International Journal of Agriculture and Forestry 2013, 3(3): 98-104
DOI: 10.5923/j.ijaf.20130303.05

Impact of Climate Change on Forests of Eastern Himalayas and Adaptation Strategies for Combating it

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Abstract The Eastern Himalayas (EH) contains a variety of flora and fauna. The forests of India, Nepal and Bhutan the three major countries of Eastern Himalayas are directly or indirectly affected by climate change. Projected climate change will adversely affect the forests and increase invasion of pests, invasive plants and cause change in forest types. These counties have so far mainly focused on mitigation strategies but now the need to explore and promote adaptation has been realized. This leads to the formulation of adaptation strategies recently. The review of these strategies has shown that the adaptation options adopted by these countries are not enough for combating climate change and for effective management of forests other adaptation strategies have to be adopted which covers areas that already adopted strategies are lacking. Adaptation options like controlling forest fires, the creation of protected and corridors would be effective in conserving the forests of these countries. There are many barriers for the adoption of adaptation strategies and there in need to overcome them for the proper implementation of adaptation options.

Keywords Adaptation, Climate Change, Climate Impacts, Eastern Himalayas

1. Introduction

Eastern Himalayas (EH) contains a wide range of flora and fauna that exhibit a high proportion of endemism[1-4]. It has been reported that there are around 700 orchids, 58 bamboos, 28 conifers, 7,500 species of flowering plants, 500 mosses, 64 citrus, 700 ferns, and 728 lichens[4]. Out of the five countries covered by EH namely Bhutan, China, India, Myanmar, and Nepal three countries i.e. India, Nepal and Bhutan are chosen for the review. The climate change will have a profound effect on the future distribution, productivity, and health of forests. Climate change is expected to affect the boundaries of forest types and areas, primary productivity, species populations and migration, the occurrence of pests and diseases, and forest regeneration[5]. Mainly two options are available for combating climate change i.e. adaptation and mitigation but so far there has been more emphasis on the mitigation as compared to adaptation both globally as well as in EH[6]. The reason for this could be that climate change emerged as a problem related to the long-term disturbance of the global geo-biochemical cycles and associated effects on the climate system[7]. But adaptation has more advantages as compared to mitigation because the results of adaptation activities are obtained faster than the mitigation. The mitigation has a broader approach whereas adaptation measures are implacable on a regional and local level. Also, even if vigorous mitigation measures are taken then also some amount of climate change is unavoidable due to previous emissions[6]. There's no doubt that a certain community based forestry programs like, Community Forestry (CF) and Leasehold Forestry (LF) in Nepal, Joint Forest Management (JFM) in India and Community-Based Natural Resource Management (CBNRM) in Bhutan[4],[8] has performed quite well in these counties but seeing the pace of climate change and their effects these programs need revisions. For the effective implementation of conservation measures at regional and local level the alliance of institutions, stakeholders, forest staffs and forest communities is required. The forest management practices adopted by local communities vary from region to region depending on soil profile and climatic conditions of an area hence it become important to acknowledge their knowledge and take it into account while framing new forest programs and policies. For better results extensive research should be carried out to find out better adaptation practices but for this first it becomes important to find out a present and future climate trends in EH. Forest policies should be flexible and adaptable at all local and national levels.

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Published online at http://journal.sapub.org/ijaf

This paper discusses the impact of climate change on the forests of India, Nepal and Bhutan. An attempt is made to choose the adaptation strategies besides the already adopted ones that could be applied to these countries by carefully examining the specific conditions (environmental, social, political, and economic) of the region. Further, the existing barriers to the adoption of adaptation strategies are also presented and ways to overcome them has been discussed with the following objective:

1) What would be the difference between the present and future climate?

2) What's the impact of climate change on forests of India, Nepal and Bhutan?

3) What would be the adaptation options other than the adaptation options that they have already framed for combating climate change?

4) What are the ways for overcoming the barriers to adopting adaptation strategies?

2. Materials and Methods

Out of the five countries traversed by the Eastern Himalayas namely Bhutan, China, India, Myanmar, and Nepal three countries i.e. India, Nepal and Bhutan are selected for the study. The reason for selecting them is firstly, they contribute to the maximum percent share of aerial extent. Secondly, geography, cropping pattern, climate, and dependence of local communities on forests are almost similar. Thirdly, till now all the climate change dialogues are carried out between these three countries which mean they are working on the same platform[4].

