PERSPECTIVE

3(9), January - March, 2017

ISSN 2394–8558
EISSN 2394–8566

Climate Change

Forest management strategies and adaptation to climate change: Experiences from South Asia

Mangala De Zoysa[1], Makoto Inoue[2]

1.Department of Agricultural Economics,
Faculty of Agriculture, University of Ruhuna,
Mapalana, Kamburupitiya,
Sri Lanka;
Tel: +94-41-2292200 (Office); +94-41-2226868 (Home); +94-77-6051540 (Mobile);
Fax: +94-41-2292385;
Email: mangalaxyz@yahoo.com *or* mangala@agri.ruh.ac.lk

2.Global Forest Environmental Studies,
Graduate School of Agricultural and Life Sciences,
The University of Tokyo, Tokyo,
Japan

Article History
Received: 4 October 2016
Accepted: 2 November 2016
Published: January-March 2017

Citation
Mangala De Zoysa, Makoto Inoue. Forest management strategies and adaptation to climate change: Experiences from South Asia. *Climate Change*, 2017, 3(9), 38-64

ABSTRACT

Climate change and an increased incidence of extreme weather events are presenting significant threats to forest ecosystems and the wider community in South Asia. The analysis of the severity of these threats and effectiveness of the management strategies of different forest ecosystems for climate change adaptation has become vitally important. Therefore, this paper reviews the literature and discusses the expansion of carbon stocks by forests and trees, conservation and maintenance of existing forest carbon (C) stocks, and management of fragile forest ecosystems for climate change adaptation in South Asia. Expansion of C stocks by forests and trees is facilitated in the region through afforestation, reforestation, and forest restoration; increase of tree cover outside forests; and enhancement of forest carbon stocks. Fire management and reduction of shifting agriculture, management of forest health and vitality, management of forest biodiversity, management of protected areas and wildlife provide great contributions to the conservation and maintenance of existing forest carbon stocks. Management of fragile forest ecosystems, particularly mountain forests and watersheds; dry-land forests; coastal forests; wetlands and peatlands are also vital for forest adaptation to climate change. Sustainable forest management strategies promoting adaptation to climate change should be an integral part of rural development activities with active community participation in the South Asian region.

Keywords: Carbon stocks. Climate change impacts. Community participation. Conservation and maintenance. Forestry adaptation in South Asia. Fragile forest ecosystems.

1. BACKGROUND

Climate change has reduced ecological resilience, the capacity of an ecosystem to persist in spite disruption in addition to reducing social resilience and human adaptive capacity. Climate change trends in the South Asian region indicate increasing temperature, declining days of precipitation and seasonal shifts in rainfall patterns, heat waves, severe floods, droughts, landslides, etc. A gradually increasing trend in surface temperatures of approximately 0.30°C and 0.57°C per 100 years have been suggested for Sri Lanka and India, respectively (IPCC, 2001). The increase in surface temperature will raise the snowline, reducing the capacity of the natural reservoirs and increasing the risk of flood in Nepal, Bangladesh, Pakistan, and North India during the wet season (Singh, 1998). Intense rainstorms and a 10-20% increase in intensity of tropical cyclones are projected as part of an increase in the occurrence of extreme weather events in South Asia. The total flood-prone area in Bangladesh has become 3.1 M ha, and in India, it is approximately 40 M ha (Mirza and Ericksen, 1996). Chronically drought-affected areas in India cover Bihar and Orissa States, in addition to the western parts of Rajasthan and the Kutch region of Gujarat. Approximately 2.7 M ha in Bangladesh are vulnerable to drought annually. Part of Nepal is affected by drought or near-drought conditions (Mirza, 1998). Bhutan is highly vulnerable to various climate change impacts and natural hazards due to geological conditions, variations in precipitation and high-elevation terrain (Lhendup 2012). In the Maldives, the problem of sea level rise is alarming, as a significant portion of the land mass is made up of low-lying atolls.

Forests provide a number of ecological services such as climate regulation, hazard protection, and water conservation while increasing social resilience to major disturbances such as floods, heat waves, and intense drought as impacts of climate change.

Anticipated temperature increases and changes in precipitation are likely to increase the risk of pest and disease outbreaks, species extinctions, forests fires, erosion and habitat loss, presenting significant threats to forests in South Asia. These impacts on tree physiology and phenology, forest growth and biodiversity adversely affect the forest-dependent people and wider society. Millar et al. (2007) suggest that no single solution fits the challenges of changing climates and that the best strategy is to mix different approaches, possibly using a toolbox approach, for different situations in managing forested ecosystems. Complying with their commitments, all South Asian Counties have submitted their National Communications (NCs) and National Adaptation Programs of Action (NAPAs) to the United Nations Framework Convention on Climate Change (UNFCCC). Adapting forests to climate change is a prerequisite for effective climate change mitigation, improving the permanence of carbon stocks and achieving eligibility for carbon financing.

The forests in the South Asia region, with high population levels, large numbers of forest-dependent and vulnerable people, and rich biodiversity, play a central role in efforts to adapt to climate change. Adaptation strategies are not popular with government systems, as they prefer to focus on shorter time frames and 'quick fixes' (Huq et al. 2006). In community-based natural-resource management, local people have a greater interest in the sustainable use of resources. In the case of specific realities of climate change occurring, adaptation is most appropriately implemented at the local level, depending on geographic differences, governance systems, public infrastructure, and resource accessibility, as well as the incorporation of traditional local knowledge in decision-making (Satterthwaite et al. 2007). The degree of community participation in forest management can range from simple consultation to consign and joint ventures (Tsegaye, et al. 2007). By reducing the likelihood of unexpected resistance, government officials can reduce uncertainties in the policy implementation process.

There is abundant literature predicting the impacts of climate change on forest ecosystems in South Asia. However, the information on successful management strategies for adaptation of forest ecosystems to climate change is rarely incorporated into the available published literature. Dixon et al. (1994) grouped forest management strategies to adapt climate change as follows: maintaining existing carbon (C) pools by slowing deforestation and forest degradation, expanding existing C sinks and pools through forest management, and creating new C sinks and pools by expanding tree and forest cover. Therefore, this paper reviews the growing information and published literature specifically addressing forest management strategies for adaptation in the face of climate change in South Asia as well as other parts of the world in general. The process of constructing the conceptual framework involves extensive review, synthesis and classification of available information of forest management strategies that addresses expansion of carbon stocks by forests and trees, conservation and maintenance of existing forest carbon stocks, and management of fragile forest ecosystems for adaptation to climate change in South Asia. The authors expect that this paper will provide vital information and directions for the initiation of adaptive research programs, development of forest management strategies, and improvement of the policy environment for further adaptation of forest ecosystems to climate change in the South Asian region.

2. EXPANSION OF CARBON STOCKS BY FORESTS AND TREES

C accumulates in forested ecosystems through the absorption of atmospheric CO_2 and its assimilation into biomass. The removal of atmospheric CO_2 by plants and storage of fixed C is implied in the term of C sequestration. Biomass C and soil C are included as main C storage in forest ecosystems (Lal 2005). Various pools, such as standing timber, branches, foliage, roots, litter, woody debris, soil organic matter and forest products in a forest ecosystem, store the carbon (Dixon et al. 1994; Kasahun Kitila Hunde, 2015b). Climate change affects the productivity and allocation of biomass of forest ecosystems. Manipulating vegetation to favor rapid growth and long-term site retention removes atmospheric CO_2 and stores carbon (Harmon and Marks 2002). Forest conservation, afforestation, reforestation and sustainable forest management can effectively combat climate change, reducing 25% of the required emissions (Sing 2008). Environmental and land-use policies in all countries of South Asia have identified a minimum forest cover that should be maintained to provide ecological stability and reverse the decline of the region's rich biodiversity as well as ensure the provision of essential forest goods and services for the society (http://www.iufro.org/science/special/spdc/actpro/keep/sa/). Participatory forestry strategies provide opportunities for sustainable rural development and poverty alleviation through income generation and employment opportunities while protecting lands and communities from impacts of climate change in the region. The coordinated efforts of communities to adapt climate change can help restore natural forest environments, which, in turn, help sink carbon and provide better-adapted areas, at the local level. Communities support collective action to manage their forest resources, and institutions tend to be developed in areas with forest degradation (Agarwal 2001).

