoral economies. Meta-data analysis found that both climate change and anthropogenic factors contributes to degradation of grassland ecosystem.

<u>Drivers</u>

Observed and predicted climate change: Both observed and predicted temperature change shows that from 1955 to 1996 average annual temperatures on the Plateau rose by of 0.16 ?/decade, much higher than the rate of increase for the northern hemisphere as a whole. The rate of increase in winter minimum temperatures (0.32-0.33 ?/decade) has been particularly rapid. Trends in precipitation are more diverse across the highlands. On average, precipitation has increased by 3.4 mm/decade, mostly due to an increasing trend in winter precipitation in terms of snowfall.

Sedentarization and increasing livestock population: Sedentarisation attempts to settle migratory peoples permanently in terms of land use, property, and settlement. As a result of sedentarisation, many nomads have converted into a sedentary lifestyle in most parts of Himalayan region. There is a widespread belief that rangelands have relatively constant carrying capacities which are derived from their native agro-ecological potential and that stocking strategies exceeding these capacities cause degradation, especially in alpine and arid zones. Therefore increasing livestock population linking with overgrazing is often blamed for causes of degradation. The intrinsic variability of rangeland ecology, however, makes it difficult to distinguish directional change (e.g., loss of biodiversity and soil degradation) from readily reversible fluctuations; hence interpretations of ‘degradation’ and ‘desertification’ should be viewed with caution. Rangelands in alpine or arid zones are increasingly seen as non-equilibrium ecosystems. Modification in the biological productivity of these rangelands on the annual to decadal time scales is mainly governed by biophysical drivers, such as climate change, and human factors such as mismanagement.

Impacts

Impacts of climate change on grasslands: As temperatures change, the location of climate belts on the high altitude will change. Some studies report changes in plant community structure, and in areas of permafrost transition, total loss of vegetation and ecosystem functions has been observed. Warming over the last 20 years has benefited vegetation growth in arid steppe and desert areas, but the currently most productive grasslands are not among areas that are predicted to benefit from global warming. Grassland productivity is highly correlated with precipitation, and more productive vegetation types of the highlands are experiencing declining precipitation trends. Some field studies report diminution of average grass height and declining yield, due declining summer (growth season) rainfall and a shortened growth season.

*Anthropogenic influences on grasslands: S*cientists generally concur that overgrazing is pervasive across the highlands. High grazing intensities is correlated with declines in vegetation height, coverage and aboveground biomass, as well as soil organic matter and nutrient content. Some research has suggested that overgrazing has been driven and exacerbated by grassland management policy, as grassland contracting has restricted herd mobility. However the optimum grazing contributes to maintenance of both biodiversity and productivity of grassland ecosystems (Klein et al., 2004).

Forest transition in the upland

Significance

Forest has multiple functions, forest area harbors biodiversity, presents landscape beauty, anchors soil and water, sinks carbon, regulates climate and tempers stream flow, but also directly supplies forest products (timber firewood and paper, non-timber forest products) for local livelihoods and economy. Over one hundred million people in the Himalayas directly depend on forest for their livelihoods particularly for the poor. Equally important, forest area can be converted into agricultural land for grazing and food production. Farmers, herders as well as shifting cultivator nurture and manage biomass in totally different ways for centuries, if not millennia, across the Himalayas. The Himalayan region the source of ten large river systems has the greatest variations in climatic zones and forest ecosystems according to longitude, latitude and altitude.

Drivers

The ‘Theory of Himalayan Degradation’ assumed that poverty and overpopulation in the Himalayas was leading to deforestation and finally disappearance of highland forests in Nepal did not come to true. There is a pseudo-linkage between highland deforestation and lowland floods. Since the early 1980s, most nation states in the Himalayas seem to have embarked on a road to forest transition after dramatic forest lost in the history. Examples are joint forest management in India, forestry user groups for community forest management in Nepal, forest tenure reform in China (known as the ‘Forestry Three Fixes’ in 1981), forestry and biodiversity conservation in Bhutan. Tree plantations, natural regeneration, establishing and expansion of protected areas followed by secured access and tenure, community participation and social fencing occurred in the mid-hills of Himalayan region. With market incentive and reinforcement of forest tenure, farmers planted more trees and managed more forestlands than ever before. The largest historical floods in Yangtze River had further stimulated Chinese state to pay for environmental conservation through land use conservation, or “Grain for Green” program.

In the other hand, mountain people still depend largely on forest resources from fodder to firewood, from timber to non-timber forest resources for their livelihoods. It is estimated that 80% of the total population in Southwest use firewood for cooking, winter heating as well as curing tobacco, the annual demand for firewood is about one hundred million m^3.

