About the Editors

Dr. G.C.S. Negi is Scientist-D (Forest Ecology) in GBPIHED. He obtained his M.Sc. and Ph.D. degrees in Botany with specialization in Forest Ecology from Kumaun University, Nainital. In his research career of about 25 years, Dr. Negi has extensively worked on structural and functional aspects of forests, grasslands and agro-ecosystems of Central Himalayan region. He has also worked on spring hydrology, watershed management, silvi-pasture development, conservation agriculture and environmental assessments of developmental projects. Currently, he is involved in research work on forest ecosystem services. He has published 50 papers in journals of international and national repute and was awarded Jawaharlal Nehru Visiting Fellowship in 1998. He was a LEAD (Leadership in Environment and Development) India Fellow in 2007.

Dr. P.P. Dhyani is the Scientist-G of the Institute (GBPIHED) and is currently the Head of Socio-Economic Development (SED) & Environment Assessment and Management (EAM) Group of the Institute. A plant eco-physiologist by training, he is the Fellow of the National Institute of Ecology and Member of the Mountain Protected Area (MtPA) Network of the World Conservation Union, USA. Dr. Dhyani has 115 research publications, including 3 books and 1 monograph, to his credit. He has research experience of 31 years in the field of eco-physiology, restoration ecology and conservation biology. Based on his outstanding contribution in the arena of scientific research, Dr. Dhyani has been named as one of the 'Leading Scientists of the World – 2009' by the IBC, Cambridge, U.K.; he has also been honored in 2009 by the 'Bharat Excellence Award' by the FFI, New Delhi and awarded by the 'Gold Medal of the Academy' in 2010 by the Indian Academy of Environmental Sciences (IAES), Hardwar.

Resolution Adopted by the United Nations General Assembly On the report of the Second Committee (A/61/422/Add.1 and Corr.1) 61/193, International Year of Forests, 2011

The General Assembly,

Reaffirming its commitment to the Non-legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests and Agenda 21, adopted at the United Nations Conference on Environment and Development, the United Nations Millennium Declaration, adopted at the Millennium Summit in 2000, the Johannesburg Declaration on Sustainable Development and the Plan of Implementation of the World Summit on Sustainable Development, adopted at the World Summit on Sustainable Development, held in Johannesburg, South Africa, in 2002,

Recalling the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change, the United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or desertification, Particularly in Africa, and other relevant conventions dealing with the complexity of forest issues,

Recognizing that forests and sustainable forest management can contribute significantly to sustainable development, poverty eradication and the achievement of internationally agreed development goals, including the Millennium Development Goals,

Recalling Economic and Social Council decision 2006/230 of 24 July 2006,

Emphasizing the need for sustainable management of all types of forests, including fragile forests ecosystems,

Convinced that concerted efforts should focus on raising awareness at all levels to strengthen the sustainable management, conservation and sustainable development of all types of forests for the benefit of current and future generations,

1.Decides to declare 2011 the International Year of Forests;

2.Requests the secretariat of the United Nations Forum on Forests of the Department of Economic and Social Affairs of the Secretariat, to serve as the focal point for the implementation of the Year, in collaboration with Governments, the Collaborative Partnership on Forests and international, regional and subregional organizations and processes as well as relevant major groups;

3.Invites, in particular, the Food and Agriculture Organization of the United Nations, as the Chair of the Collaborative Partnership on Forests, within its mandate, to support the implementation of the Year;

4.Calls upon Governments, relevant regional and international organizations, and major groups to support activities related to the Year, inter alia, through voluntary contributions, and to link their relevant activities to the Year;

5.Encourages voluntary partnerships among Member States, international organizations and major groups to facilitate and promote activities related to the Year at the local and national levels, including by creating national committees or designating focal points in their respective countries;

6.Requests the secretary-General to report to the General Assembly at its sixty-fourth session on the state of preparations for the Year.

83rd plenary meeting
20 December 2006

ENVIS Centre on Himalayan Ecology
G.B. Pant Institute of Himalayan Environment and Development
(An Autonomous Institute of Ministry of Environment and Forests, Govt. of India)
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Negi
Dhyani

GLIMPSES OF FORESTRY RESEARCH IN THE INDIAN HIMALAYAN REGION
Special Issue in the International Year of Forests - 2011

GLIMPSES OF FORESTRY RESEARCH IN THE INDIAN HIMALAYAN REGION

Special Issue in the International Year of Forests - 2011

Editors
G.C.S. Negi & P.P. Dhyani

About the Book

This special volume, dedicated for the International Year of Forests - 2011, contains articles/research papers on wide ranging and emerging areas of forestry and forest ecology contributed by leading researchers from various Institutes, Universities and NGOs working in the Indian Himalayan Region (IHR). Topics covered in this edited voluem include climate change impacts on forest structure and functioning, ecosystem services, carbon sequestration, carbon markets and REDD+, community forestry, forest fire and invasion, and priority areas for forestry research in the RIO+20 Era. Readers will find that the articles indicate a paradigm shift from the traditional studies focusing on forest structure and functioning to contemporary global thinking on forests as a natural capital for sustainable growth and development. It is hoped, this publication will cater to the need of all those who are planning new research programmes in the field of forestry and forest ecology in the IHR in particular, and elsewhere in the country, in general.

About ENVIS Centre

ENVIS Centre on Himalayan Ecology at the G.B. Pant Institute of Himalayan Environment and Development (GBPIHED) was established in 1992-93 with the financial support from the Ministry of Environment and Forests (MoEF), Government of India, New Delhi. The Centre is collecting, collating, compiling and building quantitative and qualitative databases of information related to various aspects of Himalayan Ecology. Through print/electronic media, the Centre is regularly disseminating all available information, free of cost, to various stakeholders/users, which include all District Information Centres (working in the Himalayan states of the country), ENVIS Centres of the MoEF, Universities, Research Centers, Engineering Colleges, Govt. Institutions, NGOs and experts/individuals working in the Indian Himalayan region (IHR). The main mandate of the Centre is to spread environmental awareness and help research and development in areas related to Himalayan Ecology. For Further details, ENVIS website : <http://gbpihedenvis.nic.in> may please be visited.

About the Institute

G.B. Pant Institute of Himalayan Environment and Development (GBPIHED) was established in 1988-89, during the birth centenary year of Bharat Ratna Pt. Govind Ballabh Pant, as an autonomous Institute of the Ministry of Environment and Forests (MoEF), Govt. of India. The Institute has been identified as a focal agency to advance scientific knowledge, to evolve integrated management strategies, demonstrate their efficacy for conservation of natural resources, and to ensure environmentally sound development in the entire Indian Himalayan Region (IHR). The Institute has headquarters at Kosi-Katarmal, Almora (Uttarakhand) and four regional units, namely Himachal Unit at Mohal (Kullu, HP), Garhwal Unit at Srinagar (Garhwal, Uttarakhand), Sikkim Unit at Pangthang (Sikkim) and North East Unit at Itanagar (Arunachal Pradesh). For further details,please log on to the Institute's website <http://gbpihed.gov.in>.

GLIMPSES OF FORESTRY RESEARCH IN THE INDIAN HIMALAYAN REGION

Special Issue in the International Year of Forests-2011

Editors

G.C.S. Negi
P.P. Dhyani

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2012

Glimpses of Forestry Research in the Indian Himalayan Region
Special Issue in the International Year of Forests-2011

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Cover Photo: Forest, agriculture and people co-existing in a mountain landscape of Purola valley, Distt. Uttarkashi (Photo: G.C.S. Negi)

Foreword

Amongst the global mountain systems, Himalayan ranges stand out as the youngest and one of the most fragile regions of the world; Himalaya separates northern part of the Asian continent from south Asia. The region, being a discrete geographic and ecological entity, figures prominently in major bio-physical settings on the planet earth. This vast mountain chain (over 2500 km long and 80-300 km wide and rising from low lying plains to over 8000 m amsl) produces a distinctive climate of its own and influences the climate of much of Asia. Temporal and spatial variations caused by geographical diversity have resulted into a marked difference in climate and physiography, and consequently in the distribution of biotic elements. The Indian Himalayan Region (IHR) stands at the biological and cultural cross-roads of Asia, the meeting point of floral and faunal assemblage, and cultures of the Indian sub continent. Its forests display phenomenal diversity, and along with the associated biodiversity, NTFPs in particular, meet diverse needs of the people in addition to being a source of livelihoods. The beautiful landscapes, numerous rivers and streams cascading down the mountain slopes, diversity of cultures and religions, and colourful traditions and festivals of indigenous/ ethnic communities, and a myriad of biotic forms plus unique geological features have long been a source of attraction for people from nearby regions and far away places across the globe, from naturalists, scientific investigators, wildlife enthusiasts, anthropologists, philosophers, thinkers, saints and sages, to mountaineers, adventure seekers and travelers.