2.1. Afforestation, Reforestation and Forest Restoration

Forest management strategies promoting afforestation and reforestation are designed to increase carbon sequestration by forests and trees. Reforestation and afforestation enhance the terrestrial C pool through photosynthesis into biomass and humification of part of the biomass into the soil organic carbon (SOC) pool (Lal 2005; Kumari and Nema, 2015; Afunmilayo, 2016). Asia is the first continent to display a transition from net deforestation to net reforestation, and India is one of the major contributors with an annual net gain averaging just over 1 M ha from 2000 to 2005 (Mather 2007). The increase of total forest area in South Asia in 0.12% during 2005 - 2010 is largely due to the afforestation and reforestation efforts of Bhutan, which increased forest cover by 0.34%, and India, which increased forest cover by 0.21% (FAO 2012). Afforestation, reforestation and the selection of species are important to enhancing SOC stock (Akala and Lal 2001). The trend of expanding planted forest in Sri Lanka includes almost complete cessation of planting of pines and limiting the planting of eucalypts, along with emphasis given to the planting of indigenous hardwood, such as teak (*Tectona grandis*) and margosa (*Azadirachta indica*). Passive restorations in many situations involving community interventions enhance carbon stocks of local forests. Joint Forest Management (JFM) under a community-based forest management (CBFM) policy in India restores forest cover and density, providing carbon sequestration and creating rural assets while sustaining and strengthening community livelihoods and providing access to the international carbon market (Sing 2008). Afforestation efforts by the Indian government have steadily contributed to forest growth, particularly in dense canopy forests estimated to be 3.13 M ha during the 1997 – 2007 period, mainly due to the country's protected area policies and Joint Forest Management efforts (FSI 2009). An estimated 21.4 M ha, equivalent to 31% of India's forest area, has been established by local forest committees under JFM (Poffenberger and Singh 1992). The Kyoto protocol, under its clean development mechanism (CDM), provides "carbon credits" for developing countries through carbon trading that are gained from activities related to reforestation and afforestation. Article 3.3 and Articles 6 and 12 (CDM) of the Kyoto Protocol include afforestation and reforestation. Having multiple species in forest plantations is an attractive adaptation option, as it results in such forest plantations being more resilient and less vulnerable to climate change (IPCC 2002). REDD+ initiatives are currently efficient and effective in coping with both climate change as well as dealing with the economic situation in all South Asian countries. National Adaptation Programs of Action (NAPAs) under climate change adaptation strategies in most countries in the South Asia region include forestry sector activities. The Climate Change Strategy and Action Plan (2008) and NAPA (2005) in Bangladesh include afforestation and reforestation projects as the priority areas. (http://www.fao.org/asiapacific/forestry-adaptation)

2.2. Increase of Tree Cover Outside Forests

The survival conditions for many forest species in landscapes outside of protected forest areas is hostile because of climate change, human infrastructure, and associated stressors. The in situ genetic adaptation to new climate conditions of populations of most species is not likely (Jump and Penuelas 2005). The practice of planting trees is no stranger to the people in South Asia. Trees outside forests in South Asia cover 10% of the total land area, providing wood, fruits, nuts and other non-wood forest products (NWFPs) as well as performing important social, cultural and environmental functions (FAO 2012). Social forestry programs have been implemented in almost all South Asian countries in the last three decades. The local population has participated to varying degrees in the planting of trees on a variety of lands, including village grazing commons, roadsides, along railways, private lands, homesteads and farmlands. Social forestry programs in India has planted 11.8 million ha, at an average of 1.3 million ha/year from 1980 to 1989 (Krishnaswamy 1995). Social forestry activities in Bangladesh resulted in massive increases in tree cover outside traditional forest areas. The Bangladesh Climate Change Strategy and Action Plan prioritizes forestry adaptation to climate change, including expansion of the social forestry programs on state-owned community lands (MOEF 2008). The social forestry activities aim to increase tree cover on approximately 31% of the total land area in Bangladesh (http://www.iufro.org/science/special/spdc/actpro/keep/sa/). A mixture of trees, shrubs and herbs forms a typical homestead garden in South Asia. The number and extent of homegardens in Sri Lanka is increasing steadily, currently covering 14.3% of the land area and producing more than 42% of wood requirement, as well as meeting many domestic needs of the country (FAO 2012). Agroforestry is converting spare agricultural land to forestry use, and afforestation of marginal agricultural soils or degraded soils has large potential for SOC sequestration (Ross et al. 2002; Kasahun Kitila Hunde, 2015a). Trees can influence micro-climate, resulting in predicted shifts within favorable ranges of temperature, humidity and evapotranspiration under the impact of climate change that will impact crop production (van Noordwijk and Minang 2011). Agroforestry practices maintain habitats for threatened species and maintain local biodiversity while producing food and fiber. Farmers in India cultivate perennial crops intercropped with seasonal and annual crops in high rainfall areas (Magreth Bushesha, 2015). Trees planted by farmers in arid lands are used for fodder, mulch and even food (Saxena and Ballabh 1995). Increases in the prices of forest products induce landowners to plant trees instead of crops or pasture grasses. Recent increase in forest cover in India explains the forest scarcity path to the forest transition (Foster and Rosenzweig 2003). The social forestry program implemented in India during the 1970s and 1980s increased farm tree resources significantly, growing the stock of trees outside forests estimated approximately 1.6 billion cubic meters (FAO 2012). Agroforestry systems contribute to farmers' overall livelihood systems and timber production, which is also compatible with carbon storage and sequestration under periodic rotational harvesting. The number of farm trees in Pakistan has increased from 330 to 554 million during 1992 – 2004, covering 781 000 hectares block plantation equivalents (FAO 2012). Accommodating trees in intensive agriculture land uses under high population density and scarcity of land in Bangladesh serves both the production of various timber and non-timber products and for mitigation of recurring catastrophic flood events. (http://www.iufro.org/science/special/spdc/ actpro/keep/sa/) Forestry sector policy in Sri Lanka is focused on empowering people to protect and manage multiple-use forests and expanding and enhancing the productivity of traditional homegardens, agroforestry and community forestry to meet the basic needs of the people. (http://www.iufro.org/science/special/spdc/actpro/keep/sa/) Promotion of multiple-use forest in degraded natural forests and forest plantations are being implemented in Sri Lanka for both local consumption and industrial processing. Declining wood supplies from forests and escalation of wood price have encouraged industries to establish industry-farmer partnerships supporting farm tree planting in large tracts (FAO 2012). Green space development reduce runoff and ''heat island'' effects in urban areas. The rapid urbanization of South Asia has resulted in substantial efforts to develop and manage green spaces in cities for environmental and recreational purposes under urban forestry, which has a long history in the region. The Sanjay Gandhi National Park in Mumbai, with an area of 104 square km, is one of Asia's most visited national parks, with 2 million annual visitors (FAO 2012).

2.3. Enhancement of Forest Carbon Stocks

Carbon sequestration implies transferring atmospheric CO_2 into soil organic carbon (SOC) and soil inorganic carbon (SIC) stocks through judicious land use and recommended management practices. SIC sequestration is attributed to biogenic processes and leaching of carbonates into the groundwater as a secondary carbonates (Lal 2004). Forests and trees are important components of the global C cycle as both sources and sinks of atmospheric, especially as they store large quantities of carbon in vegetation and soils (Zomera et. al. 2008). Successful tree planting programs and the protection and management of natural forests have reversed the trend of significant forest loss in South Asia in the last 20 years. Regeneration and avoided deforestation activities in Tropical Asia have the potential to sequester 3.8–7.7 and 3.3–5.8 Pg C, respectively, between 1995 and 2050 (Brown et al. 1996). C stabilizes soil against microbial attack. C forms structural aggregates, converts simple organic compounds into complex humic substances, and transfers C into subsoil, resulting in conversion into substances that are resistant to decomposition (Friedlingstein 2008). The management systems add high amounts of biomass to the soil, causing minimal soil disturbance, conserving soil and water, improving soil structure, enhancing activity and species diversity of soil fauna, and strengthening the mechanisms of elemental cycling causing the SOC sequestration (Lal, 2004; Suryanarayana et al. 2015).

Forest management in South Asia is a long tradition, and presently, the forest area in the region is covered by formal and nationally approved forest management plans of each country for the enhancement of forest resources. In Bhutan, a volume of 163 m^3 per ha and 178 tons of biomass per ha of forests are more than one and a half times the world average of 100 m^3 and 109 tons, respectively. (http://www.fao.org/DOCREP/004/Y1997E/Y1997E00.HTM) The choice of fast-growing species that accumulate more biomass and C than slow-growing species has a high potential to sequester C (Lasco et al. 2008). Because of growing concerns over higher fossil fuel prices, environmental degradation, and climate change, the planting of fast-growing fuelwood and multipurpose tree species has been given priority in Sri Lanka (De Zoysa and Inoue 2014). Biomass increases if forest growth exceeds degradation. Multifunctional homegardens in South Asia promote woody perennial-based agroforestry systems that sustain agro-biodiversity and favor resource conservation with tree-dominated habitats. Biological nitrogen fixation, recycling from subsoil, aerial deposition, use of bio-solids, and crop residues are considered several sources of nutrients for C sequestration (Nordt et al. 2000). Prominent agroforestry in South Asia includes multifunctional home-gardens consisting of fertilizer trees and integrated tree-grass/crop production systems favoring resource conservation. Stand-scale management and landscape-scale strategies, such as longer harvesting cycles or reduced disturbances, can increase forest carbon density and achieve net carbon sequestration (Canadell and Raupach 2008). The establishment of forest plantations in South Asia in particular is a major strategy to combat the deforestation caused by household fuel collection. The forest plantations have reduced pressure on the natural forests in India. The Orissa Social Forestry Project in India has significant implications concerning the collection decision by local communities in the community forests, where the forest stock has recovered and collection has been increased (Köhlin, and Amacher 2005). Overall, fuelwood consumption in South Asia also slightly decreased during 1990–2002 (FAO 2010b). Well-managed carbon sequestration projects can produce timber, fiber, and energy, providing additional income for rural development, ensuring prospects for conservation and other environmental services and supporting local communities. Community-Based Forest Management (CBFM) activities in India have improved the productivity and biomass status of degraded forests as well as increased the commercial value of timber in teak forests by 60% in Gujarat and 35% in Sal forests in West Bengal (Hill and Shields 1998). Community-protected forests in Orissa have increased the carbon sequestration rate from 1.53 to 3.01 t C/ha/yr by forest regeneration (Gera et al. 2003). The community-managed teak forests of Harda Forest Division, Madhya Pradesh, have increased the sequestration from 0.5 to 3.4 t C ha/yr (Proffenberger et al. 2001). Market-driven climate change adaptation mechanisms such as carbon funds have the potential to fetch high premiums for community-managed forests in carbon markets. South Asia has more than 65% of identified areas for the clean development mechanism (CDM) funding with population levels more than 100 persons km^2 and includes marginal and subsistence cropping areas and lower productivity grassland (Zomera, et al. 2008). The CDM allows for emission reduction credits to come from afforestation and reforestation projects while assisting developing countries in achieving sustainable development, poverty reduction, environmental benefits and cost-effective emission reductions (UNFCCC 2002).