The effects of climate change on mountain forest vegetation are upward or northward shifts in treeline. There is strong evidence that forest plant species, as many vertebrates and invertebrates species, have already followed the pace of climate change by shifting their distributions to higher altitude, a significant upward shift in tree line at a rate of 5-10 m per decade (Baker and Moseley2007), in species optimum elevation averaging 29 meter per decade (Lenoir et al., 2008) in alpine ecosystems.

Impacts

Scarcity in timber and secured tenure rights stimulate the local communities and private sector to plant more trees. As result, forest plantation significantly increased forest area from 96,000 kha in the late 1970s to 143,000kha in the early 2000s (Kauppi et al, 2006). Also benefit from free trade, China imports more timber products from other countries (Zhang, 2000). Energy technology and economic growth can also lead to substitution of forest resources. More and more rural households benefit from the development of biogas, small hydropower and solar energy, which directly reduces reliance on firewood from forest. In the decentralized forest management, government officials have shifted the ideological discourse to economic instruments for forest management and conservation, reflected both in the case of the “Sloped Land Conversion Program (SLCP)” and “Natural Forest Protection Program (NFPP)”. As a result, China has the largest planted forest in the world, a total of 71.3 million hectare in 2005 (FAO, 2007).

The Global Forest Resources Assessment 2005 (FRA2005) integrates those identifications into Forest Identity Index for comparing forest transition status in 50 nations (Kauppi et al, 2006). Net forest cover in Asia is increasing mainly due to large investments in forest plantation such as in China (FAO, 2007). However the growth in plantation does not negate the continued loss of natural forests and deterioration of environment.

The impact of a forest transition on biodiversity needs to be reexamined. Monoculture plantation has nothing contributing to biodiversity. Introduced fir (*Abies sp.*) plantation in northwest Yunnan is very vulnerable to insect attach (*Cosmotriche saxosimilis*). Since 1986 more than 20,000ha of Abies forest have been pest-affected in Shangrila County of Diqin Prefecture (Xu and Wilkes 2004). In many places endemic species have been replaced by invasive species in the disturbed habitats, so low levels of biodiversity will persist in the early state of transition.

The interactions of land, forest and water have long been discussed and debated. Land use/cover is intrinsically linked with the hydrological cycle, therefore a land use decision is often a water decision. The effects of forest expansion on stream flows and water quality appear to vary with the type and structure of vegetation as well as conditions of catchment. Ma et al. (2008) found that afforestation in the mountain watershed reduces surface water and stream flow, increase base-flow & evaporation during monsoon.

Agricultural intensification

Significance

Agricultural intensification - defined as higher levels of inputs and/or increased output (in quantity or value) of cultivated or reared products per unit area and time – exampled by Green Revolution during 1960s with doubling of the India’s food production from 1960 to 2000. Such achievements are viewed skeptically by observers contemplating the future of non-irrigated agriculture in the tropical world where intensification may be considered as environmentally untenable, owing to special biophysical constraints and socio-economic conditions that inhibit farmers (especially smallholders) access to input factors.

Drivers

Intensification is triggered by land scarcity in economies not yet fully integrated in the market, and is usually linked to growth in population and its density, whether caused by natural increase, migration, incursion of non-agricultural land uses or institutional factors (e.g. land tenure regime). Land scarcity changes land-labor ratios, driving up the intensity of cultivation and, where possible, shifting production toward the market and to higher value products such as fruits, flowers and vegetables. Markets trigger commercial intensification of agriculture in a commodification pathway. Investments in crops or livestock modify the factors and value of production per hectare. Technology innovations such as "Green Revolution" through the development of modern or high-yielding crop varieties has great contribution to agricultural intensification. In the mid-1960s, scientists developed modern varieties of rice and wheat that were extensively adopted by smallholder farmers in the region. Significant land-use intensification can also be also driven by intervention, usually in state-, donor-, or NGO-contrived projects intended to promote development in a region or economic sector, usually through commercial agriculture for national and international markets that increase income for the participants and the state.

Impacts

Rapidly developing land scarcity may trigger increase in cropping frequency unmatched by appropriate changes in inputs or management, resulting in a "stressed" system with stagnating or declining output and land degradation. This intensification pathway is vulnerable not only to markets, but to changes in ecosystem or government and development policies. As result of intensification, many traditional farming systems such as shifting cultivation have transformed into either mono-culture of modern varieties of food crops or cash crops. Much agrobiodiversity in agroecosystems have been lost forever.