The adaptation strategies these countries are adopting are very basic which includes only silvicultural aspect. No criticisms of the strategies are done because no harm would be caused by them and are applicable to the forests. The strategies lack broad and multi-scale approach and many things are neglected for example, there's no mention about local communities knowledge and active participation. In the discussion part of the paper the adaptation strategies are discussed that should be included into forest management. Two criteria's are opted for their selection: first, the already adopted strategies are compared with other tropical and some developed countries. Second, environmental, social, political, economic conditions of the countries are taken into account and the strategies that are most suitable under those conditions is selected and advised to inculcate into forest management. The barriers that will come while adopting the strategies is reported and also the ways for overcoming them are presented. The paper is concluded by pointing out the highlights.

3. Results

3.1. Current and Future Climate Projections

During the past 100 years the Himalayan region has shown continuous warming trends[9]. As far as the climatic characteristic of Eastern Himalayas is concerned very less information is available because of the non availability of appropriate climatic data. For the analysis of the effect of climate change on forests of EH climatic data for a long period of time is required but there is scarcity of such data. It has been observed that like other parts of the world EH is also experiencing warming above 0.01 per year. As shown in a table 1 that during DJF (December, January and February) i.e winter the rate of warming is more as compared to summer. The lower elevation (<1000m) has less warming rate as compared to mid (<4000m) and higher (>4000m) elevations[10].

Table 1. Temperature Trends by Elevation Zone for the Period 1970–2000 (°C/yr)

Level	Annual	DJF	MAM	JJA	SON
Level 1: (<1000 m)	0.01	0.03	0.00	-0.01	0.02
Level 2: (1 –4000 m)	0.02	0.03	0.02	-0.01	0.02
Level 3: (> 4000 m)	0.04	0.06	0.04	0.02	0.03

The future projections for the EH are[4]:

- By 2080s the rate of warming in summer would increase by at least 2.8°C whereas in the winter rate of warming is likely to increase by at least 3.6°C.
- There would be an increase in average winter as well as summer precipitation. The winter precipitation would increase by 23 to 35% and summer (monsoon) precipitation by 17 to 28%.
- It is projected that although there is an increase in summer precipitation the summers would be hot because of an increase in evapotranspiration.

For India, it is projected that by the end of the century the mean surface temperature would vary from 3.5 to 5°C. There would be a rise of 7 to 20% in mean annual precipitation[11]. General, Nepal would experience rise in annual temperature. The warming rate would be more in winter as compared to summer. There would be more precipitation in summer than winter[12] for Nepal indicate that there would be decrease in winter precipitation by 20 to 30% by 2050s, however it is expected that overall precipitation would increase[13].

3.2. Impact on Forests

3.2.1. Observed Impacts on Forests

The Eastern Himalayas are young mountains and are more fragile and this makes them vulnerable to climate change and the situation is made worse by economic marginality[4]. The people of India, Nepal and Bhutan are dependent on resources provided by the diverse Eastern Himalayan ecosystem. During recent years the rise in population has increased the pressure on natural resources. For fulfilling the needs of a growing population there is more destruction of forests and if the population would keep on increasing like this then there will be more competition for the resources this would further lead to destruction of scarce resources and services provided by them[14].

Natural ecosystems and their sustainability has been affected by climate change. Some of the ecosystems or

habitats have become critical because of climate change. One such example of critical habitat is the alpine and sub alpine regions situated between 4000-5,500 m amsl. The changes in ecotones, less rainfall, less productivity, alterations in species composition, rise in temperature has led to the formation of 'Krummholz-type' formation which was previously *Quercus-Betula* forest. The *Quercus* (oak) and *Betula* (birch) found in the *Quercus-Betula* forests are replaced by the other tree species like *Salix* (willow), *Syringia* (lilac) and *Rhododendron* (azalea)[8].

The observed impacts of climate change on forests of India, Nepal and Bhutan are[14-15]:

- Changes in phenology, migration and breeding of flora and fauna;
- More flora and fauna species becoming critically endangered;
- Reduction in forest biodiversity;
- Expansion of invasive and obnoxious weeds;
- Decrease in food, fodder and other services provided by forests;
- More incidences of forest fires, insects and pests.