3. CONSERVATION AND MAINTENANCE OF EXISTING FOREST CARBON STOCKS

Climate change impacts on forest ecosystems in South Asia are complex and are expected to increased incidence of fire, dieback, pests and pathogens, invasive species and landslides. Drought suppresses gross primary production of forests and increases tree mortality, fires, and insect damage, reducing the forest carbon sink. The efflux of CO2 from soils is related to the temperature, scalar of the soil water content and precipitation (Davidson and Janssens 2006). The carbon stocks in forests may change due to biomass losses. Pressure on forests in India is due to overextraction of 86 million tons of fuel-wood and very high over-grazing to feed 467 million grazes indicate the need to support sustainable forest management (Singh 2008). Declines in forest cover have been reversed in some countries, whereas deforestation and resource degradation are being controlled in other countries in South Asia. Climate change adaptation requires implementation of a range of measures and conservation practices to respond to both the rapid directional change and tremendous uncertainty of challenges (Heller and Zavaleta 2009). Maintaining healthy vigorous trees, keeping sites fully occupied with minimal spatial or temporal gaps, and minimizing severe disturbances by fire, insects, and disease are important goals of best forest-management practices (Stephens and Moghaddas 2005). Silvicultural practices such as soil erosion control measures, improving soil fertility, reducing shifting agriculture, and retaining forest litter and debris after logging help to maintain soil organic C. The approach toward climate change adaptation of forests focused on the exposure to climatic hazards is based on the determinants of development of sustainable forest management and the determinants of adaptive capacity from local communities. Priorities need to be set linking climate change adaptation with sustainable forest development. Policies and regulations for the sustainable management and utilization of forest resources involving local communities have been formulated and continuously updated and revised according to changing societal requirements in South Asia.

(http://www.iufro.org/science/special/spdc/actpro/keep/sa/) Transfer of the management of natural forest resources to forest user groups in Nepal and Joint Forest Management (JFM) in India are innovations in forest management during the last two decades (FAO 2012). Joint Forest Management (JFM) has been implemented as a large-scale decentralized forest management program in India. Plantation forestry under Joint Forest Management (JFM) is contributing to reductions in the net loss in forests under the public policy goal of reducing deforestation and forest degradation in India (Shyamsundar and RuchaGhatey 2014).

3.1. Fire Management and Reduction of Shifting Agriculture

The variation of carbon sinks in South Asia reflects the effects of climatic variability, both as a direct impact on vegetation and through the effects of wild fires and other natural disturbances. In South Asia, Nepal and India experienced the biggest forest fires during the period 1985 – 1987 and 2000, which burnt approximately 2.99 and 3.7 M ha, respectively (FAO 2006). Bhutan experienced 36 incidences of forest fires burning more than 5000 ha of natural forests in the country in 2010. (http://www.climatechange.panossouthasia.org) Forest fire exacerbated by climate extremes and climate change may return forest carbon stores to the atmosphere. Fire-prone ecosystems are affected by the climate-driven hydrologic balance (Davidson and Janssens 2006). The moist and dry deciduous forests and monsoon tropical forest of South Asia adapt to regular fire because of the most important adaptive traits of grass species, understory plant shrub layer, and over-story tree layer. Over 90% of the forest fires in South Asian region are set deliberately and are connected with socio-economic conditions of the rural communities (FAO 2006b). The traditional fire control policy in India concerning the fire adaptations and the possible fire dependence of economically important trees such as sal (Shorea robusta) and teak (Tectona grandis) is a controversial issue (Goldammer 2007). Most tropical pines found in dry sites of lower montane rainforests in South Asia tend to occupy burnt sites (Mirov 1967). Increased occurrence of forest fires as a projected adverse impact of climate change, increased occurrence of pests and diseases put the forests at risk. However, local communities in Nepal deliberately set forest fires to remove plant species competing with desired timber species and to control soil-dwelling pathogens and weeds (FAO 2006b). Slash and burn or shifting agriculture practices performed by local communities are also considered as one of the main causes of forest fires in South Asia. Pines in tropical Asia are strongly adapted to and favored by fire. Pine forests have frequent man-caused fires under slash and burn cultivations (Goldammer and Peñafiel 1990). Annually, fires are mainly deliberate to facilitate collection of commercially important non-timber forest products (NTFPs). Many communities set fire to collect NTFPs, such as bidipatta (*Diospyros melanoxylon*), mahuwa (*Madhuca indica*), phutki mushroom (*Schleroderma* sp.), vegetables, bankas (*Eulaliopsis binata*), and khajuri (*Phoenix humilis*), which contribute to rural livelihoods (FAO 2006b). Integrated fire management through strengthening capacities to prevent wildfires and reducing risk of large disastrous wildfires needs to be intensified and adapted as a part of climate change adaptation strategies (FAO 2010a). Integrated fire management (IFM) is a holistic approach that considers biological, environmental, cultural, social, economic and political interactions in addressing fire issues. Integrated fire management encourage decision makers to focus resources to address underlying causes and seek long-term sustainable solutions (FAO 2011). Creating "Participatory management working circles" that involve the community in forest fire management on a voluntary basis is a new management plan in Sri Lanka. The communities benefit from collecting dead wood in plantations, and they are employed in temporary jobs in forest activities. Villagers assist forest authorities in fire extinction in India and Sri Lanka. To reduce the fuel load, villagers living in the vicinity of forest areas are permitted to gather dead wood free of charge (FAO 2006b). Strengthening the capacities of forest communities that suffer most from wildfires is likely to provide the most motivation to prevent and suppress devastating wildfires and to use fire wisely as a participatory management tool also contribute to enhancing their livelihoods (FAO 2010a). Community-Based Fire Management (CBFiM) is a participatory approach involving communities that is becoming popular in Nepal (Kunwar and Khaling 2006). Community-based fire management (CBFiM) approaches manage beneficial fires for controlling weeds, reducing the impact of pests and diseases, generating income from non-timber forest products, creating forage and hunting as well as preventing wildfire and aiding in the preparation of the suppression of wildfires (FAO 2011). This type of approach was able to reduce the number of forest fires from 36 incidents in 2010 to 13 incidents in 2011 and the area of damage from approximately 5000 to 500 ha while allowing the communities to use fire for their land management activities (http://www.climatechange.panossouthasia.org). Local people use their traditional or indigenous knowledge in planning, conducting, and controlling while undertaking fire management. India and Sri Lanka use traditional practices such as creating fire lines and fire tracks, in addition to making prescribed burnings, during the fire season as forest fire management strategies (FAO 2006b). Villager-set fires are common in seasonal deciduous monsoon forests in India. Sprout emergence from the damaged shoots of these forests as clonal species is an adaptation to damage from drought, wind throw, fire, or other causes (Saha and Howe 2001). The communities often engage in positive fire management to manage their agroforestry landscape. Bhutan has developed community-based fire prevention projects including the components of education and equipping villages in an attempt to adapt to increasing fire events caused by a warming climate (Roberts 2008).

3.2. Management of Forest Health and Vitality

Plant health and vitality are the outcomes of the dynamic interactions and provide resistance to a wide spectrum of plant pathogens, abiotic disturbances and range of stress factors. The disturbances of climate influence the composition, structure and functions of forests. Climate extremes and climate change-induced insect outbreaks in forest ecosystems may return forest carbon stores to the atmosphere (Canadell and Raupach 2008). India recorded some 4.4 million hectares of forests as being affected by abiotic disturbances. The Maldives has reported considerable tsunami-caused destruction of trees and forest vegetation (FAO 2010b). Climate change has indirect impacts on ecological relationships such as the changing the abundance of competitors, parasites and predators spreading forest pests. Forest pests and the damage they cause are intensified by climate change, particularly extreme weather events directly impacting their development, survival, reproduction, spread-altering host defenses and susceptibility (FAO 2014). The biologically enriched fallow vegetation of shifting cultivation enhances and accelerates the vegetative regeneration of soil fertility and control of weeds (Long and Nair 1999). The communities in Nepal manage beneficial fires using the Community-based fire management (CBFiM) approach for controlling weeds and reducing the impact of pests and diseases (FAO 2011). Certain forest species are used by the farmers in tropics in Asia traditionally to restore forest fertility (Unruh 1990). Diverse biota have a strong influence on soil physical and biological qualities, especially with regards to soil structure, porosity, aeration, water infiltration, drainage, nutrient/elemental cycling and organic matter pool and fluxes (Lavelle 1997). The named practice of growing agricultural crops along with forest species originated from Myanmar (Burmese) as the word "Tungya" from the words "taung" (hill) and "ya" (cultivation). The practice initially developed in India has been spread to most parts of the tropics (Long and Nair 1999). Social forestry, a variety of community forest programs that have been initiated in different states in India, have provided equally variable results in terms of conserving existing quantities of fuel, fodder, timber, and other forest products; conserving existing forests; and averting ecological disasters (Khosla and Kohli 1987). Alley cropping, where crops are grown between hedgerows of planted shrubs and trees, preferably leguminous species, has demonstrated the ability to replace or reduce the use of chemical fertilizer and to maintain soil and crop productivity. "Avenue cropping" using the same alley cropping concept is a popular practice in Sri Lanka under agroforestry systems (Wijewardene and Waidyanatha 1984). Healthy soil comprises highly diverse soil biota, including earthworms, termites, ants, some insect larvae and few other soil animals important for the SOC pool and its dynamics. Integrating pest management with community participation prevents the incidence and spread of pests, ensuring healthy forests, reducing the risk of forest degradation, and increasing resilience to climate change (FAO 2014). Aggrawal et al. (2006) found positive linkages between forest health and Join Forest Management in India.

