Project Final Report

Climate Change Mitigation and Adaptation in the Forest Plantation Sector

(MAFOR)

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CICERO

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1. Background

IPCC (2014a) concludes that climate change is already impacting forest ecosystems in many parts of Asia. Key observations include changes in plant phenology, growth and species distribution in many parts of Asia. It projects that within this century, magnitudes and rates of climate change associated with medium- to high-emission scenarios (RCP4.5, 6.0, and 8.5) pose high risk of abrupt and irreversible regional-scale change in the composition, structure, and function of terrestrial ecosystems. Further, Carbon stored in the forest ecosystems is susceptible to loss to the atmosphere due to multiple pressures of climate change, deforestation, and ecosystem degradation.

IPCC (2014b) points to critical knowledge gaps in impact assessment studies in South Asia in almost all the natural and production systems including forest ecosystems. Forests, plantations and tree cover accounted for 24% of the geographic area of India in 2013 and it is estimated that Indian forests and plantations hold a carbon stock of 6,941 million tonnes in the year 2013. Protection and further enhancement of this forest and plantation cover and carbon stock is necessary for India's environmental security and for achieving the global goal of limiting warming below 2°C. REDD+ and CDM are UNFCCC Mechanisms to mitigate climate change.

REDD+ has been denoted as a highly successful idea with lots of challenges. In summarizing them Angelsen et al. (2012) mention coordination of decision making across levels, harmonization of information flows, provision of reliable data, weak negotiating power among disadvantaged groups, resulting difficulties in benefit sharing across levels, and lack of adequate national institutions to facilitate actions on the ground. These are all challenges to any country, but are strengthened considerably by weak institutions in many potential recipient countries. In addition, prospects of monetary transfers attract new actors motivated primarily by the money. Acknowledgement of these challenges explains why REDD+ has been established as a three-stage process, where understanding the REDD+ comprises the first stage, the second stage is exploration of ways to implement REDD+, and the final stage is to measure the implications.

The need to learn and gain experience suggests that the attention in REDD+ related research should focus on areas and countries with experience from REDD+ projects, such as Brazil and Indonesia. The research on REDD+ have therefore been concentrating mainly on these countries. Most of the challenges addressed in the literature relate, however, to the way that forests are managed also without REDD+, such as weak institutions (Kohonen-Kurki et al., 2012), unclear property rights (Larson et al., 2012), and lack of transparent transfer mechanisms (Streck and Parker, 2012, and Luttrell et al., 2012). It is therefore useful to study the potential for REDD+ also in countries where these issues have been dealt with in a transparent manner. The approaches taken in these countries may give ideas as to how challenges in other counties can be solved, and it can reveal more specific problems that emerge when larger and more general challenges that are immediately striking have been dealt with.

This was one of our motivations for studying the potential for REDD+ in India. The country has a long tradition with federal forest management, which started in the late 1940-ies. Today, forests are divided into production forests, which are managed for business purposes, community forests defined as a common property to the benefit of local communities, and protected forests. The different categories are subject to separate management regimes, and carbon uptake as well as socioeconomic consequences of REDD+ initiatives will therefore depend on forest category. Because of the well-defined management regimes, there are also comprehensive sets of data available, but they have weaknesses if used to measure consequences of REDD+. Still, the lack of information can be identified, and by approximations, we can address how REDD+ projects in selected regions affect carbon uptake and what the socioeconomic consequences are on the different scales, from specific regions, to the national and the global scales.

India has not yet engaged very actively in REDD+, but there are plans to get more involved. However, the policy and management regimes were developed for other reasons than to control the uptake of carbon, and REDD+ may impose new challenges related to the existing regime. A more active engagement will therefore have to be well planned, prepared and organized. The second motivation of the project has been to explore the potential for REDD+ projects in India. In this context, we take advantage of the relatively advanced forest management regime in India, and address also how climate change will affect this potential. The third motivation is to assess the forest area changes, impacts of climate change on forests and plantations, impacts on carbon stocks and REDD+ and finally to assess the vulnerability of forests to climate change.