3.2.2. Projected Impacts of Climate Change on Forests

India: Projected climate change has shown that most of the forests in India are likely to be affected by climate change[16]. There would be change in flora and fauna of forests in the future[17]. Alterations in forest types and change in the plant and animal phenology would adversely affect biodiversity[18]. Many valuable forest types that play an important role in the economics of India are projected to changes for example, *Tectona grandis* (Teak), *Bambusa* spp. (Bamboo), *Shorea robusta* (Sal) and *Pinus* spp. (Pine). It is also predicted that Net Primary Productivity (NPP) of some dominant vegetation types i.e. Tropical Xerophytic Shrubland, Tropical Deciduous Forest, Warm Mixed Forest and Tropical Semi-deciduous Forest will increase by 1.35–1.57 times[15].

The regeneration of viviparous species like *Shorea robusta* (Sal) and *Quercus semecarpifolia* (Kharsu) would be effected. Vivipary is the germination of seeds while they are still on a tree. Seed maturation and germination occurs during July during the onset of monsoon when a lot of water is available naturally due to a rainy season. Climate change can change the timing of a monsoon or hot summer may lead to earlier maturation of seeds. In both cases the regeneration of the species would be affected[4].

Nepal: Forests are the source of firewood, food, grasses and herbs for the people of Nepal. Especially forest communities are highly dependent on the forests for their livelihood[15]. Globally, it has been noticed that there is northern and upland shift in the species. Projected climate change has shown that upland shift in species will lead to the extinction of species and alterations in forest types[19-22]. It has been reported that presently there are 15 forest types in Nepal namely tropical moist, tropical dry, tropical wet, subtropical moist, subtropical wet, subtropical dry, warm temperate rain, warm temperate moist, warm temperate wet, warm temperate dry, cool temperate moist, cool temperate wet, cool temperate dry, cool temperate steppe and boreal dry bush. But due to rise in carbon dioxide level there will be left only 12 forest types namely tropical dry, tropical moist, tropical rain, subtropical dry, subtropical moist, subtropical wet, subtropical rain, warm temperate dry, warm moist, warm wet, warm thorn steppe and desert bush"[15]. The situation will be worse with a rise in temperature and rainfall variation.

Bhutan: Due to climate change some species will experience more rainfall and the forests cover of these areas are likely to increase. But there is also a danger of more attack by insect and pests. There will be an upland or northern shift of species. Some species of flora and fauna that occur in higher altitude will extinct due to an upland shift[15].

4. Discussion

There are two options available i.e. mitigation and adaptation for dealing with climate change[23]. Since the climate change came into the scenario more emphasis was on mitigation, eventually India, Nepal and Bhutan has incorporated adaptation strategies into the forest management[6]. Mitigation is related to the reduction of greenhouse gases and therefore, directly to the reduction of climate change. The IPCC[18] defines adaptation to climate change as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". The adaptation is the manner in which we adjust ourselves in response to or in anticipation of climate change[23]. The adaptation strategies that are adopted by these countries are[6],[15]:

- Avoiding monoculture and preferring mixed species forestry;
- Effective management of fires;
- Implementation of better management practices;
- Protecting biodiversity by in situ and ex situ conservation of biodiversity;
- Production of tree species that are tolerant to insect and pests; and
- Adopting practices that maintain sustainability of forests.

These strategies are mainly focused on maintaining the forest area but the other sectors related to maintaining health and vigor of forests, productive capacity of forest ecosystem and socio benefits in the forests are neglected. There are lots of adaptation options that can be adopted by these countries that have already been adopted by other countries. Keeping in mind environmental, social, political and economic conditions of India, Nepal and Bhutan the adaptation strategies that can be adopted by these countries are discussed below:

4.1. Adaptation Options for Maintaining Biological Diversity of a Forest Ecosystem

4.1.1. Reducing Deforestation and Forest Degradation

Deforestation and forest degradation is one of the biggest problems in India, Nepal and Bhutan[4]. There are many reasons for deforestation and forest degradation. Local people are dependent on non timber forest products provided by forests. Cutting of forests for agriculture is a major cause of deforestation[24]. In some areas of India and Nepal, zhoom or shifting cultivation is practiced where the piece of land where agriculture was done before was left abandoned and the area of forest is burned and cultivation is done on it for few years and left fallow again[25]. For controlling such practices, people should be made aware of the damage done by such practices also, some financial aid or employment should be provided to the local people to recover from farming or livestock failure.