3.3. Management of Forest Biodiversity

Forest biodiversity in South Asia is extremely varied, ranging from high mountain ecosystems of alpine climates to coastal lowlands in tropical and sub-tropical climates. South Asia contributes approximately 10% of the biodiversity of the world in terms of the total number of species. Bhutan is recognized as a world biodiversity hotspot where approximately 34% of the land area has been set aside for full protection. (http://www.iufro.org/science/special/spdc/actpro/keep/sa/) Indian forests are highly diverse, and India is one of the 12-mega diversity countries of the world, as it contributes approximately 8% of the total number of species to the biodiversity of the world (Khoshoo 1995). Out of 18 unique biodiversity 'hotspots', three are located in the Himalaya, Western Ghats, and Sri Lanka regions, providing storehouses of nearly 50,000 plant species or approximately 20% of the world's flora. Because of the biodiversity, 45% of the forest area in Sri Lanka is considered under protected area management. Bangladesh, India, and Nepal consider 1.7%, 23%, and 19.7% of forest areas, respectively, as protected areas because of higher biodiversity.

(http://www.iufro.org/science/special/spdc/actpro/keep/sa/) New climate-change-related biodiversity challenges have been created as the current reserves will not continue to support species ranges and ecological dynamics (Heller and Zavaleta 2009). Forest fires inhibit tree growth and reduce coarse woody debris and forest biodiversity. Forest vegetation generally shifts toward more fire-tolerant species where fire frequency tends to increase with hotter and drier conditions (Veblem et al. 1999). The floral composition of many parts of the South Asian region has been severely affected by invasive species such as eupatoreum (*Eupatorium perfoliatum*) and lantana (*Lantana camara*), lowering productivity and delaying natural succession. (http://www.iufro.org/science/special/spdc/actpro/keep/sa/) Invasive alien species have spread at an unprecedented rate and domination over native and natural species is a severe threat to natural ecosystems and biodiversity in Sri Lanka (Mattsson et al. 2009). Maintaining and restoring native ecosystems, protecting and enhancing ecosystem services, managing habitats of endangered species, and creating refuges and buffer zones can be taken into account in biodiversity-based climate change adaptive strategies. Regulating micro-climates, wind and monsoon circulation, the Himalayan mountain system supports river and wetland ecosystems in South Asia. The Ganges River ecosystem of the Himalayan mountain system alone supports 25,000 or more species, which support agricultural sustainability and provide livelihoods for millions of people (Rasul 2010). The Center for Bio Diversity (CBD) (2010) is attempting to enhance biodiversity and carbon stocks by restoring 15% of the degraded ecosystems of the world by 2020. The maintenance of forest biodiversity increases its long-term viability in cases of climate change by responding to some individual species better than a number of other native species. The re-emergence of secondary forests on uncultivated lands reduces ecological fragmentation and prevents additional extinctions by extending some species through migration and seed dispersal, and regrowth (Ferraz et al. 2003). Agroforestry in South Asia evolved over long periods and reflects the accrued wisdom and adaptation strategies of millions of smallholder farmers to meet their basic needs and sustain agro-biodiversity to climate change. Forest conservation in existing natural forest is a critical strategy to promote sustainable development because of its importance to biodiversity conservation and promotion of livelihoods of forest-dependent communities (IPCC 2002). Promoting traditional community-based resiliency and adaptation, community forestry user groups in Nepal are promoting traditional knowledge and practices that are effective for dealing with climate change impacts (Kumar 2010). Participatory Forestry Management (PFM) in South Asia is making an important contribution to the biodiversity conservation of forests degraded by climate change impacts compared with those managed under the conventional method. Biodiversity conservation under PFM gives proper attention to improvement of livelihoods of local communities and tackling their rural poverty (Tsegaye et al. 2007). The community forestry of the Livelihoods and Forestry Program supports the Koshi hills in Nepal by increasing the forest growing stock and biodiversity, increasing group funding trends, and sustaining the livelihoods of the rural poor. Program officials are preparing a vulnerability map of people and forest resources, formulating adaptation plans at different levels, establishing an adaptation mechanism and establishing funding to support the sections most vulnerable to climate change impacts (Kumar 2010). The cost of biodiversity conservation is not a sole responsibility of local communities in community forestry programs but shared among all stakeholders and supported by local communities to ensure long-term conservation strategies (Tsegaye et al, 2007).

3.4. Management of Protected Areas and Wildlife

In South Asia, 44% of the forest area has been set aside or designated as either protection or conservation purposes, and there has been increased demand for ecosystem services (FAO 2010a). Forest areas in Bhutan (73%), India (45%), and Pakistan (13%) have been set aside or designated as protected areas (FAO 2010a). Conservation strategies have been designed to safeguard the remaining habitats and species in protected forest areas in different parts of South Asia. Under the varied types of conservation management, the global conservation organizations have emphasized distinguishing between protected areas designated as either more strictly protected primarily wilderness-style management or sustainable utilization designed for sustainable land use (Zimmerer et al. 2004). There has been a paradigm shift led by the adoption of participatory approaches, enabling poor local communities to benefit in protected area management. The popular Chipko (meaning "to hug", began in Uttarakhand in the Central Himalayan region) movement in India is a powerful agency where local communities and their members, particularly women, have evolved their own traditional ways of preserving the environment and adapt to climate change (Kinkini Dasgupta Misra, 2016). In the states of Andhra Pradesh, Arunachal Pradesh, Chhattisgarh, Jharkhand, Meghalaya and Nagaland in India, the management of community resources and the commons, including forests, is a strategic priority identified by women for adaptation to climate change (Senz and Dieter 2010). Government authorities need to involve and collaborate with local communities and existing local institutions in the management of protected areas. Typical forms of forest protection and rehabilitation, including protected area management, have been implemented in Sri Lanka with different roles assigned to governmental agencies, communities and non-governmental stakeholders. Adopting participatory approaches in India, Nepal and Sri Lanka of South Asia is making local people active partners in protecting and managing protected forest areas (FAO 2012). The community forestry user groups of Nepal have, since 1980, been considered as self-regulated, autonomous institutions that make decisions about forest management and utilizations (Kumar 2010). They protect and manage 15% of forest lands with greater success in mid-Hills areas. They are entitled to 100% of the benefits flowing from forests under their protection, but the forests are owned by the government. Community-based management of natural forests in Nepal is delivering conservation benefits, including increased tree species diversity, reduced poaching of wildlife and a stabilization of some wild species populations (Bajracharya et al. 2005). The community forestry practices of Nepal promote traditional knowledge and practices developed under changing environmental conditions by indigenous and local communities over generations in the face of climate-change impacts on forest ecosystems (Kumar, 2010). The rich biological heritage of the Karakuram, Hindukush and the Western Himalayan Mountain Range in Pakistan is protected by communities through the community-based conservation approach of the Area Conservancy Project (MACP). (http://www.macp-pk.org) Local, mostly tribal, communities in the Midnapore and Purulia districts of West Bengal has been involved in protecting local forests to encourage natural regeneration of local species diverse forests. They have been especially motivated, empowered and assured of their share of a wide variety of NTFPs in the production of regenerated forest stocks (Gadgil et al. 1993).