The large-scale and high intensity of application of biocides and fertilizers had negative consequences on the health of mountain farmers who had neither proper knowledge nor access to health services. Food security does not always provide dietary diversity and balanced nutrition. The environmental consequences of input mismanagement and overuse include destruction of beneficial insects, water logging and salinization of irrigated land, pollution of groundwater and rivers, poisoning of farm workers, and excessive dependence on modern crop varieties. Research estimates show that almost half the nitrogen applied is not used by crops, but instead washes away into the forests, wetlands, lakes, and rivers. Over-fertilized trees grow faster than normal and the levels of nutrients in the foliage contain more nitrogen and less calcium and magnesium than normal trees; and about 10% of the added nitrogen is leaking out of the forest as nitrate in groundwater. In China, nitrate levels are already well above the WHO standard for public health risks, and these may well double over another half-century. Health problems are exacerbated by the impacts of biocide use when agricultural chemicals leak into irrigation canals and drinking water. Examples of diseases caused by expansion and changes in agricultural practices are associated with a range of food-borne illnesses globally (Xu et al, 2008).

Deforestation and plantation in tropics

Significance

Tropical forests at the foothills of the Himalayas are important habitats for rich biodiversity in the region. However satellite images indicated that deforestation occurred largely in the tropical areas of Southwest China, Myanmar, Northeast India and southern Nepal in past decades. The causes of tropical deforestation remain debatable. Broadly speaking, two major and divergent pathways of explanation have emerged: single factor causation vs. irreducible complexity. Shifting cultivation and population growth have been viewed as primary causes, while, on the other hand, correlates of deforestation and causative variables are stated to be many and varied, revealing no distinct pattern. The most visible transformation of the tropical landscape has come about through the creation of mono-culture plantation such as rubber, tea, tropical fruits and bananas. We thus recognize a need both for comparative analyses of the main processes of land cover change and for advanced methods to monitor and model land-cover changes at regional scales.

Drivers

Poverty- and capital-driven deforestation makes up two general pathways to tropical deforestation in the Himalayas. Poverty, in combination with other factors such as poor access to resources and institutions, low income and social deprivation, has been reported as an underlying social process of deforestation in many case studies in the region.

However poverty driven cases of deforestation are often simply associated, in various combinations, with shifting cultivation (traditional swidden farming as well as slash-and-burn agriculture), permanent smallholder subsistence farming, land reclamation and colonization in the forest frontiers.

Most poverty-driven cases are further underlain by aspects related to property rights: mainly, insecure ownership, quasi-open access, and low empowerment of local user groups (marginality, social deprivation). Similarly, market failures (in about half of the cases), but even more so market growth and commercialisation underly poverty-driven deforestation. All cases are underlain by public attitudes, values and beliefs - especially of unconcern towards the forest ecosystems.

Cases of capital-driven deforestation are related to cash flow for development in tropical frontiers through plantation economy. Commercial farming through large scale mono-culture plantation is considered as pathway to modernity and poverty alleviation in the region by state governments, in which the land use change can transform subsistence farming systems into modern society.

Impacts

Causes of tropical deforestation are often the interplay of several factors. Encroachment of subsistence smallholder farmers can be observed at patchy level in uplands and foothills. While the expansion of large-scale cash crop plantation clearly appears as the most pronounced proximate cause of tropical deforestation, shifting cultivators cannot be attributed to be key agents of deforestation. First, shifting cultivation is almost consistently caused by timber logging as an concomitant cause. Second, traditional swidden-fallow farming emerges as a regional feature of upland and foothill Himalayas, most of them poverty-driven and related to colonization due to poor in property rights and access to institutions.

Although forest-runoff link is still debatable, there is strong evidence that deforestation as well as monoculture plantation cause soil degradation and shift hydrological regime, no doubt further contribute to biodiversity loss.

Urbanization

Significance

Urbanization as land cover, in the form of built-up or paved-over areas, occupies only less than 0.1% of the Himalayan land surface. Urbanization affects land change elsewhere through the transformation of urban-rural linkages. However the economic booming in China and India, and remittance economy in Pakistan and Nepal has accelerated urbanization and rural-urban migration. More people have moved temporally and permanent from rural to urban which has great application to land use/cover change. Increasing urban inhabitants depend on mountain ecosystems services for freshwater and food supply as well as recreation. 52% of the China's population is urban in 2007, the rural-urban linkage or the urban "ecological footprint" is critical to land use trend assessments.

Drivers

Urbanization in the Himalayas is mainly driven by rapid economic growth in China and India as well as globalization through labor migration and remittance economy, such as Nepal.