The people of the IHR, like elsewhere in other mountain ecosystems, are heavily dependent for their livelihood on their surrounding natural resources and production from primary sectors such as agriculture, forestry and animal husbandry, etc. The dependency of the continually growing population on finite resources, lack of viable technologies to mitigate the mountain specificities and enhance production to meet the ever increasing demands are depleting the natural resources with concomitant increase in marginality of farmers, poverty and out migration. Recent report of Forest Survey of India (2011) has, however, shown an overall increase of 5% in the forest cover of IHR, which is a very welcome sign. Recognition of forests as a major provider of goods and services, and provision for "maintenance of forests" funds by the Planning Commission would go a long way in betterment of the forest wealth of the country.

Forests are not only the providers of a variety of ecosystem goods and services but also provide a sink for atmospheric CO_2, which is on the rise due to various anthropogenic activities. IHR provides asylum to the species, particularly to those which are likely to migrate and shift boundary ranges as a consequence of global warming, which is reportedly taking place, more so at the higher altitudes of Himalaya. The hydrological regulation by mountain forest ecosystem in the lowlands, connected with the river systems, is yet another service that needs to be understood fully and its value appreciated. Himalayan forests help maintain soil fertility and essential atmospheric moisture in the adjacent Gangetic plains through rivers originating from the region. Attempts are now required to adequately capture such Ecosystem Services (ES) of the

Himalayan forests in National Accounting System with primary focus on Gross Domestic Product (GDP). Their role would become more imminent as we move towards "Green Economy". The launch of eight National Missions, as envisaged under the National Action Plan on Climate Change (2008) is worth mentioning; two of the missions, namely Green India Mission and National Mission for Sustaining the Himalayan Ecosystem are particularly relevant for the IHR.

I hope this special issue brought out by the ENVIS Centre on Himalayan Ecology of the GBPIHED, on Himalayan forestry research on the occasion of International Year of Forests – 2011 will be useful to those engaged in forest ecology research in the Himalayan region. I thank the contributors and the editors of this volume in bringing it before the readers.

L.M.S. Palni, *FNASc, FNAAS*
Director, GBPIHED

Kosi-Katarmal, Almora

Preface

The United Nations General Assembly designated 2011 the "International Year of Forests" to raise awareness on sustainable management, conservation and development of all types of forests. "Forests for People" is the main theme of the Year, highlighting the dynamic relationship between forests and the people. National, regional and local organizations around the world are encouraged to plan "Forests 2011" events that provide an unprecedented opportunity to bring attention to the interconnectivity between people and forests. To celebrate the "International Year of Forests" and enhance capacity of human beings to address the challenges of conservation of forests for well being of people, governments, regional and international organizations and civil society organizations organized several activities all across the globe.

Forests are an integral part of global sustainable development. Forests provide us with various natural services and play an important role in economy of the nations. As per World Bank estimates, more than 1.6 billion people depend on forests for their livelihoods. The forest products traded internationally worth $270 billion. Forests provide habitats to about two-thirds of all species on earth. FAO estimates that the world's forests and forest soil store more than one trillion tons of carbon – twice the amount found in the atmosphere, and every year 130,000 km² of the world's forests are lost due to deforestation, conversion to agricultural land, unsustainable harvesting of timber, unsound land management practices and creation of human settlements, etc. Deforestation accounts for up to 20% of the global greenhouse gas emissions. Forest ecosystems play a critical role in provisioning of a variety of goods for daily living of the people, raw materials for industries, absorbing the greenhouse gases, mitigating the effects of climate change and protecting biodiversity. Many socio-cultural benefits and base for indigenous knowledge is provided by the forests. Because of the multiple roles of the forests and resources obtained from them, forests of the world are under threat due to overexploitation, deforestation, urbanization, shifting cultivation practices and natural disasters, etc. Considering the importance of forests in human survival, there is a need to better understand, manage and protect the forest ecosystems.

India is one of the countries with rich forest resource in the world. In India, forest is the largest land use next to the agriculture. The forests play vital role in harboring more than 45,000 floral and 81,000 faunal species of which 5150 floral and 1837 faunal species are endemic. As per the India State of Forest Report - 2009, the total forest cover of the country is 690,899 km² constituting 21.02% of the total geographic area of the country. In the Indian Himalayan region (IHR), forest is major land use/land cover category, which covers about 41% of geographical area in the IHR. While the rest of the country is witnessing reduction in the dense forest cover, the situation in the IHR has recorded an increase of over 5% during 1997-2007, which is generally believed to be due to many local governance institutions.

Forests of the IHR provide a myriad of Ecosystem Services (ES) to people not only to the inhabitants of the region but also to the people residing in the lowlands connected with the river systems in terms of regulated flow of water, soil and nutrients, which support many land based and developmental activities. Forest vegetation of the IHR has a large “sponging effect”, soaking up and storing rainwater that reduces the impact of downstream flood or drought. The most notable among the forest ES is carbon sequestration particularly in the face of global warming. The C pool in IHR forests (forest biomass + soil C) has been estimated at 5.4 billion t C and at regional scale the approximate values of ES of Himalayan forests with regards to C- sequestration has been estimated as Rs. 943 billion/yr.

Forests of the IHR are facing a number of anthropogenic and natural threats. Fire causes irreparable damage to the forest ecosystem, habitat loss for many of the indigenous varieties of plants and animals, and soil erosion by water and wind. Illicit felling of trees, extraction of medicinal plants and other minor forest product, poaching of wildlife, age-old practice of *Jhum* cultivation in the north-east region, destruction of forests due to mega-projects and natural events such as floods and landslides are other potential threats faced by the forests of IHR. Various measures have been taken up to conserve forests in India. India’s National Action Plan for Climate Change (NAPCC) includes National Mission for a Green India among the eight countrywide missions. This mission underlines the indispensable role of forests in the preservation of ecological balance, maintenance of biodiversity and as effective carbon sinks. It builds on the Prime Minister’s Green India campaign for afforestation of 6 million hectares and the national target of increasing land area under forest cover to 33%. Various govt. and non-governmental efforts are continuing to save the forests and wildlife in India. In the IHR, areas rich in biodiversity are designated as Biosphere Reserves (7 BR), which spread over 26,421 km^2 area. A total of 25 National Parks and 98 Sanctuaries are established to protect the forests and wildlife in the IHR, which make up about 14% of the geographical area of India.

ENVIS Centre on Himalayan Ecology at GBPIHED, under the aegis of Ministry of Environment & Forests (MoEF), Govt. of India, is mandated for collecting and compiling of information, and its dissemination to various stakeholders for helping research and development in the areas related to Himalayan Ecology. I am happy to note that this Centre of the Institute is bringing out a special volume in the form of this edited book to mark the celebration of “**International Year of Forests-2011**”. This book consists of 22 research articles contributed by various scholars engaged in the forestry research and try to provide an overview of priority issues for forestry research in the IHR in the RIO+20 Era. In general, a “paradigm shift” in the forestry research could be witnessed in terms of a broad departure of studying structural and functional aspects of forests to more focus on forest conservation and management issues to cater the need of not only academicians but also planners and policy makers. Issues of global importance such as carbon sequestration, forest ecosystem services and innovative management regimes for better conservation have figured more in the forestry research in the region. However, there is an urgent need to apply new tools and techniques, methodology and approaches to better the local-regional-national-global connect of the forestry research in the Himalayan region.

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Contents

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Twenty Priority Issues for Forestry Research with Particular Reference to Indian Himalayan Region in the RIO+20 Era

G.C.S. Negi, R.S. Rawal, P.P. Dhyani and L.M.S. Palni

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Forest ecosystems play a crucial role in sustaining life on the planet earth. In view of the increased interest in realizing the full potential of forests for global sustainable development in recent years, the United Nations General Assembly proclaimed 2011 the “International Year of Forests”. This has been instrumental in translating this interest into year-long action, as well as to raise general awareness and understanding about the vital role of forests and strengthening sustainable forest management for the benefit of current and future generations. As we preapare to “shift gears” to realize the true intent of the Green Economy from the so called era of Brown Economy, humankind must ensure, through concerted actions around the world, sustainable growth and health of all forest types for global good. “Forests for People”, the main theme of the Year, amply highlights the pivotal association between forests and the people; it is envisaged that this should catalyze a meaningful dialogue and begin the process of shared learning for achieving sustainable solutions, by bringing together best practices from governments and stakeholders, towards greater understanding and convergence of practical approaches for forests and people – and their sustainable future worldwide, who one way or the other depend on forests. The first Earth Summit held way back in 1992 at Rio De Janeiro emphasized the value of forests largely for the environmental benefits; it is encouraging to note that our understanding, over the years, has broadened considerably to value and recognize the equally important role of forests as providers of economic, social and cultural benefits.