Illegal logging is also prevalent in the forests of these countries[26]. There is need to revise forest policies and laws so that they can be implemented in effective manner to control illegal logging. Programs should be launched where local people are involved in preventing illegal logging. The rights should be given to local communities to meet their demands of fuel wood, timber or non timber forest products. The timber should be kept in stock in forest depots to avoid a shortage in case of over demand or emergency. Rural people in these countries obtain firewood from forests. The use of firewood increase concentration of carbon dioxide in the atmosphere. For reducing the pressure on forests for firewood renewable energy sources and eco-friendly equipments like solar cooker and induction cooker can be used.

4.1.2. Protected Areas

Protected areas play an important role in the conservation of biodiversity. Due to climate change more and more species are becoming endangered[23]. For conserving biodiversity there is need for creating more protected areas or extending areas of already existing protected areas. In order to allow free movement of species with changing climate the formation of protected areas along elevation gradients should be encouraged. The species selected for conservation should be chosen keeping in mind the climate of an area and must contain species that are more resilient to climate change in the habitat of protected area.

4.1.3. Maintenance or Creation of Corridors

During recent years, lots of fragmentation of forests has occurred in three countries[15]. The gaps and patches created by fragmentation adversely affect the biodiversity of forests[27]. Fragmented forests are more likely to be affected by climate change as compared to intact and large forests because of less resistance. In order to maintain the resilience of fragmented forests corridors should be created. The corridors created would allow free movement of different species of flora and fauna[28-30]. The corridors created will help in protecting species that are less in number and also those that have narrow a habitat range for example, *Hoolock hoolock* (Hoolock gibbon) and *Ailurus fulgens* (Red panda)[8]. Forecasting of the movement of species can be done by using habitat models. This would help in connecting various habitats through corridors. The warming caused by climate change would force species to move upward. It means that in the future there would be a movement of species from lower to higher altitudes[19-20],[22],[31]. Natural migration of species can be anticipated by adoption of strategies like landscape level[32]. This would help species to find more suitable habitats also called as 'new climate space'[31].

4.2. Adaptation Options for Maintaining the Health and Vigor of Forest Ecosystem

Climate change will affect the health and vigor of forests in India, Nepal and Bhutan. Climate change and warming of EH will make forests vulnerable to insects, pests and more susceptible to forest fires.

4.2.1. Forest Fire Control

Forest fires contribute to global warming. Forest fires occur due to man-made or natural reasons. In India, Nepal and Bhutan forest fires occur due to man-made reasons[33]. It means that the fire in these areas is not caused by climatic reasons but is caused due to carelessness of the people living around forests. Thus it becomes important to aware people about the harm caused by forest fires and to educate them how they can contribute in controlling factors that cause fire, in this way local communities would be involved in management of forest fires. These countries cannot afford a supply of modern equipment in all forest areas because of scarcity of funds[34]. Keeping financial constraint in mind and also lack of sophisticated equipments the alternative strategies should be adopted for management of forest fires. The adaptation strategies that can be adopted are tracing of areas that are more susceptible to fires, upgrading of fire forecasting systems, providing training to the local people for controlling forest fire, banning grazing during the hot summer, using satellite imageries for sensing forest fires, the creation of effective fire management plans, prohibiting slash burn during a dry and hot season and asking people not to practice agricultural systems that involve burning of forests for example, shifting cultivation.

4.3. Strategies for Maintaining the Productive Capacity of Forests

4.3.1. Plantations

For meeting the demand of timber and fuel wood India, Nepal and Bhutan is launching many afforestation and reforestation programs[6]. For better results some considerations should be taken into account while raising plantations. The climate and soil profile of the area should be suitable to tree species selected for plantations. The species

should be adaptable to the projected climate change. Mixed species plantation is more advantageous and successful as compared to monocultures[35-36]. It's better to have a mixture of species because monocultures are more susceptible to drought, insect and pest attack. As afforestation is mostly done on degraded land and has less productive capacity therefore those tree species should be selected that are nitrogen fixing and capable of increasing biomass production[37-38].

4.4. Strategy for Enhancing the Socioeconomic Benefits in the Forests

4.4.1. Local People Involvement

The involvement of local people in management of forests would help in adaption to climate change. "Community Forestry (CF) and Leasehold Forestry (LF) in Nepal, Joint Forest Management (JFM) in India and Community-Based Natural Resource Management (CBNRM) in Bhutan"[39] are community based programs. Though the programs are successful but there is need to upgrade them as far as rights of local communities are concerned. There is need to frame forest policies or acts by which people will be allowed to extract and also trade minor forest products from forests plantations. The involvement of people in these programs will develop a feeling of belongingness in them. This would encourage them to conserve forests and environment. These forest policies will not only help in controlling illegal extraction of timber and minor forest products but also increase forest stock. This in the long term would help in protecting forests and people from climate change.