The project points out several limitations and knowledge gaps to an assessment of the REDD+ potential in India. These include appraisals of the mitigation potential and the impacts of climate change, exploration of synergies between mitigation and adaptation, identification of challenges to forest management in specific forest types, and a more broadly based reference for recommendations to policy making than the present practice relying on case studies. To improve on these gaps, the project highlighted four themes. The first was facilitation of forest data to prepare for assessments of REDD+ potentials in India. The second theme addressed the impacts of climate change on forests. The third theme highlights what role institutions may play in foreign parties' evaluations of how attractive REDD+ projects are in different countries. The forth theme addressed the socioeconomic consequences on different scales in different forest categories. CST had the main responsibility for the first two themes, while CICERO were the main responsible partner for the third and fourth themes.

2. Forest Area: Monitoring, Estimation, Reporting and Use

Periodic estimation, monitoring and reporting on area under forest and plantation types and afforestation rates are critical to forest and biodiversity conservation, sustainable forest management and for meeting international commitments. This study is aimed at assessing the adequacy of the current monitoring and reporting approach adopted in India for forest sector in the context of new challenges of conservation and reporting under REDD+. The analysis shows that the current mode of monitoring and reporting of forest area is inadequate to meet the national and international requirements. India could be potentially over-reporting the area under forests by including many non-forest tree categories such as commercial plantations of coconut, cashew, coffee and rubber, and fruit orchards. India may also be under-reporting deforestation by reporting only gross forest area at the state and national levels. The study highlighted the need for monitoring and reporting of forest cover, deforestation and afforestation rates according to categories such as (i) natural/ primary forest, (ii) secondary/degraded forests, (iii) forest plantations, (iv) commercial plantations, (v) fruit orchards and (vi) scattered trees.

India's INDC aims to create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through afforestation and reforestation by 2030, besides India has a long-term goal of bringing 33% of its geographic area under forest and tree cover. In this context estimation of forest area, identification of suitable sites for REDD+, afforestation/ reforestation and accurate forest area reporting assumes additional significance.