The adverse effects of climate change on wildlife and their habitats is likely to occur regionally in the absence of properly designed management plans for wildlife. In an attempt to integrate conservation and management objectives, several biosphere reserves, including the Sargarmatha (Everest) National Park in Nepal and Sinharaja forest in Sri Lanka, have been designated as World Heritage sites. Under wildlife acts in South Asian countries, a committee of communities cannot be legally registered. Therefore, new wildlife acts have come into force that allow communities to register and hold rights to participate in the management of the protected area for wildlife resources after receiving initial training. The Bangladesh Wildlife Preservation Act of 1974 allowed the establishment of local institutions and the local community in decision making, planning and sustainable management of these resources. (http://www.cbd.int/doc/world/bt/bd-nr-03-en.pdf) The National Parks and Wildlife Conservation Act of Nepal amended in 1989 legally allows communities to manage multiple use conservation areas with site-specific regulations developed by local institutions and non-governmental organizations (NGOs). Over 7,000 community forest user groups in Nepal manage approximately 400,000 ha of national forests. The buffer zone management approach around national parks and wildlife reserves in Nepal with local communities sharing 30-50% of the park revenue have been very effective at poverty reduction and environmental rehabilitation (Ram Asheshwar Mandal et al. 2016), (http://www.iufro.org/science/special/spdc/actpro/keep/sa/). Local communities receive 80% of hunting fees in Community Controlled Hunting Areas (CCHAs) in north-west frontier regions in Pakistan. It has been reported that the community involvement in protection has led to an increase in wildlife populations at several sites. (http://www.macp-pk.org) The creation of national parks or other forms of fully protected areas through private company initiatives have also been recently taking place in South Asia (http://www.iufro.org/science/special/spdc/ actpro/keep/sa/)

4. MANAGEMENT OF FRAGILE FOREST ECOSYSTEMS

Forest ecosystems are likely to be most vulnerable where ecosystems contain species close to the limits of their thermal range, for forest types at higher elevations and higher latitudes, and forests in areas with poor management. The climate change impacts and disasters are amplified in ecologically fragile forest areas such as on hillside slopes, as in Nepal, and in low-lying coastal plains, as in Sri Lanka or Bangladesh. Plant species with small populations restricted to higher altitudes or enclosed valleys are more vulnerable than those inhabiting larger areas and capable of rapid dispersal. Many of the fragile forests are prone to severe degradation, weed infestation and increased susceptibility to fire and insect damage, even with slight disturbance (FAO 1993). Intensive management of fragile and unstable forest ecosystems that are unable to produce large quantities of woody biomass per unit area is incompatible with the other roles of forests, such as soil conservation and landscape improvement (Scarascia-Mugnozza et al. 2000). The Strategy and Program (1992-1996) of the South Asia Cooperative Environment Program (SACEP), which included Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka, covered regional cooperation in the management of mountain ecosystems, watersheds and coastal resources, and wildlife habitat conservation in the region as key areas (Jhansi and Mishra 2008).

4.1. Management of Mountain Forests and Watersheds

Climate changes add and magnify risks within watersheds, altering rainfall, temperature, and runoff patterns, resulting in the disruption of biological communities and the severing of ecological linkages. Mountainous regions are becoming increasingly susceptible to glacial lake outburst floods, landslides and erosions due to climate-change impacts (Lhendup 2012). Nepal lies in the Himalaya region. The high seismic zone of the world is experiencing global warming and its severe impacts. Consequently, river ecosystems and the people who depend on them are under stress due to excessive water withdrawal and land development, which are also exacerbated by changes in climate, requiring anticipation and the planning of adaptive strategies (Hulme 2005). The substitution of relatively carbon-rich secondary forests for carbon-poor agricultural land in watersheds through forest transitions slow the accumulation of greenhouse gases by increasing carbon sequestration (Houghton et al. 2000). Forest rehabilitation stabilizes the ecosystem in water catchments and overall enhancement of the environment (http://www.iufro.org/science/special/spdc/actpro/keep/sa/). Management strategies such as maintaining hydrology, reducing pollution, controlling exotic vegetation, and protecting biological diversity and integrity are important to maintaining and improving the resiliency of wetland ecosystems as well as providing important services under changed climatic conditions (Ferrati et al. 2005). Increases in forest cover of watersheds increase transpiration rates, reduce soil erosion and, by reducing sediment loads, improve water quality. Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka continue to implement different programs to attain environmental stability and sustainability in mountain ecosystems under the direction of the International Centre for Integrated Mountain Development (ICIMOD), which was established in Nepal in 1983. Disaster management and landslide restoration have been emphasized under the immediate and urgent needs to address the adverse impacts of climate change in Bhutan (Islam et al. 2016). The ICIMOD of the South Asian region is continuing different programs in the Hindu Kush-Himalayas to achieve environmental stability, sustainability of mountain ecosystems and poverty eradication (Jhansi and Mishra 2008).

Watershed management in South Asia has undergone major changes in the last few decades with particular attention to adopting integrated approaches involving all the stakeholders, especially local communities (FAO 2012). Integrated watershed management for upland conservation to meet local needs, ensuring sustained participation of communities in upland restoration, is the most important priority in the South Asian region. Various integrated watershed management projects have been implemented extensively in many South Asian countries, including Nepal, India, Pakistan, Bangladesh and Bhutan to improve conditions, particularly in the degraded high lands, and to avoid future degradation (Jhansi and Mishra 2008). New forest policies in Bhutan and Nepal emphasize the conservation of mountain ecosystems and protection of forests against natural hazards under the management responsibilities of local communities. Most of the forest rehabilitation efforts in Bhutan with extensive forest cover and low population density are an integral component of watershed management programs. (http://www.iufro.org/science/special/ spdc/actpro/keep/sa/) To increase the resilience of ecosystems to flood events caused by heavy rainfall and glacial melt due to climate change, Bhutan has also developed community-based afforestation programs (Roberts 2008). In Nepal, the middle hills and the high mountains are considered very fragile ecosystems, and community forestry concepts have been successful to some extent in these areas. The Forest Department of the Nepalese government has introduced Sloping Agriculture Land Technologies (SALT) to control soil erosion on the cultivated hill slopes to withstand the effects of climate change, increasing its vulnerability to future disasters. The District Forest Office has registered forest user-groups; institutionalized their own rules, regulations and norms; and provided seeds and seedlings to encourage tree planting (Bhandari 2008). Rehabilitation of hill forests and watershed management with a focus on slope stabilization through tree planting on the basis of community participation are important initiatives in India. (http://www.iufro.org/science/special/ spdc/actpro/keep/sa/) National and state policies in India have emphasized participatory natural resource management for practices of watershed development and agroforestry. The Reforestation and Watershed Management Project in Sri Lanka has conserved and stabilized watershed and mountain forests while providing natural renewable energy for communities from fuel-wood species and commercial resources from bamboo and rattan species. The Village Watershed Committee in Maharashtra of India was crucial to reducing the threat to areas that were in the process of being reforested. These committees ensure that they legally work on state-owned common land and have ownership of the agricultural production from the land while protecting areas for regeneration (FAO 2012).

4.2. Management of Dry-Land Forests

With respect to Asia, diffuse concentrations and extensive areas of dry forest occur along eastern India and Sri Lanka in South Asia. North-eastern India and Sri Lanka are also emerging as the most threatened areas of the Asian region in terms of the proportion of tropical dry forest area affected by threats (Miles et al. 2006). Many of the tropical dry forests of Asia are fragile forests and often merge into arid or desert margin zones (FAO 1993). The greatest loss of forest cover is within protected areas in dry forests of South Asia where the protected areas are relatively small (Defries et al. 2005). The patterns of degraded dry-lands in Asia are most likely remaining the same. Climate-driven hydrologic balance affects the leaf litter hydrophobicity associated with drought-prone ecosystems (Davidson and Janssens 2006). Increased mortality among many tree species from tropical dry forests in northwest and southwest India is associated with severe droughts (Khan et al. 1994). In Bangladesh, only approximately 54% percent of the mountain forests are under forest cover, whereas 46% is remaining as denuded or barren lands mostly due to shifting cultivation.

Dry land degradation leading to desertification and irreversible loss of productivity is one of the major environmental problems facing most countries in South Asia (FAO 2012). Desertification has affected 35% of the productive land in Asia, including a significant extent in Pakistan and India in the South Asian region (Jhansi and Mishra 2008). In South Asia, 50% of the dry-lands face the threat of desertification. In Pakistan and India, 63 M ha of rain-fed croplands and 16 M ha of irrigated lands land have been lost due to desertification (Perera and Fernando 2004). The area of dry lands as a percentage of productive agricultural land and the population on dry lands as a percentage of population on agriculturally productive land, two indicators of desertification, are extremely high in India and Pakistan and, to some extent, in Nepal. The food insecurity of the populations in dry lands is further exacerbated by climate change-induced events (FAO 2012). The government of Bangladesh has financed and implemented forest rehabilitation projects to combat desertification in the Thar Dessert. (http://www.iufro.org/science/special/spdc/actpro/keep/sa/) The women of Morkhoon in the mountain desert areas of Pakistan have promoted forest plantations on the boundaries of fields, communal land, private land and other areas where original vegetative cover has disappeared to overcome fuelwood and fodder shortages. Planting trees on family plots and adopting crop rotation practices, they have somewhat ameliorated the desertification process as well as earned incomes from selling fruits from the trees, which has empowered them both economically and socially (UNCCD 2007). The hills and desert areas of India and Nepal provide firewood for their local communities, and they satisfy 65% and 95% of their total domestic energy needs, respectively (Agarwal 1987). There is a substantial need for the expansion of the protected area network to include dry tropical forests areas that are subjected to multiple pressures, often simultaneously (Miles et al. 2006).

4.3. Management of Coastal Forests, Wetlands and Peat-Lands

Increase heat waves and increases in sea-surface temperature in 2-4 °C are projected due to climate change in the South Asia region (Knutson and Tuleya 2004). Climatic change increases the risks of flooding and erosion due to storm surges and increased runoff in coastal areas in addition to the possibility of inundation as a result of sea level rise. In Bangladesh, the consequences of climate change are a serious threat in low lying deltaic country with high poverty and high-density populations. Bangladesh is subjected to regular flooding with consequent disruption and economic loss even in the locations protected from flooding by structural measures such as dikes and flood barriers (Nicholls et al. 1995). The coastal areas of the Asian region are predicted to experience a sea level rise of 32 cm by 2050, as well as increases in tropical cyclone intensity and storm surge height. Rapid sea-level rise as an impact of climate change has become a threat to mangroves, which occur along the coasts of south Asian countries (Alongi 2008). Climate change effects, including sea level increases and storm surges, reduce biodiversity in the coastal wetlands and cause widespread saline intrusion. Sea level rises have already threatened to drown tropical mangroves in the Asian region. However, small clusters of mangroves species are reported in the protected sites along the beaches of a number of islands in the Maldives. The mangrove plant communities found along the shores, lagoons and river deltas in Sri Lanka are highly adapted to the saline habitat.