4.5. Barriers

There are obstacles to the adoption of adaptation strategies in India, Nepal and Bhutan. These challenges will affect efficiency of adaptation strategies. The barriers are discussed below:

4.5.1. Lack of Laws and Institutional Capacity

Various capacity building actions like training, research are taken for dealing with climate change. But nothing much has been done yet at policy level and still India, Nepal and Bhutan lack the laws that would lead to adoption of climate change in government rules and policies[4]. The reason for this lack is poor institutional capacity. Adaptation should be incorporated into forest laws and policies. For effective capacity building it is must to accept climate change in government planning, conduct research on the past, present and future climate change trends, and develop models suggesting various adaptation options at different climatic conditions.

4.5.2. Lack of Knowledge and Research

There is a lot of knowledge gap and little information on the impact of climate change on India, Nepal and Bhutan[5]. There is need to conduct more and more research to find out the impact of climate change on forests at local, national and international level. Studies should be done to explore the rich flora and fauna of EH and take immediate actions to conserve the vulnerable and endangered species. Collaboration among governments and research institutes of not only India, Nepal and Bhutan but all the Eastern Himalayan is needed so that effective adaptation strategies are applied for combating climate change. The creation of a proper information-sharing mechanism would enable exchange of information among all EH countries[4]. For collecting information and data on climate change trends across EH a climate base stations should be created.

4.5.3. Poor Association between Natural Resources Conservation and Poverty Reduction

The forest communities are directly and indirectly dependent on forests[8]. For combating climate change the government might restrict the access of the communities to forests or other natural resources. This may lead to the conflict between the forest communities and the government that will automatically negatively affect conservation efforts. For the successful conservation of resources the local communities should be involved in the forest management. The governments should take efforts to decrease the dependence of local communities on forests by educating them about the impact of climate change and arranging for alternative non-forest based income sources for example, beekeeping and herb cultivation.

4.5.4. Lack of Funding

For effective implementation of adaptation strategies lots of funds are required. In India, Nepal and Bhutan fund are mostly allocated for mitigation strategies[6]. For more flow of money it is essential to aware donors about benefits of adaptation. There is need to carry research for calculating value on biodiversity. Determining of value would help in convincing donors and planners.

4.5.5. Transnational Co-operation among EH

Transnational co-operation among EH countries for combating climate change is needed. It is clear that co-operation among EH countries is necessary because climate change cannot be dealt on an individual country basis. In 2010, four Himalayan countries i.e. Bangladesh, Bhutan, India and Nepal held meeting in Nepal to discuss the actions that can be taken to tackle climate change which is termed as Himalayan consensus-2010. The EH countries should conduct seminars, symposiums and meetings to discuss the impact of climate change and adoption and implementation of adaptation strategies.

5. Conclusions

EH are known for its rich biodiversity. Like other parts of world climate change is affecting EH. The countries covered

by EH contain a variety of forest types. Forests not only has an aesthetic and regulating role but are also a source of food, fodder, timber and minor forest products to local communities[4]. The rise in temperature and variation of rainfall is affecting flora and fauna of forests. To combat the effect of climate change on forests India, Nepal and Bhutan are adopting mitigation and adaptation strategies. Adoption of adaptation strategies will maintain health, productive capacity and biological diversity of forests. Those strategies should be adopted that would be most effective for combating climate change for long term.

Not only in India, Nepal and Bhutan but also in other EH countries people are dependent on forests. Therefore, if the local community is not involved in planning of adaptation strategies and the measures taken for protecting forests from climate change then adaptation strategies adopted will fail in its objective. It is necessary that the knowledge of forest communities should be taken into consideration and people are involved in forest management.

There is need to analyze trends of climate change in the future because the choice of strategies that will be adopted today is completely dependent on the state of climate in the future. Institutional planning should be done in a manner that would effectively approach the climate change issues keeping in mind all national and local needs. Climate change is not something that is restricted to a particular area therefore, all the Eastern Himalayan countries should join hands together to combat the climate change menace. Adaptation if done properly will prove to be very effective in combating climate change on EH.

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