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ORIGINAL ARTICLE

Mitigation and adaptation synergy in forest sector

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Abstract Mitigation and adaptation are the two main strategies to address climate change. Mitigation and adaptation have been considered separately in the global negotiations as well as literature. There is a realization on the need to explore and promote synergy between mitigation and adaptation while addressing climate change. In this paper, an attempt is made to explore the synergy between mitigation and adaptation by considering forest sector, which on the one hand is projected to be adversely impacted under the projected climate change scenarios and on the other provide opportunities to mitigate climate change. Thus, the potential and need for incorporating adaptation strategies and practices in mitigation projects is presented with a few examples. Firstly, there is a need to ensure that mitigation programs or projects do not increase the vulnerability of forest ecosystems and plantations. Secondly, several adaptation practices could be incorporated into mitigation projects to reduce vulnerability. Further, many of the mitigation projects indeed reduce vulnerability and promote adaptation, for example; forest and biodiversity conservation, protected area management and sustainable forestry. Also, many adaptation options such as urban forestry, soil and water conservation and drought resistant varieties also contribute to mitigation of climate change. Thus, there is need for research and field demonstration of synergy between mitigation and adaptation, so that the cost of addressing climate change impacts can be reduced and co-benefits increased.

Keywords Mitigation and adaptation synergy · Forest ecosystems · Vulnerability of forests · Forest sector mitigation

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1 Introduction

The earth's climate has demonstrably changed on both global and regional scale since pre-industrial era with some change attributed to human activities (IPCC 2001a). The projected climate change is likely to impact natural ecosystems and socio-economic systems (IPCC 2001b). Climate change is caused by human induced greenhouse gas (GHG) emissions and the resulting increase in its concentration in the atmosphere. Global efforts to address climate change include two basic responses; mitigation and adaptation. Mitigation is defined as an anthropogenic intervention to reduce the sources or enhance the sinks of GHGs. Actions that reduce net GHGs reduce the projected magnitude and rate of climate change and thereby lessen the pressure of climate change on natural and human systems. Therefore, mitigation actions are expected to delay and reduce damages caused by climate change, providing environmental and socio-economic benefits (IPCC 2002).

Adaptation is adjustment in natural or human systems in response to actual or expected climatic stimuli and their impacts on natural and socio-economic systems, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished including anticipatory and reactive adaptation, private and public adaptation and autonomous and planned adaptation (IPCC 2002). Adaptation measures can occur at population, community, and personal or at production system (food, forestry and fisheries) level. It is very important to note, especially from the developing country's perspective, that climate mitigation strategies will have a long-term global impact on greenhouse damage, whereas adaptation policies generally have a positive direct immediate effect for the countries and regions that implement them.

The focus of Climate Convention, Kyoto Protocol as well as majority of the global mechanisms is mitigation. The goal of UNFCCC is to achieve stabilization of GHG concentration in the atmosphere at levels that would prevent dangerous anthropogenic interference with climate. Is mitigation alone adequate? Now it is well known that even with the most ambitious mitigation policy, climate change seems likely to occur. Even under a most aggressive mitigation scenario, climate change is likely to leave an impact, particularly given the long life of different GHGs in the atmosphere (Bruce et al. 1996). Thus, adaptation is a necessary strategy to complement mitigation efforts. Adaptation can complement mitigation in a cost-effective manner to reduce climate change risks.

Normally in literature, global negotiations and policy-making mitigation and adaptation are addressed separately, including in the IPCC reports where Working Group II addresses adaptation and Working Group III addresses mitigation (Ravindranath and Sathaye 2002). This was and continues in Assessment Report IV of IPCC, which is under preparation. However, Assessment Report IV of IPCC for the first time is attempting to address the synergy and trade-offs between mitigation and adaptation. IPCC (2002) attempted to address the synergy between mitigation and adaptation in the context of 'climate change and biodiversity', highlighting the linkage between climate mitigation and biodiversity conservation as well as implications of conservation of biodiversity for mitigation. Thus, there is a need to explore the possibility of promoting synergy between mitigation and adaptation. The global effort should be to promote the synergy and reduce or avoid any trade-off between mitigation and adaptation.