Precipitation and flooding of wetlands and peat-lands cause decomposition of large stocks of carbon substrates owing to a lack of oxygen. The climate-driven drying of wetlands and peat-lands has exposed large stocks of carbon substrates to aerobic decomposition (Davidson and Janssens 2006). In the South Asia sub-region, most of the large cities are situated, along with the majority of the population, along the coasts. The restructuring of coastal ecosystem management to adapt to climate change and reduce anthropogenic influences has brought about thorough local economic changes in South Asian countries. The rehabilitation of coastal area is also an important component of forest rehabilitation in the South Asia region. Reforestation of coastal areas, particularly mangrove ecosystems, is mostly financed and implemented by the government of Bangladesh to enhance the environment. (http://www.iufro.org/science/special/spdc/actpro/ keep/sa/) With the wider goals of coastal zone management in South Asia, where densely populated low-lying areas are at risk, flood impacts due to the sea-level rise need to be assessed together with other implications of climate change (Nicholls et al. 1999). Mangrove forests, which provide important ecosystem goods and services, are distributed in the inter-tidal region between the sea and land in the South Asian region (Giri et al 2008). Compared with the major forest domains in the world, mangroves have exceptionally high mean C storage among the most C-dense forests in the tropics (Donato et al. 2011). The conservation of mangrove forests ecosystems is, therefore, vitally important in adapting to climate change. Compared with the upland tropical forests, the carbon density in mangrove forests is more than four times higher (Donato, et al. 2011). Mangroves exhibit a high degree of ecological stability in terms of environmental constancy, community persistence, and community or ecosystem response to disturbance (Alongi 2008). Variably thick, tidally submerged 'peat' or 'muck' layers of mangrove soils support anaerobic decomposition pathways with moderate to high C concentrations (Kristensen et al. 2008). As tidal forests, mangrove ecosystems provide nursery grounds and breeding sites for birds, mammals, fish, crustaceans, shellfish, and reptiles (Manson 2005). Coastal forests, particularly, mangroves act as a windbreak in reducing the impact of cyclones and coastal storms on local communities. Mangrove forests serve as breeding and nursing grounds for marine species and are sources of food, medicine, fuel and building materials for local communities in the region (Giri et al. 2008). Mangrove ecosystems are important sources of food, timber, fuel, and medicine, especially in developing countries (Alongi 2008). Among the South Asian countries, large extents of mangrove forests are located in Bangladesh (438,764 ha), India (337,727 ha), and Sri Lanka (10,379 ha) (Giri et al. 2008). Bangladesh has placed emphasis on coastal afforestation under an immediate and urgent need to address the adverse impacts of climate change.

After the devastating Indian Ocean tsunami of December 2004, many national governments and international organizations have begun implementing conservation and rehabilitation programs for mangrove forests covering the coastal areas of Bangladesh, India and Sri Lanka (Giri et al. 2008). The importance of mangrove forests is highlighted, as they are a 'bio-shield' that protects vulnerable coastal communities from natural disasters. Many studies have confirmed the vital role played by mangroves in protecting and reducing the effects of the tsunamis on the southern coast in Sri Lanka (Mattsson et al. 2009). Mangroves offered a significant defense against the full tsunami impact in southeastern India, the Andaman Islands, and Sri Lanka. A casuarina (*Casuarina equisetifolia*) plantation also reduced the effects of the tsunami around coastal areas in Hambatota beach in Sri Lanka (De Zoysa 2008). Mangrove ecosystems create sites for the accumulation of sediment, nutrients, and contaminants and offer protection from waves, tidal bores, and tsunamis, in addition to being capable of dampening shoreline erosion (Alongi 2008). Sunderbans forests in southern Bangladesh helped to mitigate the effects of the cyclone in November 2007 (FAO 2008). The south-eastern coast of Bangladesh and Pichavaram, Devi Mouth, and Godavari in India have been selected as major mangrove reforestation and afforestation areas. The reforestation and rehabilitation programs of mangrove forests in both India and Bangladesh, which were initiated by the governments and local communities, have increased the mangrove forest areas. Mangrove forests in Bangladesh (+0.14%) and India (+0.04%) have been slightly expanded since 1995 after the initiation of the reforestation programs (Giri et al. 2008). The largest tracts of the remaining mangrove forest in the Sundarbans, an example of the coexistence of human, terrestrial and aquatic plant and animal life, have not been changed significantly in the last 25 to 30 years because of a strong commitment by the local communities and the governments of India and Bangladesh (Guha et al. 2015). The establishment of forest reserves, wildlife sanctuaries, national parks and international designations comprise the various protection measures taken by the governments of India and Bangladesh to keep the Sundarbans mangrove forest relatively intact (Roy and Hossain, 2015). Smaller patches of mangrove forests found in Sri Lanka and India are under immediate threat from human exploitation, as they are without the protection of the existing protected areas network. In some cases, local communities manage these small patches of mangrove forests (Giri et. al 2008).

5. CONCLUSIONS AND POLICY IMPLEMENTATION

The adverse impacts of climate change have significantly affected the quantity and quality of forest ecosystem services in South Asia. The South Asian region has already adopted a wide range of forest management strategies with community participation that have made great contributions to global climate change adaption actions. Each country in South Asia has implemented many different forestry management strategies addressing the expansion of carbon stocks by forests and trees, conservation and maintenance of existing forest carbon stocks, and management of fragile forest ecosystems for climate change adaptation. Climate change adaptation measures adopted in the forestry sector vary widely, reflecting the uncertainties associated with potential climate change scenarios and their likely impacts in each country. Forestry adaptation measures adopted at different locations in each country are context specific and dependent on the forms and extent of impacts, adaptive capacity and livelihood options for people vulnerable to a particular impact. Adaptation activities have moderated the adverse impacts of climate change by adjusting forest ecosystems and community management systems in South Asia. Adaptation to climate change should be considered as an integral part of sustainable development of forest resources and rural development strategies that are flexible and resilient to changing climatic conditions and central to community-based adaptation strategies in the South Asian region. Strengthening the adaptive capacity of the forestry sector requires mainstreaming climate change adaptation in development planning at the regional level as well as the implementation of specific programs at the national level for a transition toward a climate-resilient and low-carbon economy in South Asia.

REFERENCE

1. Agarwal B (2001) Participatory exclusions, community forestry, and gender: an analysis for South Asia and a conceptual framework. World Development 29 (10):1623–48.
2. Agarwal B (1987) Under the cooking pot: The political economy of the domestic fuel crisis in rural South Asia. IDS Bulletin 18 (1) (1987):1–22
3. Afunmilayo O. (2016). Africa's Shrinking Forests: A peep into Nigerian situation and its implications on socio-economic development. *Climate Change*, 2(6), 93-103
4. Akala VA, Lal R (2001) Soil organic carbon pools and sequestration rates in reclaimed mine soils in Ohio. J Environ Qual 30:2098–2104.
5. Alongi DM (2008) Mangrove forests: resilience, protection from tsunamis, and responses to global climate change. Estuar Coast Shelf Sci 76:1–13
6. Bajracharya SB, Furley PA, Newton AC (2005) Effectiveness of community involvement in delivering conservation benefits to the Annapurna conservation area, Nepal. Environmental Conservation 32 (3):239-247
7. Bhandari D (2008) Improving resilience: coping with global climate change locally. In: Komal Raj Aryal and Zaina Gadema (ed) Proceeding Climate change and disaster impact reduction, UK-South Asia young scientists and practitioners seminar on climate change and disaster impact reduction June05-06, 2008, Kathmandu, Nepal
8. Brown S, Sathaye J, Cannel M, Kauppi P, (1996) Management of forests for mitigation of greenhouse gas emissions. In: Watson RT, Zinyowera MC, Moss RH (ed) Climate change 1995: impacts, adaptations, and mitigation of climate change: scientific-technical analyses, Chapter 24, pp. 775-797
9. Canadell JG, Raupach MR (2008) Managing forests for climate change mitigation. Science, 320 1456 (2008) 95 http://www.sciencemag.org. Cited March 2014
10. CBD (2010) Decision adopted by the conference of the parties to the convention on biological diversity at its tenth meeting: the strategic plan for biodiversity 2011–2020 and the Aichi biodiversity targets http://www.cbd.int/decisions/cop. Cited March 2014
11. Davidson EA, Janssens IA (2006) Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. NATURE 440|9 March 2006:165-173
12. Defries R, Hansen A, Newton AC, Hansen MC (2005) Increasing isolation of protected areas in tropical forests over the past twenty years. Ecological Applications 15(1)