3. Impacts Of Climate Change On Forests and Implications For REDD+

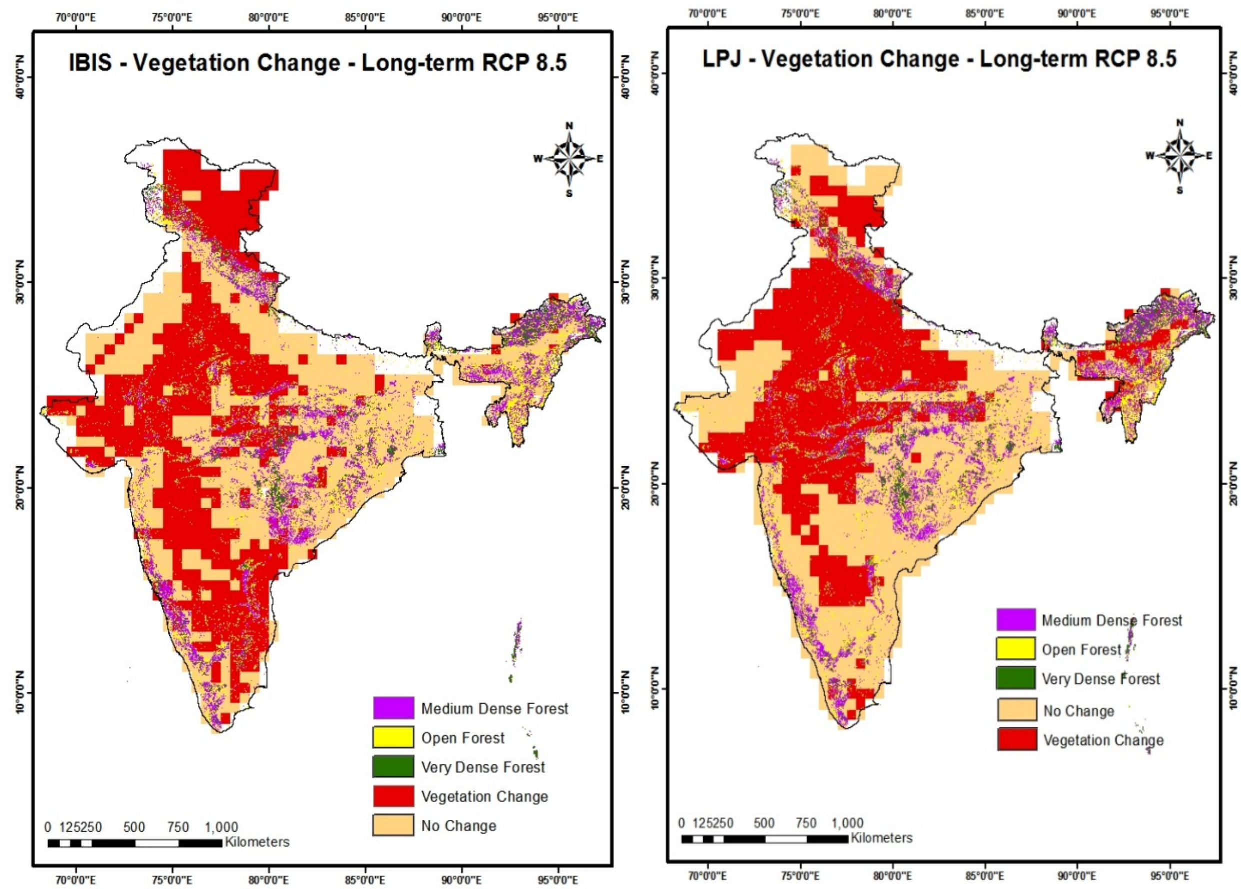
Multiple Dynamic Vegetation Modelling: The forests and plantations are subjected to potential impacts of climate change. Impact of climate change on forest ecosystems was assessed using a single GCM namely HADRM3 and for SRES scenarios A2 and B2. Further, the impact of climate change was assessed using a DGVM – IBIS. During the current phase of the project, we are using CMIP5 GCM outputs. We have developed an ensemble of CMIP5 models and using two Representative Concentration Pathways (RCPs) namely RCP 4.5 and RCP 8.5 Watts/m^2. Further, we are using DGVM LPJ in addition to IBIS. LPJ has been validated for Indian forest types. Impact of climate change has been assessed for Indian forest sector using both the DGVMs. The outputs are available as an input to the macroeconomic model developed by CICERO. It is proposed to integrate biophysical DGVMs with macroeconomic GRACE model. Preliminary studies indicate that forest plantations are projected to be impacted by climate change much more compared to natural forests.

Two dynamic global vegetation models (DGVM), namely IBIS (Integrated Biosphere Simulator; version 2.6b3) and LPJ (Lund-Potsdam-Jena; version 3.1.1) have been used in Sharma et al (Under preparation). Since climate change projections using a single climate model is very likely to have higher level of uncertainty, this study uses ensemble mean climatology from five CMIP5 climate models, namely BCC-CSM1.1, IPSL-CM5A-LR, MIROC5, MIROC ESM and MIROC ESM CHEM.

The PFTs represented in IBIS-DGVM and LPJ-DGVM are listed below.