In this paper, an attempt is made to assess the need for and opportunities to promote synergy between mitigation and adaptation, by taking forest sector as an example. Forest sector provides opportunities to promote synergy between mitigation and adaptation since forest ecosystems on the one hand are likely to be significantly impacted by the projected

climate change (IPCC 2001b) and on the other forest sector or broadly Land Use Land-Use Change and Forestry (LULUCF) is expected to provide significant opportunity to mitigate climate change at about 2 Gt Carbon annually, according to the Third Assessment Report of IPCC (2001c). The paper finally highlights the need for incorporating adaptation component in mitigation projects and vice-versa. In this paper, the economic aspects of synergy and trade-off between mitigation and adaptation and political aspects of mitigation or adaptation are not addressed.

2 Climate impacts on forest sector

Ecosystems, particularly forest ecosystems, are critical for environmental sustainability as they are of fundamental importance to various environmental functions. Forests also provide several direct benefits such as food, timber and non-timber products, and indirect benefits such as watershed protection. Forests preserve biodiversity and have cultural, religious, aesthetic and recreational value to communities. It is very important to ensure that climate change does not limit the ability of forest ecosystems to provide a range of products and services to local communities, the national economies and global environment.

The ecosystems are subjected to many pressures such as land-use change, harvesting, grazing by livestock, fire, introduction of new species and natural climate variability. Climate change constitutes an additional pressure that could change or endanger these ecosystems. Recent modeling studies show potential significant disruption of ecosystems under climate change. Some of the potential impacts on the forest ecosystems as summarized in the Third Assessment Report of the IPCC (2001b) are as follows:

- Populations of many species that are already threatened are expected to be placed at greater risk by the synergy between the stresses of changing climate and land-use change that fragments the habitats.
- The latest vegetation distributional models suggest that mass ecosystem or biome movement is most unlikely to occur due to different climatic tolerance of the species involved, different migration abilities and the effects of invading species.
- Species composition and dominance could be altered, resulting in ecosystem changes.
- Some species that are currently classified as ''critically endangered'' could become extinct, without adaptation.
- Terrestrial ecosystems appear to be storing increasing quantities of carbon. Productivity gains are occurring due to changes in climate parameters as well as changes in uses and management of land.
- Global timber market studies that include adaptations through land and product management suggest that climate change would increase global timber supply and consumers will benefit from lower timber prices, while producers may gain or lose depending on regional changes in timber productivity and potential dieback effects.
- In arid or semi-arid areas (dry forests, woodlands and rangelands) where climate change is expected to decrease the available soil moisture, biomass productivity is expected to decrease. However, increased CO_2 concentration may counteract some of these losses. Many of these areas are affected by El Nino/La Nina, other climate extremes and fire. Occurrence of such events could lead to loss of productivity, potential loss of stored carbon or decrease in the rate of carbon uptake.

- Forests or heathlands will replace some wetlands, and those overlying permafrost are likely to be disrupted as a result of thawing of permafrost.

Though there are uncertainties with respect to projections of climate change impacts on forest ecosystems, evidence is growing to show that climate change, coupled with socio-economic and land use pressures, is likely to adversely impact forest biodiversity, carbon sink, biomass productivity or carbon uptake rates, livelihoods of forest dependent communities and economies.

3 Mitigation opportunities in the forest sector

The forestry sector mitigation activities can be broadly categorized into three groups viz., forest carbon sink conservation and management measures; carbon storage management (expanding forest carbon sinks); and fossil fuel substitution management activities (Brown et al. 1996). Some of the features of the forest sector are discussed below (Ravindranath et al. 2000).