Globally forests are now regarded as the major repository of nature to be conserved and managed for posterity, and not to be regarded solely as an important source of revenue. In the Indian context, forests are a prominent

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feature of the Indian landscape, covering almost 79 million hectares which represents almost a quarter (23.8%) of the geographical area of the country (FSI, 2011). These forests are integral to the environment, economy, culture and history of the country. While providing multiple tangible benefits such as timber, fuel-wood, pulp-wood, fodder, fiber, medicines, grasses and other valuable non-wood products, forests also regulate the hydrological cycle, protect aquifers, conserve biodiversity, enhance carbon sequestration as a spin-off effect of forest conservation, and promote ecotourism (Dilip Kumar, 2011; In Press). Accordingly recent decades have witnessed several challenges in forestry research and management. This paper attempts to highlight the need to bring about a paradigm shift in the traditional thinking and approach in forestry research in respect of the Indian Himalayan Region (IHR) and evolve research programmes that are sensitive to stakeholder needs in addition to being forest friendly and in tune with the fast changing global thinking on the subject, especially in Rio+20 scenario.

The IHR stretches over 2,500 km from Jammu & Kashmir in the north-west to Arunachal Pradesh in the north-east, and covers partially/fully twelve mountainous states of India (Fig.1). The region with a geographical coverage of over 5.37 lakh sq Km (appx. 16.2% of the geographical area of the country) is inhabited by about 42 million people. Biogeographically, the IHR represents three biogeographic zones (namely, trans Himalaya, Himalaya and North East India) and nine biogeographic provinces. Each of these provinces has remarkable cultural, ethnic and biological diversity. The region contains snow-clad peaks, glaciers and dense forests with rich diversity. Over 9,000 Himalayan glaciers and high altitude lakes form a unique reservoir storing about 12,000 km^3 of fresh water (Valdiya, 1998). Mighty streams like the Indus, Sutlej, Yamuna, Ganga, Kali, and Brahmaputra arise from the Himalayan region[1]. Through geological time in the region, warm, wet periods have alternated with cool, dry ones. Along with the rise in maximal elevation (from less than 2500 m in the mid-Miocene to more than 8000 m today), such changes in climate have caused extinctions and also have facilitated immigration of taxa from surrounding regions. For example, between 8000 and 4500 years ago, as the climate warmed and snow melted, oaks expanded their importance at the expanse of pine trees (Zobel and Singh, 1997).

1. The “Foreword” in this publication may be seen for general appreciation of the true value of the region, not just for those who inhibit IHR but also for the people who live far beyond its boundaries.

Fig. 1: Indian Himalayan region (Source: G-SHE, 2009)

FORESTS OF THE HIMALAYA

In the IHR forest is major land use/land cover category (as recorded forest area). According to the State of Forest Report (FSI, 2011), forests cover ~41% of geographical area in the IHR out of which 16.9% area is under very dense forest cover, 45.4% under moderate forest cover and the remaining 37.7% under open forest category (Table 1). Himalayan states show that considerable forest area in these states is private (42%), followed by area under community management (33%) and revenue department (25%). According to a recent Report of the Task Force, Planning Commission (Anonymous, 2010) Uttarakhand is the only state where all types of ownerships exist, while Nagaland has mainly private forests. Although the rest of the country seems to be witnessing a reduction in the dense forest cover, situation in the IHR appeared to have improved as per the FSI assessments of 2001 and 2011, and is generally believed to be due to many local governance institutions (e.g., Van Panchayats).

Table 1: Contribution of the IHR to total forest cover of India (2011)

Region	Geographical area (km^2) (values in %)	Forest cover (km^2)			
		Very dense (% of total)	Moderate (% of total)	Open (% of total)	Total (% of total geographic area)
IHR	537435 (16.3)	37648 (16.9)	101005 (45.4)	83881 (37.7)	222534 (41.40)
India	3287263 (100)	83471 (12.1)	320736 (46.3)	287820 (41.6)	6920274 (21.1)

Himalayan forests are extensive and diverse and they differ significantly from both tropical and temperate forests with respect to structure, phenology and function; as well as in terms of ecosystem processes (Zobel and Singh, 1997). The forest vegetation in the Himalayan region ranges from tropical dry deciduous forests in the foothills to alpine meadows above timberline (Champion and Seth, 1968). The biomass productivity (17.0 -21.0 t/ha/yr) of the pristine forests of the region is comparable to the highly productive forests of the world ranging from 15.0 – 30.0 t/ha/yr among major forests of the region (Singh and Singh, 1992). Diversity and uniqueness of Himalayan forests has contributed significantly towards richness of biodiversity elements at different levels that places the region amongst 34 identified Global Biodiversity Hotspots. Richness and uniqueness of biodiversity in Himalayan hotspot is included in Table 2.

Table 2: Richness and uniqueness of biodiversity in Himalayan hotspot

Taxonomic group	Species	Endemic species	% of Endemism
Vascular Plants	10,000	3,160	31.60
Mammals	300	12	4.00
Birds	979	15	1.53
Reptiles	177	49	27.68
Amphibians	105	42	40.00
Freshwater Fishes	269	33	12.26

Source: http://www.biodiversityhotspots.org

THE GLOBAL CONTEXT

The Mountains, which cover nearly one quarter of Earths' land area, host over 12% of global human population. More importantly, >50% of global human population draws benefits directly or indirectly from resources and services emanating from the mountain ecosystems (Messerli and Ives, 1997). These regions, although well recognized for their evolutionary significance and ecological value manifested by ecosystem integrity, adaptability and services, have largely remained marginalized from economic development perspectives. However, in the aftermath of Rio Earth Summit and the implementation of its Agenda 21, awareness about the mountains has increased manifold, and the region is being institutionalized on mainstream developmental agenda. In this context, on account of richness (diversity), representativeness and uniqueness, the mountain biodiversity elements have gained considerable attention. Further, under the provisions of Convention on Biological Diversity (CBD), the global value of Mountains has been recognized in the form of a specific Programme of Work on Mountain biodiversity. The programme elements include: (1) Direct actions for conservation, sustainable use and benefit sharing; (2) Means of implementation for conservation, sustainable use and benefit sharing; and (3) Supporting actions for conservation, sustainable use and benefit sharing (http://www.cbd.int/mountain/wopo.shtml?prog=p1). Therefore, while defining research agenda and any other action priorities pertaining to mountain biodiversity, including the forests, it is important to consider these work elements, goals and specific actions suggested therein. In this context, as indicated above, the globally recognized 'Himalayan Biodiversity Hotspots', represents a unique bio-physical entity with a huge range of diversity in forest types and their life sustaining values. Therefore, this unique system has always remained an attraction for researchers from different parts of world. However, in the Rio+20 era, when global attention has increasingly focused on sustainable development needs under the accelerated global change scenario, there is an urgent need to reorient research priorities to address the changing global needs, e.g., to scientifically develop sound methodologies for estimation of ecological services in order to arrive at realistic monetary contribution of tangible and intangible benefits of forests to the GDP (collectively at the global level and at individual country level). Furthermore, the current global thinking on forests supports cross-sectoral and cross-institutional policies promoting sustainable forest management and stresses the importance of integrating sustainable forest management objectives and practices into the mainstream of economic policy and decision making.