2005:19–26

13. De Zoysa M (2008) Casuarina coastal forest shelterbelts in Hambantota city, Sri Lanka: assessments of impacts. Small-scale forestry 2008 7:17–27
14. De Zoysa M, Inoue M, (2014) Climate change and agroforestry management in Sri Lanka: adverse impacts, adaptation strategies and policy implications. Proceedings of World Congress on Agroforestry 2014 (WCA2014), February 10-14, 2014, Delhi, India
15. Dixon RK, Brown S, Houghton RA, Solomon AM, Trexler MC, Wisniewski J (1994) Carbon pools and flux of global forest ecosystems. Science 263:185-190 http://academic.engr.arizona.edu/HWR/Brooks/GC572-2004/.../dixon.pdf. Cited May 2014
16. Donato DC, Kauffman JB, Murdiyarso D, Kurnianto S, Stidham M, Kanninen M (2011) Mangroves among the most carbon-rich forests in the tropics. Nature Geoscience 2011- 4:293–297
17. Ferrati R, Canziani GA, Moreno DR (2005) Estero del Ibera: hydrometeorological and hydrological characterization. Ecol Model 186:3–15
18. Ferraz G, Russell G, Stouffer P, Bierregaard R, Pimm S, Lovejoy T (2003) Rates of species loss from Amazonian forest fragments. Proceedings of the National Academy of Science 100, 14069–14073 http://www.pnas.org/content/100/24/14069 Cited March 2014
19. FAO (2014) Global review of forest pests and diseases http://www.fao.org/forestry/43795/en/. Cited February 2014
20. FAO (2012) South Asian forests and forestry to 2020; sub-regional report of the second Asia-Pacific forestry sector outlook study, Rap Publication 2012/10, Asia-Pacific Forestry Commission, Food and Agriculture Organization of the United Nations, Bangkok, 2012 pp 32-36 http://www.fao.org/docrep/016/i2785e/i2785e00.pdf. Cited February 2014
21. FAO (2011) Community-based fire management - a review, FAO – Forestry Paper 166, Food and Agriculture Organization of the United Nations Rome, 2011 pp 1-3 http://www.fao.org/docrep/015/i2495e/i2495e00.htm. Cited February 2014
22. FAO (2010a) Asia-Pacific forests and forestry to 2020 - Asia-Pacific forestry sector outlook study II, RAP Publication 2010/06. Bangkok, FAO regional office for Asia and the Pacific Bangkok, 2010 pp 30-32 http://www.fao.org/docrep/012/i1594e/i1594e00.htm. Cited March 2014
23. FAO (2010b) Global forest resources assessment - 2010. Rome: Food and Agriculture Organization of the United Nations pp 11-12 http://www.fao.org/docrep/013/i1757e/i1757e04.pdf. Cited March 2014
24. FAO (2006) Global forest resource assessment, progress towards sustainable forest management. Food and Agriculture Organization of the United Nations. Rome http://www.fao.org/forestry/fra/2620/en/. Cited March 2014
25. FAO (2006b). Global Forest Resources Assessment 2005 – Report on fires in the South Asian Region. Fire Management Working Paper 14. http://www.fao.org/forestry/site/fire-alerts/en. Cited March 2014

26. FAO (1993) Forestry policies of selected countries in Asia and the Pacific. FAO Forestry Paper 115. FAO, Rome http://www.fao.org/docrep/016/ap426e/ap426e00.pdf. Cited March 2014

27. Forest Survey of India (FSI) (2009) State of Forest Report, Ministry of Environment and Forest http://www.fsi.nic.in/sfr_2009.htm. Cited February 2014

28. Foster A, Rosenzweig M, (2003) Economic growth and the rise offorests. The Quarterly Journal of Economics 118:601–637

29. Friedlingstein P (2008) A steep road to climate stabilization. Nature 451:297–298

30. Gadgil M, Berkes F, Folke C (1993). Indigenous knowledge for biodiversity conservation. Ambio 22 (2–3) (1993):151–156

31. Gera M, Bist NS, Gera N (2003) Carbon sequestration through community based forest management. Indian Forester 129(6)(2003):135–140

32. Giri C, Zhu Z, Tieszen LL, Singh A, Gillette S, Kelmelis JA (2008) Mangrove forest distributions and dynamics (1975–2005) of the tsunami-affected region of Asia. Journal of Biogeography 35-3:519–528

33. Goldammer JG (2007) History of equatorial vegetation fires and fire research in Southeast Asia before the 1997–98 episode: a reconstruction of creeping environmental changes. Mitig Adapt Strat Glob Change (2007)12:13–32

34. Goldammer JG, Peñafiel SR (1990) Fire in the pine-grassland biomes of tropical and subtropical Asia. Ecological Studies 84 1990:45-62

35. Guha P, Aitch P, Bhandari G. (2015) Climate change and its impact on the ecological system of the Indian Sundarban region. *Climate Change*, 1(4), 432-438

36. Harmon ME, Marks B (2002) Effects of silvicultural treatments on carbon stores in forest stands. Canadian Journal of Forest Research 32:863–877

37. Heller NE, Zavaleta ES (2009) Biodiversity management in the face of climate change: a review of 22 years of recommendations. Biological Conservation 142 (2009):14 – 32

38. Hill I, Shields D (1998) Incentives for JFM in India: analytical method and case studies. The World Bank, Washington, DC (1998) Technical Paper 394 http://www.elibrary.worldbank.org/doi/pdf/10.1596/0-8213-4143-X. Cited January 2014

39. Houghton R, Skole D, Nobre C, Hackler J, Lawrence K, Chementowski W, (2000) Annual fluxes of carbon from deforestation and regrowth in the Brazilian Amazon. Nature 403:301–304

40. Hulme PE (2005) Adapting to climate change: is there scope for ecological management in the face of a global threat? J Appl Ecol 43:617–27

41. Huq S, Reid H, Murray LA (2006) Climate change and development links, the gatekeeper series. London: International Institute for Environment and Development. pp 23-25

42. IPCC (2002) Climate and Biodiversity. IPCC Technical Paper V. In: Gitay H, Suarez A, Watson RT, Dokken DJ (ed) Intergovernmental Panel on Climate Change (IPCC) https://www.ipcc.ch/.../technical-papers/climate-changes-biodiversity-en. Cited January 2014

43. IPCC (Intergovernmental Panel for Climate Change) (2001) Climate change 2001 – impacts, adaptation and vulnerability, contribution of working group II to the Third assessment report of the intergovernmental panel on climate change. https://www.ipcc.ch/publications.../publications_and_data_reports.shtml. Cited January, 2014
44. Islam MS, Al. Imran M, Mandol S, Bhuyan MS. (2016) Restoration of saltmarsh as mitigative measure of climate change impact at Chittagong coastal area of Bangladesh. *Climate Change*, 2(8), 313-329
45. Jhansi SC, Mishra SK (2008) Environmental concerns in Asia-Pacific region. Asia-Pacific Social Science Review 8:2 (2008):117-127
46. Jump AS, Penuelas J (2005) Running to stand still: adaptation and the response of plants to rapid climate change. Ecology Letters. 8 (9):1010-1020
47. Kasahun Kitila Hunde. (2015a) The role of Agroforestry system as strategy to adapt and mitigate climate change: A review with examples from Tropical and Temperate regions. *Climate Change*, 1(1), 20-25
48. Kasahun Kitila Hunde. (2015b) Evaluation of Soil Carbon Pool potential under different Land use system and Its Correlation with different Soil Properties in North Wales, UK. *Climate Change*, 1(2), 54-61
49. Khan JA, Rodgers WA, Johnsingh AJT, Mathur PK (1994) Tree and shrub mortality and debarking by Sambar Cervus-Unicolor (Kerr) in Gir after a drought in Gujarat, India. Biological Conservation 68:149–154
50. Khoshoo TN (1995) Census of India's biodiversity: tasks ahead. Current Science 69 (1995):14–17
51. Khosla PK, Kohli RK (1987) Social forestry for rural development. Indian Society of tree scientists, Solan, H. P., India pp 44-46
52. Kinkini Dasgupta Misra. 2016. Women as agents of environmental change. *Climate Change*, 2(5), 34-43
53. Knutson TR, Tuleya RE (2004) Impact of CO2-induced warming on simulated hurricane intensity and precipitation: sensitivity to the choice of climate model and convective parameterization. J Climate 17:3477–3495
54. Köhlin G, Amacher GS (2005) Welfare implications of community forest plantations in developing countries: the Orissa social forestry project. Am J Agr Econ (2005) 87 (4):855-869.
55. Krishnaswamy A (1995) Sustainable development and community forest management in Bihar, India. Society and Natural Resources 8:339-350
56. Kristensen E, Bouillon S, Dittmar T, Marchand C (2008) Organic carbon dynamics in mangrove ecosystems. Aquat Bot 89:201–219
57. Kumar N (2010) Practice of community adaptation to climate change: a case of community forestry user groups of Nepal. Livelihoods and forestry program, Kathmandu, Nepal. pp 22-23
58. Kumari P, Nema AK. (2015) Soil carbon sequestration enhancement techniques: an emergent technology to mitigate climate change. *Climate Change*, 1(4), 463-468
59. Kunwar RM, Khaling S (2006) Forest fire in the Terai, Nepal causes and community management interventions. International Forest Fire News 34(2006):46-54
60. Lal R (2005) Forest soils and carbon sequestration. Forest

Ecology and Management 220 (2005):242–258 95 http://www.elsevier.com/locate/foreco. Cited April 2014

61. Lal R (2004) Soil carbon sequestration impacts on global climate change and food security. Science 304 11 June 2004:1623-1627 http://www.sciencemag.org. Cited April 2014