i) *Long gestation period*: Forestry projects (such as natural regeneration or hardwood plantations) could take 50–100 years to provide significant carbon mitigation benefits. The long gestation period leads to uncertainties regarding carbon abatement, socio-economic impacts and permanence of carbon stocks.
ii) *Subsistence economy and mitigation*: In tropical countries, millions of indigenous and rural households depend on forests for their livelihood, while, in temperate countries, forests meet the commercial needs of the population. Forestry projects would therefore impact the livelihood and local economies in developing countries either positively or negatively.
iii) *Subject to natural disturbances*: Forests and plantations are susceptible to fire, drought, pests and diseases affecting the carbon stocks and flows, giving rise to the issue of permanence of stocks.
iv) *State control of forests*: In most countries, particularly in the tropics, forests are largely controlled and managed by the State Forest Departments, often leading to conflicts with local communities, with implications for sustaining carbon stocks.
v) *Links to local and global environmental factors*: Decisions on forestry mitigation will affect biodiversity and other ecological aspects such as watershed protection, resilience to climate change and prevention of desertification.
vi) *Low economic returns*: Some forestry options have low or even negative economic return. This impedes the investments from private (commercial) sectors.
vii) *Participation of local communities*: Local community participation is required for implementing mitigation projects in regions where communities currently reside in or depend on the forests.

Thus, the mitigation opportunities in LULUCF sector are associated with many uncertainties and is linked to environmental and socio-economic concerns. A potential list of mitigation activities along with implications for carbon sequestration or emission reduction, biodiversity conservation and socio-economic benefits are given in Table 1.

The most obvious primary mitigation opportunities relate to slowing or halting deforestation to reduce carbon emissions, and reforesting the deforested lands to sequester or remove carbon from the atmosphere. Potential mitigation activities vary from country to country due to land availability, soil quality, land tenure policies, dependence on forests,

Table 1 Climate mitigation activities, mitigation potential, benefits and impacts

Activities, practices and management systems	Carbon sequestration or emission reduction potential	Biodiversity conservation	Socio-economic benefits
Carbon conservation			
Deforestation reduction through policy changes	+++	+++	++
Formation of protected areas	+++	+++	++
Monitoring forest area and vegetation changes	++	++	++
Sustainable forest management	+++	++	+++
Fire protection techniques	++	++	+
Reduced impact logging	++	++	+++
Recreational reserves	++	++	+++
Carbon sequestration			
Afforestation	++	++	++
Reforestation	+++	++	++
Industrial plantations	++	+	+++
Agro-forestry	++	++	+++
Urban forestry	++	++	+++
Carbon offsets (substitution for fossil fuels and unsustainably harvested wood)			
Short rotation forestry for biofuels	+++	++	+++
Sustainable biomass plantation	+++	++	+++
Waste use for energy	++		+++
Efficient processing technologies	++	+	++
Recycling of forest products	++	++	++
Bioenergy (Bioelectricity through gasification of biomass or combustion)	+++	++	++
Fuel efficient stoves	+	++	+++
Biogas for cooking	+++	++	+++
Efficient charcoal kilns	++	++	++
Carbon offsets from wood products			
Recycling forest products	++	+	+
Substitution of fossil-fuel intensive products with wood products	++	+	+
Storage in long-term wood products	++	+	

Source: Ravindranath et al. (2000)

Notes hasis>: + Low Positive Impact; ++ Medium Positive Impact; +++ High Positive Impact

level of economic development and so on. The Third Assessment Report of the IPCC estimates that LULUCF activities together offer a biological mitigation of 100 Gt C by 2050, equivalent to about 10–20% of projected fossil fuel emissions during the period (Kauppi and Sedjo 2001).

4 Adaptation to projected climate change in the forest sector

Adaptation to projected climate impacts in forest sector is critical due to the following (based on IPCC 2001d).

- *Threat to unique ecosystems and biodiversity*: Climate change could cause irreversible damage to unique ecosystems and biodiversity, rendering several species extinct, locally and globally.
- *Distributional impact*: In developing countries there is a large proportion of population depending on the climate sensitive sectors such as agriculture, forests and fisheries. Forest dwellers form one of the poorest sections of society in the developing countries that are likely to be adversely impacted due to climate change. Climate change could also adversely affect timber production, markets, trade and prices.
- *Adaptation capacity*: Due to poorly developed institutions, markets, technology transfer pathways and lack of financial resources, developing countries and particularly forest dependent communities have low capacity to cope with or adapt to adverse impacts. Those with the least resources and the least capacity to adapt such as forest dwellers are the most vulnerable.
- *Extreme weather events*: Forest sector is likely to be vulnerable to extreme events such as droughts coupled with warming leading to increased occurrence of fires to which local governments and institutions, especially in developing countries, could find it difficult to cope with.
- *Long gestation periods for developing and implementing adaptation strategies*: Development and implementation of adaptation strategies and practices in the forest sector would require long gestation periods, years of research and development, institutional building and education.