THE NATIONAL CONTEXT

The Himalayan region being a forest dominated landscape; the forestry sector calls for immediate attention and implementation of action oriented programmes. In this context, keeping the experiences of on-going forestry research in the region in view, and recognizing the current needs, an attempt has been made through this article to highlight twenty important issues which require in-depth efforts to better understand the forests of this region, particularly for their role in human well-being and sustaining the Himalayan ecosystem. The emphasis in identification of issues is to highlight hitherto neglected and/or less explored areas of research that have convergence with the contemporary global thinking as well as hold greater significance for emerging priorities at the national level. For instance, India's National Action Plan on Climate Change - NAPCC (GoI, 2008), considering national and global importance of the Himalayan Ecosystem, has made special provision of a National Mission for Sustaining Himalayan Ecosystem, one of eight missions and the only mission which is location specific. This mission, among others, aims to: (i) understand, whether and to which extent, the Himalayan glaciers are in recession and how the problem could be addressed, (ii) establish an observational and monitoring network for the Himalayan environment, (iii) promote community based management of the ecosystem through incentives to community organizations and panchayats for the protection of forested lands. Furthermore, specifically focusing on forestry sector, the National Mission for a Green India has given directions for defining priorities specially in order to address climate change (CC) vulnerabilities in the landscape by way of: (i) enhancing carbon sinks in sustainably managed forests and other ecosystems, (ii) enhancing resilience and ability of vulnerable species/ ecosystems to adapt to the changing climate, and (iii) enabling forest dependent local communities for better adaptation in the face of climate variability.

Considering the above, it is an opportune time in the "International Year of Forests"- 2011 to rethink and reorient our forestry research in the region to contribute in achieving long-term national and international goals of environmental conservation and sustainable development.

IHR FORESTRY RESEARCH – CONTEMPORARY ISSUES

1. Quantification and valuation of forest ecosystem services (FES) has occupied the centre stage of research agenda the world over. Emphasis is being paid to value the intangible services of the forest ecosystems so that conservation efforts of the stakeholders are rewarded in economic terms. In the IHR, FES is intricately linked with the livelihood of the people, hence well recognized but poorly understood (Singh, 2007; Joshi and Negi,

2011). Therefore, systematic studies are required to better understand, quantify and value the FES. Particularly the regulating services of the forests such as pollination, soil and water conservation, soil fertility maintenance, C-sequestration, biodiversity conservation, etc., deserve priority attention so that compensation mechanisms are devised and brought into the policy framework. The 2010 report of the Task Force for Planning Commission, GoI (Anonymous, 2010), has emphasized the need for highlighting contribution of forests of the IHR to the national accounting system (so far forest contribution to the GDP of India is taken as <2%) and quality of life. It would follow from such estimation that the nation must be willing to pay for maintaining such services. There is a great scope for using Himalayan forests as C-sink and developing C-markets through the involvement of local inhabitants in management of community forests. As such, there has been an increasing global interest in translating the concept of ecosystem services into practice, both as a rationale for conservation of biological diversity and as a method to design policies that maximize benefits from the sustainable management of ecosystems (Sutherland *et al*., 2009). Ecologists and environmental economists must come together to address this aspect.

2. A larger part of the Himalayan population is agriculture based, and the hill agriculture is organic in nature and continues to be dependent on forest biomass. With the changing trends of climate and global economies, the agricultural patterns and systems in the region are fast changing. This obviously impacts on the forests and forest resources. In this context, the carrying capacity of forests vis-à-vis agricultural intensification / diversification needs to be understood and calls for the forest based resources to be projected not only in view of the CC, but should also take stock of the aspirations of local communities and changing scenario of crops and cropping patterns. This requires deeper understanding of existing systems and the undergoing transformations therein. This understanding would follow only if these issues are systematically considered as proper research questions.

3. While considering intricate linkages of forests with other land based production systems (i.e., agriculture and horticulture) in the region, among others, the role of forests in providing "pollination services" to the agricultural and horticultural landscapes needs to be taken up on priority. This need is evident, as over 90% of flowering plants are pollinated by animals and majority of crop plants are pollinated by insects; bee pollinated crops alone contributing about 30% of human food. Further, studies have

indicated that pollination often becomes a constraint in insect pollinated species that results in marked reduction in crop productivity. This has been attributed to reduction in the population of native pollinators, due to habitat loss of insects (Shivanna, 2011). Therefore, land use changes and consequent impacts on pollinators diversity and density that affect the potential of agriculture and horticulture crops, becomes an interesting area of investigation. The interest has been triggered by the increasing number of cases where reduction in insect pollinations led pollination deficit-yield reduction because of insufficient pollination (Mburu *et al*., 2006). Also there is a lack of common methods for valuing the pollination services (Mburu *et al*., 2006). This calls for attention from researchers to make valuation methods more consistent and their assumptions more explicit, by way of using pollination services as model ecosystem service. Also, it is important to look into values at different scales that range from local, regional to national and global. While considering local scale, commissioning studies for assessing the contribution of various forest types and their health in maintaining the diversity of pollinators and consequent flow of pollination services assumes greater significance and should be integral to any action agenda for the region.

4. Forests play a key role in removal of accumulated CO_2 in the atmosphere, and sequester it in vegetation, soil and wood products. In spite of modest beginning towards assessing the carbon sequestration potential of forests, there exists considerable scope to undertake systematic studies to design mitigation strategies in terms of potential trees of multiple use / forest types. Focus needs to shift from the hitherto major produce from the forests (e.g., timber) to minor forest products (e.g., medicinal plants, wild edibles etc.). In the decade ending 2005, the carbon stocks in the forests in India and tree cover have reportedly increased registering an annual increment of 38 million tons of carbon, equivalent to 138 million tons of CO_2. This CO_2 removal is considered enough to neutralize 11.25% of India's total greenhouse gas emissions at 1994 level (Dilip Kumar, 2011; In Press). Also, there exists a huge potential for enhancing the C sequestration in the vegetation and soils of the Himalayan region, provided strategies are developed with adequate research based information for restoration and improved management of degraded/waste lands through plantation of eco-physiologically hardy mix of multipurpose tree species and employing soil and water conservation measures. Deployment and use of CO_2 towers for assessment of C-sequestration potential of various forest types (including sub alpine regions and alpine meadows), in different seasons, would go a long way in choosing appropriate forest species for plantation purposes.

These studies would also help in defining the age at which particular forest types become net CO_2 emitter (rather than sink); noteworthy initiatives in this direction have been taken by the Forest Department in Uttarakhand State in recent years. The role of forests in maintaining the health of alpine meadows with huge C-sequestration capacity also need to be highlighted based on sound data; other largely unexplored area of work involve understanding the linkages between forest types and associated microbial biomass and elucidating the role thereof.

5. As is well known, forests are also a rich repository of genetic diversity. In future biodiversity is expected to bring enhanced and economic prosperity to the people living in biodiversity rich areas, like the Himalaya. There is, therefore, an overwhelming need, with community participation, to make special plans, and provisions for initiating activities that will facilitate the maintenance, protection, conservation and wise use of biodiversity in the entire IHR. The issues of forest biodiversity conservation, sustainable use and benefit sharing, as defined in the CBD Programme of Work for Mountains, deserve priority in forestry research. Among others, the role of forests as habitat for unique (i.e., endemic, charismatic, flagship or umbrella species) and high value (e.g., medicinal plants, wild edible plants, etc.) elements of biodiversity also requires adequate research attention. Moreover, studies to adequately understand risks of forest habitat loss, cost of restoration and reintroduction, vis-a-vis benefits of conservation need to be given higher attention. Studies on response of forest biodiversity, especially the unique and high value taxa, towards changing climate and harvesting intensities would help in appropriately defining the effective forest management regimes. Further, the development of modern science and technologies notably biotechnology and information technology have increased the value of biodiversity and associated traditional knowledge of its use and conservation. The Biological Diversity Rules, 2004 published by Govt. of India under section 22 states that ‘every local body shall constitute a Biodiversity Management Committee (BMC) within its jurisdiction’. National Biodiversity Authority at National level and State Biodiversity Boards (SBBs) at State level have been formed and the process of constituting BMCs and maintaining ‘People’s Biodiversity Registers’ has already begun in the country. The adequate research must flow in for making the products of this nationwide process authentic and acceptable across stakeholder groups.