	IBIS-DGVM	LPJ-DGVM
Trees based PFTs		
1	Boreal conifer evergreen trees	Boreal conifer evergreen trees
2	Boreal conifer deciduous trees	Boreal conifer deciduous trees
3	Boreal broadleaf deciduous trees	Temperate conifer evergreen trees
4	Temperate conifer evergreen trees	Temperate broadleaf evergreen trees
5	Temperate broadleaf evergreen trees	Temperate broadleaf cold-deciduous trees
6	Temperate broadleaf cold-deciduous trees	Tropical broadleaf evergreen trees
7	Tropical broadleaf evergreen trees	Tropical broadleaf deciduous trees
8	Tropical broadleaf deciduous trees	
Shrubs and grasses based PFTs		
9	Evergreen shrub	Cold grass (C_3)
10	Cold-deciduous shrub	Warm grass (C_4)
11	Cold grass (C_3)	
12	Warm grass (C_4)	

Figure given below compares the vegetation change projections from IBIS to LPJ. This model intercomparsion demo nstrates the uncertainties involved in the ecosystem modelling and highlights the usefulness of multi-model analysis. However, it is very clear that forests and plantations in significant part of India will be impacted by climate change. The existing vegetation may experience forest dieback leading to complete loss of biodiversity and biomass and carbon stocks, even if initially the forests may gain some carbon stocks.



Vegetation change as projected by Dynamic Vegetation Models IBIS and LPJ under R-CP 4.5.

4. Impact Of Climate Change On Forest Plantations

In this study we assessed the impact of climate change on forest plantations. According to the Forest Survey of India about 5% of the forest area in India comprises plantations. In this study we explored as to how climate change and increasing CO_2 concentrations in the atmosphere is already impacting the Indian plantation systems and project the impact of climate change on these systems based on the simulations of dynamic global vegetation model IBIS for the RCP scenarios 4.5 and RCP 8.5 using the ensemble mean climatology from five CMIP5 climate models, namely BCC-CSM1.1, IPSL-CM5A-LR, MIROC5, MIROC ESM and MIROC ESM CHEM. This assessment suggests that 24.6% of plantation grids are likely to undergo vegetation type change under the RCP4.5 scenario and 27.3% under the RCP8.5 scenario by the end of this century. Net Primary Productivity (NPP) is projected to increase by up to 10% under the RCP4.5 and RCP8.5 scenarios, while soil organic carbon (SOC) in the plantation systems is projected to increase by 19.8% and 20.7% under the RCP4.5 and RCP8.5 scenario respectively.

5. Vulnerability Assessment

Forests are subjected to several socioeconomic pressures leading to forest degradation, fragmentation and conversion making them vulnerable to current climate risks and long term climate change. Assessment of vulnerability of forests to current climate risks helps in devising strategies to reduce vulnerability to future climate change impacts. Thus it is necessary to assess the vulnerability of forest under the two scenarios namely,

- Scenario 1: Vulnerability assessment under current climate scenario (Inherent Vulnerability)
- Scenario 2: Vulnerability assessment under future climate scenario (Climate change driven vulnerability)

A. Assessment Of Forest Vulnerability At National Level

Managing change and conserving forests under future climate would be challenging. However, assessment of and addressing the sources of vulnerability is useful to deal with the risks to forests. We have assessed the inherent and climate change vulnerability of forests in India during the twenty-first century. Four indicators namely biological richness, disturbance index, canopy cover and slope are used to assess the inherent vulnerability of forests. We have presented spatial profile of inherent vulnerability in low, medium, high and very high vulnerability classes. 40% forest grid points show high and very high inherent vulnerability. For the first time, representative concentration pathways (RCP) scenarios and multi-model climatology from five climate models are used to force a dynamic global vegetation model (DGVM) to assess the climate change impact on Indian forests. The Integrated Biosphere Simulator (IBIS) DGVM used in the present study simulates vegetation-shifts in 22 and 23% of the currently forested grid points under RCP4.5 and 8.5 respectively in the short term (2030s), and such grid points are 31 and 37% in the long term (2080s). Climate change vulnerability of forests is assessed by combining inherent vulnerability and projected climate change impacts. While 46% forest grid points show high to extremely high vulnerability in the short term under RCP 4.5 as well as RCP8.5, such grid points are 49 and 54% in the long term. Minimizing anthropogenic disturbance and conserving biodiversity are critical to reduce forest vulnerability under climate change. For disturbed forests and plantations, adaptive management aimed at forest restoration is necessary to build long-term resilience.