Impacts on mountain biodiversity and ecosystem services

The not-so-simple pathways of urban impacts on rural land cover. At least two broad urbanization pathways lead to different impacts on rural landscapes. In the well-developed world, large-scale urban agglomerations and extended peri-urban settlements fragment the landscapes of such large areas that various ecosystem processes are threatened, including the migration and sustainability of biota. However, ecosystem fragmentation in periurban areas may be offset by urban-led demands for conservation and recreational land uses. In a different vein, economically and politically powerful urban consumers tend to be disconnected from the realities of biological rich habitats, resource production and largely inattentive to the impacts of their consumption on distant locales. Cities attract a significant proportion of the rural population by way of permanent and circulatory migration, and the wages earned in the city are remitted by migrants to rural homelands, in some cases transforming the use of croplands and creating “remittance landscapes.” Perhaps most importantly, this urbanization changes life-ways ultimately associated with demographic and land use transitions increasing expectations about consumption, and potentially a weakened understanding of production-consumption relationships noted for the well-developed world, all with implication to biodiversity and ecosystem services.

Alternative pathways

The economic growth and land use transition in the Himalayas has also geopolitical implication in the world. Converting arable land to urban construction and tree plantation directly affects domestic food security with the potential to influence global commodity markets. China imported a total of 5.8 billion US dollars of animal feed with average annual change of 57% in value during 1999-2003, 94% is soybeans, largely from Latin America including Brazil and Argentina, which has potential implication to land use and land cover in Amazon. Free trade can export the impacts of one nation’s timber consumption to anther national that harvests the timber. With implementing NFPP or logging restrictions in 1998 and tariff reductions on forest products in 1999, China’s annual timber product imports from Myanmar more tripled between 1997 and 2002.. There are increasing instances of exported impacts or leakage of one nation’s timber consumption to another’s forests worldwide in Asia (Kauppi et al, 2006). While the robust economy in the region wants more lands for plantation. There are instances of exported impacts of land use to another’s forestland. Chinese investors search for more lands for rubber plantation in neighboring countries such as Laos and Myanmar. Conversion of secondary forest areas to rubber is considered as economic opportunity both for local decision-makers and farmers. Rubber plantation will eventually become predominant landscape in the tropics of mainland Southeast Asia. Following China, the India had reached turnaround of forest transition, both enjoy forest expansion and strong economic growth (Kauppi et al, 2006). It is matter of time to have great impacts on global commodity market. Alternative pathways have to be developed locally with sustainable land use management and lifestyle with low-carbon economy. Some alternative pathways include payment for environmental services, mosaic agroforestry landscape, and sustainable forest management.

Payment for ecosystem services

Himalayan forest and grassland ecosystems provide society with a wide range of services – from reliable flows of freshwater to productive soil and carbon sequestration. In response to growing concerns from urban and downstream people, markers are emerging for payment for ecosystem services around the world, voluntary or mandated by policy now exist related to carbon, water and even biodiversity. Due to late growth in private sectors, the Sates in the Himalayas take leading role in such payment. China allocated large-scale fund to pay upland farmers to convert farmlands in the upper watersheds into conservation, often called as “Sloping Land Conversion Program” or “grain for green”. Municipalities try to pay for headwater farmers to change their land use practices for example reducing chemical fertilizers for conserving watersheds for drinking water.

Agroforestry landscape

Agroforestry – managing tree with agricultural crops – has the potential for provision of ecosystem goods and services in human-dominated landscapes. Agroforestry is uniquely suited to address both the need for increased food and biomass resources and the need to sustainably manage agricultural landscapes to provide critical ecosystem services such as water, biodiversity, and carbon sequestration. Moreover, it is suited to achieving these objectives in areas of high rural poverty such as Himalayas. Agroforestry reinforces natural intensification, which can be further strengthened by increased access to markets for agroforestry products. In fact millions of smallholder farmers grow trees on farms and in agricultural landscapes of Himalayas for millennia years. Many traditional agroforestry practices can be found from tropical to temperate areas of Himalayas. Two trends seem almost universal in the Himalayas: the number of trees in forests is declining, and the number of trees on farms is increasing.

<u>Sustainable forest management</u>

Although forest transition occurs, the forest density is still very low. Chinese forest cover has significantly increased from 14% in 1978 to 19% at present, however forest density is still very low with no increasing at all in past three decades. Most forests are not managed at all with low average stocking volume: 85 m^3/ha (140 tCO_2/ha) in Chinese forestlands, even much lower for plantations: 47 m^3/ha (80 tCO_2/ha). The potential activities for sustainable forest management include: a) increasing target diameter/rotation period; b) terminating current practices to extract premature future crop trees & focusing future increment on poor performing trees; c) increasing vertical and horizontal structure by converting monocultures into close to nature forests; d) improving site species matching in existing stands by supporting natural regeneration of desired tree species. Financing carbon forestry can achieve not only economic but also ecological benefits of mountain ecosystem.

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