Inertia in climate, ecological and socio-economic systems make adaptation inevitable and already necessary in some cases. The forest dependent communities and forest ecosystems that are vulnerable to climate change are also under pressure from factors such as population growth, depletion and degradation of forests and pastures. Many of the measures needed to address current pressures could also reduce vulnerability and thus contribute to sustainable development.

Adaptation to climate change in forest sector is characterized by long gestation periods requiring advance planning, implementation and monitoring. Adaptation to climate change in forest sector include 'no regret' strategies that are required to address current stresses such as deforestation, forest fragmentation, cattle grazing and non-sustainable extraction as well as, dedicated strategies some examples of which are listed below. It is important to recognize that currently, the knowledge about dedicated adaptation strategies is limited in the forest sector. Further, adaptation to losses in natural ecosystems and biodiversity may be difficult or impossible (IPCC 2001b). The following strategies and practices are likely to reduce vulnerability of forest and plantation ecosystems:

- Forest conservation and biodiversity conservation
- Expansion of protected areas
- Sustainable logging and management of forests
- Mixed species forestry
- Anticipatory planting and assisted natural migration through transplanting plant species

- Silvicultural practices for ameliorating the effects of climate change (Solomon et al. 1996) on forest sector some examples are; sanitation harvest, shortening of rotation cycle, thinning and fire control practices.

5 Mitigation and adaptation; synergy

Under the UNFCCC, mechanisms such as the Global Environmental Facility (GEF), Clean Development Mechanism (CDM), activities under Article 3.3 (afforestation, reforestation and halting deforestation) and 3.4 (forest and grass management, etc.) of the Kyoto protocol and many mechanisms such as Adaptation Fund etc. are being operationalized or implemented. Many of them aim at implementation of either mitigation or adaptation technologies or policies; GEF and Adaptation Fund support adaptation strategies and GEF, CDM, and Article 3.3 and 3.4 activities under the Kyoto Protocol aim at promoting mitigation. Thus, it is necessary to explore if a synergy is possible in planning and implementation of mitigation and adaptation projects to derive maximum benefit to the global environment as well as local communities or economies. Thus, the focus is on exploring if adaptation technologies and strategies can be incorporated in mitigation projects in the forest sector and vice versa. Activities beyond the narrow set of activities included under the Kyoto Protocol are also considered. The synergy is addressed with a few examples of mitigation and adaptation practices and projects. In this paper, the economic aspects of synergy and trade-off between mitigation and adaptation and political aspects of mitigation or adaptation are not addressed.

LULUCF mitigation activities (afforestation, reforestation, avoided deforestation and improved forest and grassland management practices) may affect biodiversity and in turn increase the vulnerability of the forest ecosystems. Similarly, climate change adaptation activities can promote conservation and sustainable use of biodiversity, and in turn conserve or enhance the carbon stocks in forest ecosystems (IPCC 2002).

5.1 Incorporating adaptation in mitigation projects

Mitigation projects are already being implemented or are in the planning stage especially in the LULUCF sector. Further, global negotiations will soon start for the second commitment period beyond 2012 under the Kyoto Protocol. It is quite likely that the scope of sink or LULUCF sector and activities may increase beyond the narrow set of activities included in the Kyoto Protocol. Adaptation opportunities exist in mitigation projects under forest conservation, afforestation, reforestation and fossil fuel substitution activities. Further, examples of how mitigation opportunities can actually become adaptation strategies are discussed in this section.