B. Assessment Of Vulnerability At State Level

CASE-STUDY 1**: Climate Change Impact and Vulnerability Assessment of Forests at State level in the Indian Western Himalayan Region: A Case Study of Himachal Pradesh, India**

The study is aimed at assessing the impact of climate change on forest ecosystems in the Himalayan state of Himachal Pradesh. Climate change impact and vulnerability assessment at state and regional level is necessary to develop adaptation strategies for forests in the critical Himalayan region. The present study assesses forest ecosystem vulnerability to climate change across Himachal Pradesh under a range of climate scenarios and presents ranking of districts in the order of forest vulnerability under 'current climate' and 'future climate' scenarios. The forests of Himachal Pradesh, which are part of the Indian Himalayan Region, are projected to be impacted over the next decades as a result of climate change. Vulnerability of forests under 'current climate' scenario is assessed by adopting indicator-based approach, while the vulnerability under 'future climate' scenario is assessed using climate and vegetation impact models. Based on the vulnerability index, which combines projected climate change impacts and the current vulnerability, five districts - Chamba, Kullu, Shimla, Mandi and Kangra are identified as the most vulnerable districts by 2030s under the RCP 8.5 scenario. Identifying vulnerable forests will help policy makers and forest managers to prioritise forest management interventions, to restore health and productivity of forests and to build long-term resilience to climate change.

C. Assessment Of Vulnerability At Landscape Level

CASE-STUDY 2: **Assessment of inherent vulnerability of forests at landscape level: a case study from Western Ghats in India**

This case-study presents a methodological approach to assess inherent vulnerability of forests at landscape level in the forests of Western Ghats in the Karnataka state of India. The approach involves use of vulnerability indicators, the pairwise comparison method, and geographic information system (GIS) tools. Four vulnerability indicators, namely biological richness, disturbance index, canopy cover, and slope, are selected. We find that forests in 30, 36, 19, and 15 % grid points in this region show low, medium, high, and very high inherent vulnerability, respectively.

D. Assessment Of Vulnerability At Local Scale

CASE-STUDY 3: **Assessing "inherent vulnerability" of forests at local scale: a methodological approach and a case study from Western Ghats, India**

This case-study uses an analytical framework that enables selection of vulnerability criteria and indicators systematically, application of pairwise comparison method (PCM) for assigning weights, and synthesis of a composite vulnerability index. This methodological framework is applied at local scale to Aduvalli Protected Forest in Western Ghats in South India, where a vulnerability index value of 0.248 is estimated. Results of the case study indicate that 'preponderance of invasive species' and forest dependence of community are the major sources of vulnerability at present for Aduvalli Protected Forest. This methodological approach can be applied across forest-types after appropriate changes to criteria and indicators and their weights, to estimate the inherent vulnerability to enable development of adaptation strategy.

E. Application Of Vulnerability Assessment To Greening India Mission

India's climate pledges (INDC) to UNFCCC builds on the Greening India Mission, and emphasizes both on mitigation and adaptation. Vulnerability studies at different scales from national to landscape to local scale assist the forest managers in identifying the most vulnerable forest types and locations in India for building resilience and prioritising adaptation interventions. Our studies have stressed particularly on the inherent vulnerabilities of the forest ecosystems in India. Spatial assessment of inherent vulnerability of forests at landscape level is particularly useful for developing strategies to build resilience to current stressors and climate change in future.

6. Institutional Capacities And Evaluation Of REDD+

This part of the project has addressed the possible role that strong institutions in forest management may have for evaluation of REDD+ projects, both by investor countries and in the performing countries. It has drawn on the synergies between IISc knowledge of local forests and forests institutions in India and CICERO's competence on international carbon markets. By identification of key determinants of the supply of REDD+ projects and the international demand of forest carbon offsets, we have studied under which circumstances India may find it beneficial to undergo institutional reform to benefit from the REDD+ mechanism. The research has highlighted what role institutional capacities may have in dealing with the vast uncertainty related to the future price of carbon. One study addresses the challenges in institutional adaptation to unexpected shifts in carbon prices, and the second focuses on the control of how a REDD+ project will stimulate emissions from other places or leakage.