6. Fire has now become an integral part of the mountain landscape, particularly around the human settlements. Forest fires of medium to severe magnitude are often witnessed in the region in late spring and summer, and sometime during the long dry spells in winter also. Further, anthropogenic pressures magnify the loss of forest wealth due to fire. For example, in the western

Himalayan region because of biotic pressure on oak forests (which provide quality fuel wood, fodder, bedding leaves for cattle, minor forest products, medicinal plants etc.), chir pine (an early successional and less useful species for the local people) has slowly but steadily invaded the oak (late successional species) forests (Singh *et al.*, 1984). Pine forests represent a fire adapted ecosystems (Semwal and Mehta, 1996), and the upward expansion of chir pine in the oak zone is ushering changes in the composition and FES accrued from the same. Some pioneering studies on forest fires do exist; however, fire being a powerful tool that affects the forested landscape and also contributes to black carbon in the atmosphere. These aspects need to be studied in some detail, particularly with respect to several structural and functional attributes of forests (such as, soil erosion, nutrient leaching, invasion of weeds, loss to the native biodiversity, etc.) and the extent to which black carbon is emitted and the distance it travels along with seasonal effect, if any, following different intensities of fire. Whether, the present management practices of fire-fighting employed by forest department could be changed suitably to minimize the loss to forests, e.g., by the use of pine needles as a source of bio-energy and other alternative uses such as making of fuel briquettes which is being tried in the region (particularly Uttarakhand) at a pilot scale. The long term ecological consequences of pine needle removal from the forest floor needs to be investigated, particularly in respect of nutrient dynamics.

7. The IHR, due to a plethora of reasons, including the changing economic aspirations of its inhabitants, is going through a phase of rapid transformation. As a result land use and land cover changes are a common occurrence. In particular, competition for resource use, development of road networks, hydro-power projects and other developmental activities, mineral extraction, recreation related changes, market oriented agriculture, forestry and livestock grazing, etc., have contributed towards such changes. Land use change also changes the local albedo by influencing the ground cover and altering the amount of sunlight that is absorbed. Further, deforestation also causes change in precipitation, temperature and ultraviolet beta radiation arising from changes in CO_2 levels in the atmosphere, and the consequential damage to the ozone layer. Forests that experience a net loss of biomass volume through mortality due to disease or fire become net C emitters (Kyrklund, 1990). However, we lack adequate research on most of these aspects. Among others, effective use of RS and GIS technology towards assessment of patterns and intensity of land use and land cover change in the region, and development of likely scenarios both at spatial and temporal scale should form an immediate research agenda in the region; incidentally remote sensing should be widely used for monitoring the spread of fires (and thereby as a tool for combating the same) and assess the ensuing damage (see previous point 6). These

programmes would need to involve deployment of state-of-art techniques and generation of comparable data sets.

8. Impact of CC on forest ecosystems is a subject of recent origin. In this context biophysical models in association with regional CC scenarios need to be used to assess the impact of CC on forest ecosystems at national and regional levels in terms of the (i) shifts in boundary of forest ecosystems and upward movement of tree lines, (ii) forest ecosystem change matrix, (iii) change in species mix and composition of vegetation types, and (iv) species vulnerability to identify vulnerable forest ecosystems, regions and hotspots. Implications of CC on biodiversity, biomass production and net primary productivity also need to be kept in view in designing programmes of work (Anonymous, 2009). It is envisaged that the effects of CC on the sub-alpine and alpine plant species that inhabit mountain ranges with restricted habitat availability, above the tree line, would experience severe fragmentation, habitat loss, or even local extinction if they fail in moving to higher elevations (Singh *et al.,* 2010). Identification and management of corridors for facilitating effective movement of biota in the face of CC have, therefore, gained global attention. There is imminent need at the regional level, to have reliable information to predict the most vulnerable forest types as well as regions. Likewise, research based evidences are required to project future scenarios of shifts in boundaries, and/or to highlight potential corridors for movement of forest species and wildlife under changing climate. These aspects, and many more, require immediate attention of the planners, researchers, forest managers with adequate sensitization of stakeholders.

9. In many of the old–growth forests regeneration is hampered on account of abiotic factors. Limited openings in the forest canopy to allow penetration of sunlight for forest regeneration is increasingly being emphasized by studies elsewhere. In this respect only a few studies have been conducted in the region (e.g., Singh *et al.,* 1997). A preliminary study involving 180 plots of chir pine forests of Uttarakhand by Forest Department found that the growing stock (that is a function of crop height and density) was better at sunny sites under seeding felling plots that makes a basis for scientific management (i.e., allow felling trees selectively) only on sunny slopes. Likewise, a more recent study by Rawal, *et al*. (2011, in press) has reported disturbance sensitive recruitment patterns amongst oak forests of the region. Recognizing the value of such leads from studies, and to evolve effective management regimes, it would be pertinent to undertake systematic studies across diverse forests, under varying disturbance intensities, so as to understand trends of natural regeneration and suggest appropriate silvicultural measures.

10. Community managed/conserved forests, such as Van Panchayats (VPs) in Uttarakhand state, are amongst the oldest surviving examples of community based forest management in the region. Today there are 12089 VPs in the state of Uttarakhand managing some 16% forest area of the state. Many community managed/conserved forests are in excellent condition, thereby contributing significantly to environmental conservation and providing a range of ecosystem goods and services to the stakeholder communities. Also these VPs meet essential requirements to operationalize REDD$^+$ provisions in the region. Similarly, a rich tradition of conservation and management of forests in NE India by the tribal communities following their respective customary norms and traditional institutions is noteworthy. For example, among the Naga community the village land is divided in different zones such as woodlands, common village land and homesteads to meet various requirements of the village people (Pathak, 2009). The relationship of communities with forests, relevance and effectiveness of community conserved areas under changing scenario, therefore, emerge as important areas of research for biologists and social scientists alike. More research efforts are needed to strengthen best management practices including the community managed forests. Proper acknowledgement (with adequate reward) of the contribution of indigenous communities in the maintenance of goods and services emanating from the Himalayan ecosystems is essential and justified. There is need for putting in place appropriate mechanisms to compensate and further encourage the indigenous communities that maintain and contribute towards improvement of such services (G-SHE, 2009). Any attempt to develop such strategies would, necessarily require adequate and authentic information base emerging from research outcomes.

11. The Himalayan forests, on account of large dependence of inhabitants for a variety of biomass needs, are under different levels of chronic disturbance. However, understanding of the relationships between disturbance levels, vegetation (and regeneration) patterns, which provide important basis for predicting the status of species diversity and population dynamics in plant communities is poorly understood for the Himalayan forests (Singh and Singh, 1992). Few studies in recent years have, however, provided empirical evidences of disturbance sensitive patterns and processes of Himalayan forests. For example, significant impacts of disturbance intensities on compositional patterns highlighted the need for different management strategies across disturbance intensities in diverse oak forests (Rawal *et al.*, 2011 in press) and sub-alpine forests (Gairola *et al.*, 2009) of the west Himalayan region. Considering these clues, forests in the region require

more intensive investigations for better understanding the impacts of ongoing changes under continued anthropogenic pressure. Likewise, categorization of disturbance intensities, using multiple factors (e.g., density of useful taxa due to selective removal, fruit/seed production, seedling establishment, etc.) has not been attempted. In this context, it is important to realize that while qualifying the disturbance levels, consideration (and their impact) of existing management/protection practices is relevant. Thus identification of zones under chronic stress due to anthropogenic pressure, and prioritization for such zones for implementation of afforestation and reforestation programmes in nearby community wastelands to divert the pressure from surrounding forests should be used for devising research and action agenda. Also it is imperative to assess and monitor these forests from ecological integrity perspective. In this context, ecological niche studies need to consider the contribution of native species both in forest ecosystem composition and function (Dhar *et al*., 1997).

12. A critical assessment of available information on Himalayan forests is essentially required and the outcome should be used to create a globally acceptable Himalayan forest database, so as to remove confusion and bring in clarity on various issues, such as: (i) most often, in existing literature, the ecological value of selected prominent (dominant/co-dominant) taxa has been exaggerated with gross underestimation of the role of other associates. As a result, management and conservation prescriptions of forests are largely focused on issues related to dominant taxa; (ii) there is very little information on possible effects of habitat/spatial heterogeneity on demographic processes of individual species (including the widely known dominants). Therefore, the potential predictive values associated with a species remain masked, and questions on inter and intra-specific interactions of plants have remained unanswered; (iii) most of the available information appears to be biased in favour of hermaphrodite or monoecious group of species. Therefore, many significant dioecy dependent effects on structure and function of forest stands have remained unaccounted. These aspects, and many others, highlight the gaps in Himalayan forest database (Rawal *et al*., 2003). Such gaps can be filled through appropriately designed research studies in the region.