i) *Forest conservation*: Area under forests declined by around 15 Mha in the tropics during 1990–2000 (FAO 2001). Deforestation and forest degradation and fragmentation lead to emission of carbon. Thus, forest conservation, by halting deforestation and forest degradation, is a dominant mitigation option. Is forest conservation also an adaptation option? Yes, it is a very important adaptation option. Forests, especially the biodiversity rich tropical forests are more resilient to climate impacts than monoculture plantations or any artificial forest. A forest consisting of multiple species are more

resilient or less vulnerable due to different climate tolerance of different species, different migration abilities and effectiveness of invading species (IPCC 2001b). Native species are less likely to be vulnerable than exotic species to climate change. Forest conservation should be a dominant mitigation option to address climate change not only because of the large contribution to GHG emissions from deforestation, but also due to low vulnerability of natural forests rich in biodiversity and dominated by native species, to climate change. Thus, forest conservation that is both mitigation as well as an adaptation option to address climate change, should get priority in global efforts. Forest conservation is also a critical strategy to promote sustainable development due to its importance for biodiversity conservation, watershed protection and promotion of livelihoods of forest dependent communities (IPCC 2002).

ii) *Protected area management*: Expansion of protected area and its management could lead to protection of forests from degradation and promote regrowth of trees since formation of protected area and its effective management prevents forest degradation and conversion. Prevention of felling of trees and conversion of forestland leads to conservation of carbon sink in the forests. Regrowth of trees due to effective protection will lead to carbon sequestration. Formation and management of protected areas also leads to conservation of biodiversity, in turn reducing the vulnerability to climate change. One of the additional adaptation strategies to be incorporated while forming a protected area is to link different protected areas to create opportunities for migration of flora and fauna, which facilitates adaptation to changing climate.

iii) *Afforestation and reforestation*: Afforestation and reforestation are the dominant mitigation opportunities currently being pursued in the global negotiations as well as the focus of literature concerning mitigation in the forest sector. Afforestation and reforestation are also included under Article 3.3 as well as Article 12 of Kyoto Protocol under CDM. The annual area brought under afforestation in tropical countries is around 3 Mha compared to a deforestation rate of around 15 Mha (FAO 1999 and 2001). Thus, there is a large opportunity to undertake afforestation and reforestation globally, particularly in tropical or developing countries.

Afforestation and reforestation activities proposed as mitigation activities, provide opportunity for adaptation. Some examples of adaptation practices that can be and need to be incorporated in any afforestation and reforestation mitigation project are as follows:

- Promotion of regeneration of native species through protection and natural regeneration in degraded natural forest lands, to reduce vulnerability to changing climate
- Promotion of multi-species plantation forestry incorporating native species, in place of monoculture plantation of exotic species to reduce vulnerability
- Adoption of short rotation species in commercial or industrial forestry to enable adaptation to any adverse impact of climate change
- Incorporation of several silvicultural practices such as sanitation harvest, increased thinning to reduce occurrence of pests and diseases
- Incorporation of fire protection measures to reduce vulnerability of forests to fire hazard due to warming accompanied by droughts
- Incorporation of soil and water conservation measures to reduce the adverse impacts of drought on forest growth.

The above measures could be incorporated into afforestation and reforestation mitigation projects to reduce vulnerability of forest plantations to changing climate with no or minimal additional costs.

iv) *Bioenergy plantations*; produce feedstock for biomass energy systems. Normally bioenergy plantations are likely to be intensively managed to produce biomass for energy. To ensure sustainable supply of biomass feedstock and to reduce vulnerability to climate change it is necessary to adopt the practices mentioned above for afforestation and reforestation projects such as, mixed species forestry, short rotation species and fire protection measures. Such practices, which conserve biodiversity, are likely to reduce vulnerability of energy plantations.

v) *Agro-forestry*; has a large potential to sequester carbon, particularly in tropical countries. Agro-forestry practices including multi-purpose trees and leguminous species can reduce the vulnerability of crop production to climate change, particularly droughts.

vi) *Sustainable forest management*: Currently only a small proportion of the forest is sustainably managed leading to reduction in CO_2 emissions. Sustainable forest management practices not only contribute to reduction in CO_2 emissions but also reduce the vulnerability of forests to climate change.

vii) *Urban forestry*; involves formation of parks, planting trees along the avenue, and growing trees within residential compounds. It is necessary to adopt multi-species and multi-purpose approach in urban forestry to reduce vulnerability of tree species to climate change. Urban trees along the avenue and the residential compounds provide shade, reduce need for air conditioning, thus an adaptation option to heat stress due to warming.