The long tradition with strong institutional capacity in managing forests in India was initiated for other reasons than to control the uptake of carbon with involvement from other countries. It has been argued that REDD+ projects ought to be concentrated in countries with high rate of deforestation and weak institutions, because forest management in these countries can be adapted more easily to a REDD+ regime. In this study, we ask what the institutional capacity may have to say for the implications of the uncertainty in the future price of carbon. Weaker institutions most certainly implies that adjustments needed to adapt to lower carbon prices than expected, so-called institutional reversal, will become more costly. Consequently, countries with strong institutions have a comparative advantage in this respect. The findings suggest that the vast uncertainty about future carbon prices should attract much more attention in evaluations of countries that potentially will host REDD+ projects than it has done until now.

Drawing on this study, the second study analyses further whether strong institutions contribute to strengthen or weaken the risk of carbon leakage when there is uncertainty about future price or carbon. While previous studies suggest that leakage has a clear-cut negative role in climate actions, such as REDD+, the question is raised under what conditions this is true. We use a simplified, conceptual model with two regions and a common wood market. Forests in both regions may be either managed or unmanaged. Then, leakage is analysed under different combinations of managed forests in the two regions. It is shown that when regions are of the same type, unilateral forest carbon mitigation and enhancement actions lead to positive carbon leakage. When regions are of different types, such unilateral mitigation actions result in negative carbon leakage, thereby suggesting that countries with well-managed forests should prioritize REDD+ projects in countries with well-managed forests to reduce the risk of leakages.

7. Transformation Of Results From Vegetation Models To Economic Models

Besides providing data that better fill the needs to assess the potential of REDD+ initiatives, the project also aimed at using these data for economic analyses. These refer to aggregates over physical quantities, meaning that “the amount of available forests” in an economic analysis is a composite of different forest species, specified in vegetation models. The aggregate is measured by the value of the forest in a base year, or volume, and the analyses of the management of the forest is based on the dynamics of this aggregate. A reliable link between the output of dynamic vegetation models and economic models therefore has to be based on a range of assumptions, which have been clarified in this project. The findings suggest that there is a linkage between forest densities and management objectives in production forests and community forests, which enabled an assessment of the availability of forests within each of the Indian regions addressed. The dynamic properties of forests in the different regions differ a lot, however. This indicates that pressures on deforestation and forest degradation varies a lot across regions, although the conclusions must be inter. These results were taken as a point of departure for the economic analyses, commented below.

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8. Socioeconomic Consequences

The provision of forestry data and facilitation of these data to socioeconomic analyses presented above prepare the ground for an indebt analysis of the uptake of carbon from specific REDD+ projects and their socioeconomic consequences. In India, the prospects for REDD+ are primarily production forests with possible extensions to afforestation in deforested areas. Analyses of potential initiatives in India should therefore concentrate on production forests, where the alternative is a continuation or extension of commercial forestry.

The classification of forests according to designated users provides, however, a unique opportunity to address dependencies between benefits of forest utilization and user category, which is considered a major challenge to the implementation of REDD+ in general. Therefore, the analysis of the socioeconomic consequences includes both forest categories by highlighting the dependencies between user groups and forgone benefits from REDD+, that is, the shadow price of carbon. To do so, a micro-model for the management of forests was developed. In the first step, the model is interpreted from the perspective of managing production forests and integrated in a macroeconomic model to assess the consequences of REDD+ on different levels. In the second step, the micro model is interpreted from the perspective of community forest management with the aim of determining foregone benefits to communities in case the forests are protected.