13. Soil and water conservation (SWC) is one of the most important ecological services of the forests. Regulation of hydrological regimes (streamflows and atmosphereic moisture) by the forest vegetation both at local and regional scale drives a variety of ecosystem functions. Provisioning of water for people and role of forests in soil formation and soil fertility

replenishment has both local and regional relevance (Singh, 2007). In spite of this crucial link of forests and water the hydrology of the forests and forested watersheds in the IHR is least understood (Negi, 2001). It is still uncertain that which of the forest types (viz., broadleaf or conifer) and tree life forms (evergreen or deciduous) are desirable for achieveing SWC in the region without compromising other ecosystem services resasonably. Therefore, hydrological studies on forests are essential for planning afforestation and soil and water conservation programmes in the IHR.

14. Invasion of weeds such as, *Lantana*, *Eupatorium*, *Parthenium*, spp. etc. have posed an additional risk to forest biodiversity and resources in the region. Ways and means of systematic eradication of such weeds is required. The impact of invasive (alien) species on native biodiversity elements and overall ecosystem processes should form one of the action problems of applied value for the consideration of researchers. Further, possibilities of utilization of these species, as a part of participatory eradication strategy, need to be worked out following in-depth researches along with cost-benefit assessments. Identification of potential areas of invasion, particularly under changing climate scenario, and likely impacts on ecosystem structure and function also needs urgent attention (Negi and Palni, 2010).

15. In spite of rapid economic growth in recent decades, incidence of poverty is relatively high in remote and isolated areas, such as the Himalaya, even under the hype of “inclusive” and “more inclusive” growth. Dominance of forested landscapes in such mountainous areas is often viewed as a hindrance in mainstream development, and thus some people wrongly refer to the protection of forests as a part of perpetual poverty trap. Further, the contribution of forests to direct (cash) income of rural masses, by and large, has remained limited. Therefore, working out feasibility of forest resources and forestry activities in promoting rural development in the region should be considered as a part of intensive research agenda. For example, the hidden wealth of non-timber forest products (NTFPs) in Himalayan forests could contribute significantly to the primary sector based domestic products, pushing up the per capita income of local communities. Likewise, forest bio-diversity based industrial potential holds promise for various kinds of manufacturing activities in pharma, nutraceuticals and cosmetic sectors (Tolia, 2011, in press). Harnessing such potential would, however, depend on reliable data and research.

16. While considering the possibilities of linking forests with rural poverty alleviation, the 12th Five Year Plan of India lays particular focus on service sector with emphasis on tourism and hospitality sectors so as to increase the participation of a much larger proportion of people in the process of growth. The diversity and extent of forests in the region, thus provides an

option and opportunity to work in tandem, both for developing sustainable forest/wilderness and responsible tourism in the region based on the same. This would, however, require systematic investigations across diverse sectors ranging from micro-to-macro levels, including product and infrastructure development, marketing, branding and promotion, planning, policy and investment (Tolia, 2011, in press). All this should come through after in-depth analyses of concepts and field based investigations.

17. With the fast changing national and international policy dimensions and upcoming frameworks on environmental protection and sustainable use in general, and forestry sector in particular, there is a growing need for an improved understanding of all such policies so as to accrue benefits to the region and its people. For example, special efforts need to be made for the implementation of Payment for Ecosystem Services (PES) in the region under the upcoming international climate framework, and adequate steps should be taken to harness benefits from programmes like 'Reduced Emission from Deforestation and Forest Degradation' (REDD) under the United Nations Framework Convention on Climate Change (UNFCC). Likewise, there is ample scope for obtaining benefits from existing national/ international opportunities (Kishwan and Pande, 2011). This can be achieved if adequate emphasis is given to integrate policy studies also in the forestry research domain.

18. Reports indicate that approximately 15% area of the Himalayan Biodiversity Hotspot has some form of legal protection; this percentage comes down to 10% when only areas under the IUCN categories I to IV are considered. In view of the significance of the region, Government of India has established over 173 Protected Areas (PAs) in the Indian Himalayan states, which cover approximately 47, 500 sq km area. The coverage under PA network in IHR has steadily expanded over the years (MoEF, 2009). While there have been success in establishing PAs and more experimental, multiple land use conservation areas in the region, much remains to be done to safeguard the biological wealth of the IHR currently present in areas outside formally protected reserves. The PAs in the Himalayan region, particularly in the lowlands along south-facing slopes, are too small to maintain viable populations of threatened species. Further, while considering the issues of adequate protection of representative forests, there is a serious need for analyzing the IHR-PA Network for gaps in forest protection with respect to achieving 10% protection target as per CBD for each forest types along with the representativeness features (Schmitt *et al*., 2009). Also, there is a need to have a systematic conservation planning, which considers the detailed distribution patterns of biodiversity within forests, the socio-economic situations and conservation effectiveness of existing PAs (Langhammer *et*

al., 2007). Besides, legally designated PAs, the Biosphere Reserves (BRs), which represent characteristic ecosystems in different biogeographic regions and consider human communities as their integral component, are increasingly receiving greater attention across the globe. In this context, India has taken definite strides. The Himalayan BRs, with extensive vertical gradient and biogeographic representation from east to trans north west Himalaya, have emerged as important candidate for anchoring research, training, capacity building and demonstration agenda of MAB (Man and the Biosphere Programme). Among others, linking of BRs with concerted promotion of local level economic development that is sustainable both in terms of ecology and socio-cultural milieu has been suggested for infusing dynamism in Indian BRs (Palni *et al*., 2011, In press). All such needs from PAs and/or BRs call for an immediate attention and appropriate research studies and surveys in the region.

19. In keeping with the fact that, due to unique vertical gradient, the Himalayan biodiversity is highly sensitive to CC as well as to the anthropogenic impacts, and in turn this would define the future of mountain ecosystems and local people, there is an urgent need to understand intensity and direction of consequent on-going and potential impacts of changes on structure and functioning of biodiversity elements, especially in forested ecosystems, in the region. On the whole, the data on climate change in the region is very fragmentary. As a result, the relationships between biodiversity response and CC have not been developed. Realizing the importance of understanding relationships of CC and biodiversity through systematic datasets, covering various aspects of environment, biodiversity and socio-economy, there is, therefore, imminent need to promote Long-Term Research and Monitoring in the region. Towards meeting this goal, the region would require a strong network of Long-term Observational Sites. This will ensure continuity of long term research and monitoring following globally accepted protocols, so as to benefit the region by way of developing: (i) Reliable and continued availability of climate data for this largely data deficient region, (ii) Early warning indicators, and (iii) Strong research based plans for conservation and sustainable utilization of representative and unique forest biodiversity elements. This initiative, along with the ones suggested earlier (particularly under point 12), would help in adequately representing hitherto less represented Himalayan forest data base (Zobel and Singh, 1997) in global data base. This aspect needs serious thinking along with an emergent need to update the methodology (both field and laboratory) in several aspects of forestry research considering fast changing environmental and socio-cultural scenario, and technological advancements. Vital aspects such as plant-animal interaction, reproductive

biology, tree architecture, hydrological and soil and water conservation function of forests (c.f. Negi, 2001), soil binding capacity of root system, etc. have remained marginalized due to the so called anthropocentric bias in research activities; the situation calls for hard core taxonomists, ecologists, wildlife biologists and environmental engineers, etc. to take-up these challenges in more holistic and integrated manner.

20. Realizing that the Himalaya is considered almost a ‘white spot’ in terms of climate data, development of long-term data sets relating to mountain meteorology and related aspects of atmospheric science have emerged as a research priority. Therefore, establishment of a network of reliable weather stations (or wherever possible climate profilers) across the region is an urgent need. Further, effective linking of data sets thus generated, especially in pursuing researches on impact of CC on forests and other biodiversity components, emerges as a challenging area. Establishment of a chain of long-term environmental monitoring sites in representative forest types and application of uniform, globally acceptable monitoring protocols would help in generating reliable data sets on diverse aspects of forest ecosystem structure and functioning. Subsequently these data sets would feed to environmental modeling needs in the region and elsewhere as well.