Consideration of adaptation practices in mitigation activities and projects shows the presence of synergy. Adaptation practices could be incorporated synergistically in most mitigation projects in the LULUCF sector. Further, many of the mitigation projects such as forest conservation or protected area formation are also adaptation activities reducing the vulnerability of forest ecosystems. Land management and sustainable forest management actions to offset GHG emissions can have an impact on overall environmental quality including soil quality and erosion, water quality, air quality, and wildlife habitat; in turn, these can have impacts on terrestrial and aquatic biodiversity (IPCC 2002).

5.2 Mitigation in adaptation strategies and projects

Adaptation strategies include *'no regret'* as well as dedicated strategies or practices to reduce vulnerability of forest ecosystems to climate change. In the previous section, the potential and need for incorporating adaptation concerns and practices in the emerging mitigation programs and projects was presented. Here the need for incorporating the mitigation concerns and practices in adaptation projects as well as the complimentarity that could exist is assessed. It must be noted that there is little information on how mitigation practices can be incorporated into any adaptation project, unlike the information on the adaptation practices in mitigation projects. Adaptation practices such as forest and biodiversity conservation, protected area formation and mixed species forestry based afforestation are not only mitigation options reducing CO_2 emissions or sequestering carbon, but are also adaptation options to reduce vulnerability of forest ecosystems to climate change. Some examples of adaptation options and practices, which also contribute to mitigation by reducing CO_2 emissions or sequestering carbon, are as follows:

- *Soil and water conservation*; a key adaptation practice aimed at reducing vulnerability also reduces carbon loss from soils as well as enhances soil carbon density by increasing biomass growth rate of forests or plantation or grassland.
- *Drought resistant varieties or clones*; not only reduce vulnerability of tree and grass species to droughts and water stress but also increase carbon sequestration rates.
- *Enhancing soil organic matter content*; through organic manuring to increase the moisture retention and soil fertility not only reduces the vulnerability to drought and moisture stress but also increases the carbon sequestration rates of trees as well as grass species.
- *Forest and biodiversity conservation*; through halting deforestation, expanding protected areas and adoption of sustainable harvest practices are important adaptation strategies to reduce vulnerability of forest ecosystems. All such programs or practices could also be considered as mitigation options to conserve forest carbon sink.
- *Urban park and tree planting*; promotes adaptation to heat stress in urban areas by reducing air conditioning needs, also leads to carbon sequestration in trees and soil.

Thus, it is interesting to note the complementarity or synergy between many of the adaptation options and mitigation. However, there could be many dedicated adaptation strategies or practices which are neutral to mitigation for example; mixed species forestry based afforestation, silvicultural practices such as thinning, sanitation harvest and fire protection. It is quiet likely that dedicated adaptation strategies which are only aimed at reducing vulnerability may also be necessary to address impacts of climate change.

6 Conclusions

The global community is about to launch mitigation and adaptation strategies, programs and projects, on a large-scale to address climate change. So far, research efforts as well as global negotiations have focused more on mitigation than adaptation and also treated mitigation and adaptation as separate approaches to address climate change. The time has come now to address the synergy, and if any trade-off, between mitigation and adaptation, while addressing climate change. No mitigation activity should increase the vulnerability of forest ecosystems, plantation forestry, food production, etc. Further, it is necessary to explore the possibility of incorporating adaptation practices into mitigation programs and projects, to reduce vulnerability and enhance resilience of forests.

Currently, there is inadequate knowledge about the potential synergy between mitigation and adaptation, particularly in biological sectors such as agriculture and forests. Thus, there is a need for research and field demonstration of the linkages and synergy between addressing climate impacts through adaptation and climate mitigation. The synergy is very critical to biodiversity rich diverse forest ecosystems of tropical countries. Even the IPCC Assessment Reports so far have not addressed the issue of linking mitigation and adaptation strategies and practices, which also could be an indicator of lack of scientific knowledge.

Promotion of synergy between mitigation and adaptation will also advance sustainable development, since mitigation activities contribute to reducing the vulnerability of natural ecosystems or socio-economic systems. All the examples of adaptation practices in mitigation projects, such as forest and biodiversity conservation, are also strategies to promote sustainable development, even in the absence of climate change concerns.

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