The analysis of the production forests is based on a computable general equilibrium model, GRACE (Aaheim and Rive, 2005). The version used in this project divides the Indian economy into eight regions, while international trade is taken is care of by one additional region, the rest of the world. As an experiment, REDD+ is implemented by protection of 10 percent of production forests in one region, Rajasthan, which corresponds to 0.5 percent of the total stock of production forests in India.

The resulting increase in uptake was derived from so-called growth curves of the biomass, which was estimated on the basis of results from the biophysical models in the project. The first years, the uptake of carbon corresponds to the increase of protected by the REDD+ project, and amounts to 1.65 MtC per year. As the growth of forests is non-linear, this increase decreases over time, to 0.45 MtC after 10 years, and to zero after thirty years, when the protected area is fully dense. Because of the estimated characteristics of forests in Rajasthan, this decline in the uptake is sharper here than in other Indian regions.

In a second experiment, REDD+ was implemented in forest plantation in all regions in India, and costs to India and resulting leakages were studied. As a result, uptake amounted to more than 100 MtC per year over the first ten years, but decline rapidly thereafter to 50 MtC after 20 years and vanishes after approximately 75 years, when the protected forests are fully dense. Protection of the forest leads to increased imports of timber, which increases steadily over time, and reaches the carbon uptake resulting from the implementation of the REDD+ after 25 years. It must be added, however, that the numbers related to leakage are hampered with significant uncertainty. If the leakage are disregarded, the loss of income from the forests that need to be compensated again depends on the time perspective that is taken, but also on whether it is India as a country (loss of GDP) or it is the forestry sector that is to be compensated. The longer time horizon, the higher costs. If calculated over the first ten years only, the cost to India is 0.80 US$/tC, while the cost to the forestry sector is 1.42 US$/tC. The cost to India increases by approximately 15 percent per year extension of the time horizon, but the difference between the national costs and costs to the forestry sector level out over time.

Although it is unlikely that REDD+ will be implemented in community forests, it is of interest to address the question of foregone benefits to households who utilize a variety of forest services for subsistence in case the forests are protected. The point of departure is again the dynamic characteristics of biomass. Here, we address community forests for the same eight regions as in the analysis of production forests, and again, the time profile for carbon uptake vary a lot across regions. Referring to previous studies on the utilization of forests by households, we moreover derive indicators for their dependency on forest services in the different regions. Preliminary results indicate that the dependency varies substantially across regions, with a high dependency in northern regions and lower in southern regions. It is also indicated that variations relate partly to variations in available access to forest services, and partly to the availability of alternative sources of livelihood. Thus, if the time households spend on harvesting timber or other products from the forest is rather equally distributed across regions, the time sharing between getting access to these forest services and alternative sources of livelihood varies substantially.

The results thereby show that the social costs of REDD+ in countries where forests are utilized for subsistence depends critically on who the users of the forests are. If used for commercial purposes, a carbon price may apply to compensate foregone benefits. If used for subsistence, such a compensation will vary considerably depending on where the REDD+ project takes place.

9. Summary

The study aims to first assess the climate change impacts, vulnerability and adaptation in Indian forests and plantations. During this phase impacts of climate change on the forests and forest plantations are assessed using multiple Dynamic Vegetation models of Integrated Biosphere Simulator (IBIS) and Lund, Postdam and Jena (LPJ) model, and using multiple climate (CMIP5) models. The studies find that a significant extent of forests and plantation systems will be impacted, leading to shifts in forest types and forest die-back. Climate change is likely to act as an additional stressor on the fragmented and disturbed forests, based on this premise vulnerability assessment of India's forests is carried out at the national, state, landscape and local forest administrative units.