In conclusion, the entire nation which is based on a “Aranya Sanskriti”, and the inhabitants of IHR who in particular share a forest dominated landscape must rejoice in what has said by Josip Kozarac, esteemed Croatian writer and forester, in the late nineteenth century “Lucky are nations sharing their lives with forests, even luckier are those who appreciate the wealth they possess”. We must also keep in our minds the famous words of a Kashmiri saint, Nundrishi, that remind us that “The food will last as long as the forests last” – so true in the context of IHR where agriculture is largely fuelled by energy derived from the forest biomass, apart from the intricate link between many goods and services and the health of forests in the region. Broadly divided into eastern and the western Himalaya, each region has its unique culture and cultural diversity. A wide spectrum of bio-physical gradients when superimposed with socio-cultural diversity make the IHR all the more heterogeneous, necessitating formulation of location specific development plans (in tune with the principle of more inclusive growth) as well as finding solutions to the local problems, based on stakeholders needs, and through appropriate research investigations. There is a distinct social awareness on conservation and natural resource management in the region, as reflected by the origin of world famous environmental movement “Chipko”, that has its roots in the Garhwal region of IHR. Our actions on the ground and research agenda, both in the short-and long-term, must ensure that forests should continue to sustain livelihoods, host biodiversity, help stabilize the climate, provide sustainable materials and renewable energy, contribute to greening the economy, protect soils and water, and prevent floods, erosion and avalanches. Fragmented approaches and singular actions are bound to fail when attempting to address the complexity of these expectations and challenges. The concept, principles and practice of sustainable forest management does provide the basic framework for securing the long-term economic, environmental and social functions of forests comprehensively and in a balanced manner. What is required is to enhance our efforts, strengthen our commitments, establish robust political roadmap at all levels along with well thought out research priorities, and appropriate and dynamic strategies to put sustainable forest management in practice. At the end keeping Rio+20 and mountains (IHR included) in focus, the central question is "how to keep the mountains green and reduce poverty"- forests are likely to provide lasting solutions for both.

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Forest Cover Status in the Indian Himalayan Region

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The “Great Southern Watershed” of Himalaya is divided into different administrative boundaries (Fig. 1A) which includes exclusive mountainous countries (Nepal and Bhutan) and several hilly states (stretching from west to east) within the India. Variation in longitude, altitude, geology, and soil has resulted a great forest diversity along these bioclimatic gradient stretched over 5000 km in different administrative and political boundaries. This prime natural resource in these countries has ecological and biological significance for a greater landscape of the earth, particularly Indian sub-continent.

The forest cover in the different Himalayan states (or hilly region) of the country (i.e., Indian Himalayan Region) varies considerably from 2,289 km^2 (West Bengal Hills) to 67,353 km^2 (Arunachal Pradesh) in the year 2007 (FSI, 2009). As a percent of an administrative boundary (state or hilly district) this forest cover contributes from 10.2% (Jammu and Kashmir) to 91.2% (Mizoram) among the states. The lower contribution in Jammu & Kashmir state is due to the fact that most of the area in the state lies in the high altitude region (above the limit of tree growth) and trans-Himalayan region, otherwise no where in the Indian Himalayan states forest cover contributes less than one-fourth of the administrative region in the year 2007 (Fig. 1B).

In the North-Western Himalayan region (west of the Nepal) generally forest cover remains less than 50% of the total area of a state where total human population is high (67.2% of the total population) in the IHR while in the east of Nepal (eastern and north-eastern region) all the Indian states have more than 75% forest cover in each state (except Sikkim). Sikkim state has 47.3% of the area under forest cover as it has considerable area in the high altitudes and snow covered which is beyond the limit of tree growth. Per cent contribution

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of forest cover to the total geographical area of a state is given in Table 1. Since the first forest cover assessment (1987) in the country, forest cover status has been improved in the IHR states (Fig. 1C) such as in Himachal Pradesh (an increase of 17.5% since 1987) in the north-western region, and Meghalaya (5.1% increase) and Tripura (35.6% increase) in the north-eastern region. Decline in forest cover of two states of the north-eastern region was also recorded between the two decades (1987 and 2007) viz., Manipur (reduction of 1.1%) and Nagaland (reduction of 6.4%).

Table 1: Forest cover (% of the geographical area) in the IHR

States/Region	Geographical area (Km^2)	Forest cover (% of total geographical area)	
		1987	2007
North-Western region			
Jammu and Kashmir	222,236	9.4	10.2
Himachal Pradesh	55,673	22.4	26.3
Uttarakhand	53,483	NA	45.8
Eastern region			
Sikkim	7,096	38.8	47.3
Arunachal Pradesh	83,743	76.5	80.4
West Bengal Hills	3,149	NA	72.6
North-Eastern region			
Manipur	22,327	78.2	77.4
Meghalaya	22,429	73.4	77.2
Mizoram	21,081	90.5	91.2
Nagaland	16,579	86.8	81.2
Tripura	10,486	56.7	76.9
Assam Hills	15,322	NA	84.8

Among the different regions (north-west, eastern, and north-eastern region; for corresponding states and regions refer to Table 1) composition of the total forest cover in the IHR has changed in these two decades (1987-2007). In the north-western region forest cover has increased ~10% of the total forest cover (19.2% in 1987 and 29.7% in 2007) of the IHR (excluding hills of West Bengal and Assam for these two regions separate statistics are available 2001 onwards) while forest cover has gone down in other two regions (eastern region 38.5% *vs*. 34.0%, and north-eastern region 42.3% *vs*. 36.3%), which is due to inclusion of separate statistics of the Uttarakhand state from 1997 onwards. During this

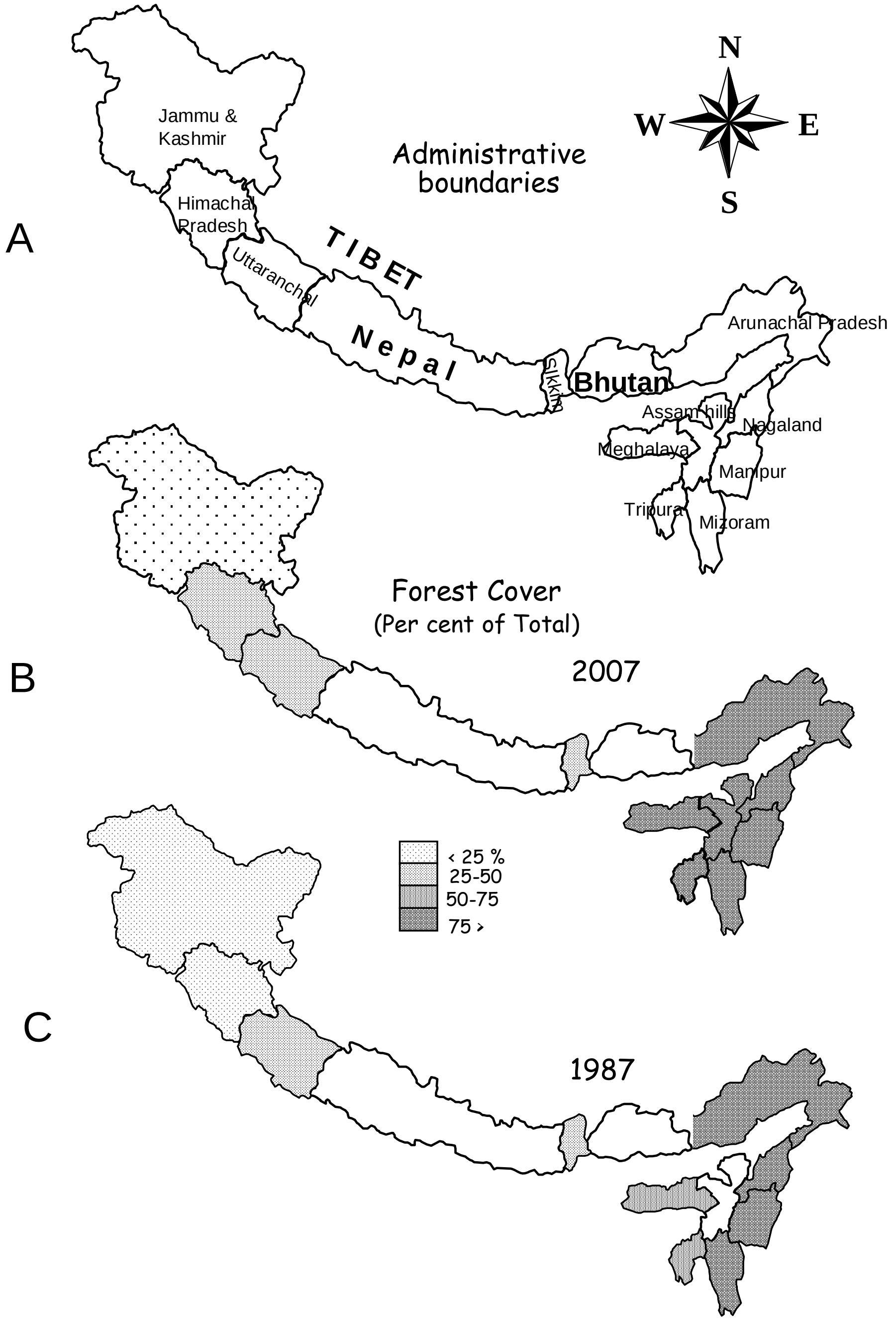

Fig. 1: A= Hilly states of Indian Himalayan region; B= Forest cover in different hilly states of IHR in 2007 (1 B); and in 1987 (1 C)

period (1997-2007) contribution of north-western region to the total forest cover has been increased by more than 1% of the total forest cover of IHR. In the north-eastern region despite of the total gain of 4,457 km^2 of forest cover (in Meghalaya, Mizoram, and Tripura), a reduction of 895 km^2 forest cover (in Nagaland and Manipur) limited the forest cover contribution of the north-eastern region to the total of IHR by 0.3%. Eastern region during 1997-2007 period witnessed a decline of ~2% of contribution of regional forest cover to the total forest cover of the IHR which could be attributed to the loss of 1,249 km^2 area of forest cover in Arunachal Pradesh in this period, however Sikkim has a gain of 228 km^2 of forest cover.