62. Lasco RD, Pulhin FB, Sanchez PAJ, Villamor GB, Villegas KAL (2008) Climate change and forest ecosystems in the Philippines: vulnerability, adaptation and mitigation. Journal of Environmental Science and Management 11(1):1-14 (June 2008)

63. Lavelle P (1997) Faunal activities and soil processes: adaptive strategies that determine ecosystem function. Adv Ecol Res 27:93–132 http://horizon.documentation.ird.fr/exl-doc/pleins...7/.../010015216.pdf. Cited May 28, 2014

64. Lhendup P (2012) Integration of climate adaptation into development and conservation planning in Bhutan: issues and recommendations, adaptation knowledge platform, Partner Report Series No. 1., Stockholm Environment Institute, Bangkok. pp 3-5 http://www.climateadapt.asia/resources/publication/view/97. Cited January 2014

65. Long AJ, and Nair PKR (1999) Trees outside forests: agro-community and urban forestry. New Forests 17:145-174

66. Magreth Bushesha. (2015) Analysis of Seasonality Variations and Copping Strategies among Cocoa Growers: A Case of Kyela and Rungwe Districts. *Climate Change*, 1(2), 112-121

67. Manson RA, Loneragan NR, Skilleter GA, Phinn SR (2005) An evaluation of the evidence for linkages between mangroves and fisheries: a synthesis of the literature and identification of research directions. Oceanography and Marine Biology: An Annual Review 43:483 - 513

68. Mather AS (2007) Recent Asian forest transitions in relation to forest-transition theory. International Forestry Review 9(1) 2007:491-502

69. Mattsson E, Ostwald M, Nissanka SP, Holmer B, Palm M (2009) Recovery of coastal ecosystems after tsunami event and potential for participatory forestry CDM – examples from Sri Lanka. Ocean and Coastal Management 52:1-9

70. Miles L, Newton AC, DeFries RS, Ravilious C, May I, Blyth S, Kapos V, Gordon JE (2006) A global overview of the conservation status of tropical dry forests. Journal of Biogeography (2006) 33:491–505

71. Millar CI, Stephenson NL, Stephens SL (2007) Climate change and forests of the future: managing in the face of uncertainty. Ecological Applications 17(8) 2007:2145–2151

72. MOEF (2008) Bangladesh climate change strategy and action plan – 2008. Ministry of environment and forests, government of the People's Republic of Bangladesh, (MoEF: Dhaka, 2008) pp. 37

73. Mirov NT (1967) The genus pinus. The Ronald Press, New York, 602 pp

74. Mirza MQ (1998) Modeling the effects of climate change on flooding in Bangladesh diss. international global change institute (IGCI), University of Waikato, Hamilton, New Zealand, pp. 277-80

75. Mirza MQ, Ericksen NJ (1996) Impact of water control projects on fisheries resources in Bangladesh. Environmental Management 20(4):527–539

76. Nicholls RJ, Hoozemans FMJ, Marchand M (1999) Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses. Global Environmental Change 9 (1999) S69-S87
77. Nicholls RJ, Leatherman SP, Dennis KC, Volonte CR (1995) Impacts and responses to sea-level rise: qualitative and quantitative assessments. Journal of Coastal Research Special Issue 14:26-43
78. Nordt LC, Wilding LP, Drees LR, (2000) Pedogenic carbonate transformations in leaching soil systems: implications for the global C cycle. In: Lal R, Kimble J, Mtimet A, Eswaran H, Scharpenseel H (ed) Global Climate Change and Pedogenic Carbonates, Lewis Publishers, Florida pp 43-64.
79. Perera N, Fernando K (2004) Sustainable land management: South Asia perspectives. Proceedings of sub-regional workshop on development of the South Asia sub-regional action program for combating desertification and Promoting sustainable land management, July 5-8, 2004, Colombo, Sri Lanka
80. Poffenberger M, Singh C (1992) Emerging directions in Indian forest policy: legal framework for joint management. Wasteland News Feb-Apr:4–9.
81. Proffenberger M, Ravindranath NH, Pandey DN, Murthy IK, Bist R, Jain D, (2001) Communities and climate change: a case study from Harda forest division, Madhya Pradesh, India
82. Ram Asheshwar Mandal, Pramod Kumar Jha, Devi Chandra Pokhrel. (2016). Evaluating Climate Change Resilience Capacity of Community Forests Users in Terhathum Districts, Nepal. *Climate Change*, 2(8), 300-312
83. Rasul G (2010) The role of the Himalayan mountain systems in food security and agricultural sustainability in south Asia. International Journal of Rural Management April 2010 6 (1):95-116
84. Roberts G, (2008) Policies and instruments for the adaptation of forests and the forest sector to impacts of climate change as indicated in United Nations Framework. Convention on climate change national reports; IUFRO Occasional Paper No. 22. Vienna, Austria http://www.iufro.org/.../policies-and-instruments-for-the-adaptation-of-forests. Cited January 2014
85. Ross DJ, Tate KR, Scott NA, Wilde RH, Rodda NJ, Townsend JA (2002) Afforestation of pastures with pinusradiata influences soil carbon and nitrogen pools and mineralization and microbial properties. Aust J Soil Res 40:1303–1318
86. Roy TK, Hossain ST. (2015). Role of Sundarbans in Protecting Climate Vulnerable Coastal People of Bangladesh. *Climate Change*, 1(1), 40-44
87. Saha S, Howe HF (2001) The bamboo fire cycle hypothesis: a comment. American Naturalist 158:659-664
88. Satterthwaite D, Huq S, Pelling M, Reid H, Romero LP (2007) Adapting to climate change in urban areas: The possibilities and constraints in low- and middle income nations. London: International institute for environment and development http://www.alnap.org/pool/files/10549 iied.pdf. Cited March 2014
89. Saxena NC, Ballabh V (1995) Farm Forestry in South Asia. Sage, New Delhi, India

90. Scarascia-Mugnozza G, Oswald H, Piussi P, Radoglou K (2000). Forests of the Mediterranean region: gaps in knowledge and research needs. Forest Ecology and Management 132 (2000):97-109

91. Senz A, Reinhardt D (2010) Green governance - one solution for two problems? Climate change and economic shocks: risk perceptions and coping strategies in China, India and Bangladesh. Duisburger Arbeitspapiere Ostasienwissenschaften, 86/2010 http://hdl.handle.net/ 10419/45002. Cited January 2014

92. Shyamsundar P, RuchaGhatey R (2014) Rights, rewards, and resources: lessons from community forestry in south Asia. Rev Environ Econ Policy (Winter 2014) 8 (1):80-102

93. Singh PP (2008) Exploring biodiversity and climate change benefits of community-based forest management. global Environmental Change 18 (3) August 2008:468–478

94. Singh P, (1998) Effect of global warming on the stream flow of high-altitude Spiti River. In: Chalise SR, Herrmann A, Khanal NR, Lang H, Molnar L, Pokhrel AP (ed) Ecohydrology of high mountain areas International Centre for Integrated Mountain Development, Kathmandu, Nepal, pp. 102–109

95. Stephens SL, Moghaddas JJ (2005) Silvicultural and reserve impacts on potential fire behavior and forest conservation: 25 years of experience from Sierra Nevada mixed conifer forests. Biological Conservation 25:369–379

96. Suryanarayana K, Harinath P, Venkata Ramana SP. (2015) Impact of climate change on butterfly diversity in Seshachalam bio reserve forest of Southern Andhra Pradesh. *Climate Change*, 1(1), 26-39

97. Tsegaye T, Arsema A, Irwin BC (2007) Watching the tree grow: participatory forest management takes root in Africa. Proceedings of international conference on poverty reduction and forests, Bangkok, September 2007 pp 23~28

98. United Nations convention on combating desertification (UNCCD) (2007) Women pastoralists: preserving traditional knowledge facing modern challenges. Bonn, UNCCD. http://www.preventionweb.net/english/professional/publications/v.php?id=1831. Cited January 2014

99. UNFCCC (United Nations framework convention on climate change) (2002) Report of the Conference of the Parties on its seventh session, October 29–November 10, 2001, Marrakech. http://www.unfccc.int/resource/docs/ cop7/13a01.pdf. Cited January 2014

100. van Noordwijk M, Minangn P (2011) Another Missing Link in Climate Change Policy. Trees Outside Forests, Apr 4, 2011, University of Copenhagen, Denmark. http://ccafs.cgiar.org/blog/another-missing-link-climate-change-policy-trees-outside-forests. Cited January 2014

101. Veblem TT, Kitzberger T, Villalbda R, Donnegan J (1999). Fire history in northern Pantagonia: the role of humans and climate variation. Ecological Monography 69 (1999):47–67

102. Wijewardene R and Waidyanatha P 1984 Conservation farming systems, techniques and tools. Dept. of Agriculture, Sri Lanka and the Commonwealth Consultative Group on Agriculture for the Asia-Pacific Region 38 pp

103. Zimmerer KS, Galt RE, Buck MV (2004) Globalization and multi-spatial trends in the coverage of protected-area

conservation (1980–2000). AMBIO: A Journal of the Human Environment 33(8):520-529. 2004

104. Zomera RJ, Trabuccob A, Bossioc DA, Verchot LV (2008) Climate change mitigation: a spatial analysis of global land suitability for clean development mechanism afforestation and reforestation. Agriculture, Ecosystems & Environment 126 (1–2) June 2008:67–803):239-247