Assessing the vulnerability of forest ecosystems is a challenging task, as the mechanisms that determine vulnerability cannot be observed directly. Based on suitable indicators key drivers and hotspots of inherent and climate change projected vulnerabilities are identified and the methodology demonstrated at the national level, state level, land scape level and at a forest administrative (local) level. Vulnerability analysis is very critical for India to achieve the ambitious forest sector goals of INDC which aims to increase the forest and tree cover in the countries so as to sequester an additional 2.5-3 billion tonnes of CO_{2e} in the Indian forests by 2030. Our study highlights the importance of assessing the current or inherent vulnerability of the forest and national afforestation and reforestation programmes. REDD+ programme aim to conserve existing forests, our studies on climate change impacts and vulnerabilities highlights the regions or forest areas that are resilient and can be prioritized for forest conservation related activities.

Further, India has an ambitious Greening India Mission which aims at promoting Mitigation and Adaptation in about 10 million hectares including, bringing about 5 million hectares under new forests. These new forests or plantations are likely to be more vulnerable to climate risks. Thus, the type of impact and vulnerability studies conducted during this phase of the project would help prioritise areas for implementing adaptation initiatives to build resilience in forest eco-systems to climate change. Similarly, these studies also assist in identifying forest types and locations, which require protection and conservation under REDD+ project.

10. Publications Directly Resulting From the Project

1) N. H. Ravindranath, I. K. Murthy, Joshi Priya, Sujata Upgupta, Swapan Mehra and Srivastava Nalin (2014): Forest area estimation and reporting: implications for conservation, management and REDD+. ***Current Science*** 106:1201-1206

2) Sharma J, RK Chaturvedi, G Bala, NH Ravindranath (2013): Challenges in vulnerability assessment of forests under climate change. ***Carbon Management*** 4 (4), 403-411

3) CASE-STUDY 1): Upgupta S, Jagmohan Sharma, MathangiJayaraman, Vijay Kumar and N H Ravindranath (2015): Climate Change Impact and Vulnerability Assessment of Forests in the Indian Western Himalayan Region: A Case Study of Himachal Pradesh, India. ***Climate Risk Management***, Available online 4 September 2015;DOI:10.1016/j.crm.2015.08.002

4) CASE-STUDY 2: Sharma J, RK Chaturvedi, G Bala, NH Ravindranath (2015): Assessing "inherent vulnerability" of forests: a methodological approach and a case study from Western Ghats, India ***Mitigation and Adaptation Strategies for Global Change*** 20 (4), 573-590

5) CASE-STUDTY-3: Sharma J, S Upgupta, R Kumar, RK Chaturvedi, G Bala, NH Ravindranath (2015): Assessment of inherent vulnerability of forests at landscape level: a case study from Western Ghats in India. ***Mitigation and Adaptation Strategies for Global Change***, 1-16. DOI 10.1007/s11027-015-9659-7

6) Climate Change Impact and Vulnerability Assessment of Forests at national level in India **–** ***under preparation***

7) Impact of climate change on forest plantations in India - ***under preparation***

8) Implication of forest policy and programmes for the vulnerability of forests in India/ Promoting forest adaptation under climate change in India: implications of forest policies and programmes ***- under preparation***

9) García, J.H., A. Aaheim, N.H. Ravindranath, J. Sharma: "Carbon price uncertainty and local institutions", - ***draft***, presented at EAERE conference, Helsinki, June 1015.

10) García, J.H., A. Orlov, A. Aaheim: "Positive vs Negative Carbon Leakage: The Role of Forest Management Regimes" - ***draft***

11) Aaheim, A., A. Orlov, N.H. Ravindranath, R. Kumar, A. Sagadevan, P. Joshi: "Forest management and economic consequences of REDD+ in Indian production forests" – ***under prepapation***

12) Aaheim, A., A. Orlov, N.H. Ravindranath, R. Kumar, A. Sagadevan, P. Joshi: "Foregone benefits of REDD+ in Indian community forests" – ***under preparation***

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Luttrell, C., L. Loft, M.F. Gebara, D. Kweka (2012): ”Who should benefit and why? Discourses on REDD+ benefit sharing”, Chapter 8 in Angelsen et al. (2012)

Streck. C., C. Parker (2012): ”Financing REDD+”, Chapter 7 in Angelsen et al. (2012)

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