The impacts of human activities are being felt in all ecosystems. Human population is settled all across the IHR from east to west but density of population differs markedly in different regions (Census of India, 2011). Societal dependence of mountain communities exhibit diverse patterns across the region from east to west, as well as north-south gradient in these mountains. Due to utilities in various forms world's natural forests continue to shrink. Till the end of 1995, 180 million ha forests were lost worldwide out of 3454 mha of forests in 1980, which represents an annual loss of 12 mha; between 1980 and 1990, 10% of the forested area in the tropics was fragmented, which represents partial deforestation, with a loss of approximately two-thirds of the original forest cover (Braatz, 1997). Considering this rationale the increase in forest cover during 1997-2007 in the IHR is appreciable but the quality of the forests is always in question due to extraction of various tangible goods for the sustenance of the surrounding societies (Singh and Singh, 1992). Further, rapid growth of developmental projects, e.g., road construction, river valley projects etc. also accounts for depletion of forest cover as evident in Arunachal Pradesh which has otherwise least human population density in the entire country.

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3

Community Forestry in the Indian Himalayan Region

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Community forestry is a branch of forestry which deals with the management of forests in such a way that not only help conserve forests but also contributes in enhancing part of household income from timber and non-timber forest products (NTFPs). In addition, in the present day context community forestry helps augmenting ecosystem services for local as well as larger communities. The word community forestry has different connotations in different parts of the world including the Indian Himalayan Region (IHR) depending upon a variety of factors. In this paper the word community forestry has been described with a view that its scope is not only restricted to forestry on communal land but also on government forests and tree planting by the people in their private land as there exist a variety of ownerships and control even over forest land across the IHR. In IHR three broad types of community forestry regimes are presently in vogue viz., state sponsored JFM programme being implemented in all the IHR states, Van Panchayat in Uttarakhand, and a traditional system mainly in north-eastern Himalaya. Most of the forest area is managed by the State Forest Departments through scientifically written management plans under various categories: reserved forest, protected forest and protected areas in Western IHR states (99.8% in J&K, 66% in Himachal Pradesh and 69% in Uttarakhand). However, such information is not available for most of the north-eastern IHR states, except for Arunachal Pradesh which has only 2% of forest area under such plan. About 20,778 km^2 of forest area in states like Himachal

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Pradesh, Uttarakhand, Mizoram and Nagaland is outside the control of state forest department and is under the control of Revenue Department (25%), community ownership (33%), and private ownership (42%). Uttarakhand is the only state in the IHR where all types of ownerships exist; while in Nagaland private ownership of forests is the dominant feature (Task Force Report on Indian Hill Areas, Planning Commission, 2010). Thus while in the Western IHR states including Sikkim, majority of forests are state owned and managed, in the seven eastern IHR states large chunks are community owned (Table 1). There exist a large number of traditional and formal community forestry institutions in the IHR that had and still have been playing a significant role in managing forests and forest based livelihoods in the region since long. Constitution and functioning of some of them is highlighted in Boxes 1-7.

THE VAN PANCHAYATS OF UTTARAKHAND

The institution of Van Panchayats (VPs) in Uttarakhand came into existence in early 1931 after a long struggle of local people against the forest management policy of the then colonial government. The VPs of Uttarakhand are one of the oldest examples of participatory forestry institutions not only in India but perhaps across the globe. Presently 12,089 VPs (nearly half of which have been created after Uttarakhand got statehood in 2000) of the state are managing over 5,449 km^2 forest area in the 11 hill districts of the state, which is about 16% of the total forest area of the state (Table 2). After 2005 amendments in Uttarakhand Panchayati Forest Rules a VP consisting of nine elected members will preferably be called as the Van Panchayat Management Committee (VPMC) with provisions of reservation for women and weaker sections of the society i.e. Scheduled Castes and the Scheduled Tribes as per Uttarakhand Panchayati Forest Rules (UPFR), 2001. Though the forests are protected and managed by VPMCs and come under the jurisdiction of State Revenue Department, State Forest Department provides technical and financial assistance through Forest Development Agency (FDA) for the management of a sizable number of VPs after 2001.

Despite of success in management of VPs achieved over last 80 years, presently, the institution has been facing several challenges such as: smaller forest area; nearly 60% VPs are of <15 ha, while 13% VPs are having <3 ha forest area under their management; lack of adequate financial resources and appropriate incentives; low awareness and capacity; less social recognition of VP Sarpanch and VPMC due to curtailed autonomy; non-holding of timely elections; shortage of trained staff in participatory forestry in forest department; complexities to link livelihoods with forest conservation; increased pressure due to ever increasing population; inadequate mechanisms for constant

Table 1: Forest area under different categories in the IHR states

Particulars	J&K	Himachal Pradesh	Uttarak-hand	Sikkim	Arunac-hal Pradesh	Megha-laya	Nagaland	Manipur	Mizoram	Assam	Tripura
Total Geographical Area (sq Km)	222,236	55,673	53,483	7,096	83,743	22,429	16,579	22,327	21,081	78,438	10,486
Forest Area (sq Km)	20230	37033	34651	5841	51500	9496	9222	17418	16717	26832	6294
Forests Cover (Sq Km)	22686	14668	24495	3357	67353	17321	13464	17280	19240	27692	8073
Percent of GA in relation to Forest Cover	10.21	26.35	45.80	47.31	80.43	77.23	81.21	77.40	91.27	35.30	76.95
Reserved Forests (Sq Km)	17642	1899	24636	5452	10539	1112	85.8	1466	7909	17865	4175
Protected Forests (Sq Km)	2551	33059	9882	389	9527	12.5	508	4172	3567	00	189
Unclassed State Forests (USFs)/ (Sq Km)	36	2075	132	00	31415	8371	8628	11780	5241	8967	2117
Population (2011census)	12,548,926	6,856,509	10,116,752	607,688	1,382,611	2,964,007	1,980,602	2,721,756	1,091,014	31,169,272	3,671,032

monitoring; large scale encroachments; timber pilferage; and lack of dedicated and clearly spelt out mechanisms to link VPs horizontally with Panchayat Raj Institutions (PRIs) to bring forestry in development agenda. Policy, institutional, technical and financial interventions are required besides adequate attention on determining viable size of VPs, and other field realities to take action to meet the aforementioned challenges. In this regard, Central Himalayan Environment Association (CHEA) is making efforts for developing a model for strengthening VPs of Uttarakhand. Similarly, state forest department in Uttarakhand has made some innovative interventions for sharing conservation benefits with local communities.

TRADITIONAL INSTITUTIONS FOR COMMUNITY FOREST MANAGEMENT IN THE EASTERN IHR

A multiplicity of traditional community forestry systems and institutions operate in various north-eastern IHR states. Over the centuries, the traditional institutions have acquired unique authority and power with different patterns of constitution and composition ranging from head of the institution by inheritance to the village republic where the head and members of Village Councils (VCs) are elected by consensus for a specified period of time. Even the relatively new in origin, the VCs are known by different names such as *Kebang* and *Buliang*, respectively, by *Adis* and *Apatanis* tribes of Arunachal Pradesh, *Syiemship* by Khasis of Meghalaya, *Doloiship* of Jaintias of Meghalaya, *Hangvu* of Tangkhuls of Manipur, *Hodra* of Jamatias of Tripura etc. (Pathak, 2009). These institutions hold the land and forests on behalf of the community, either as owners or custodians in the north –eastern IHR. Some important laws related to forests and forestry in north-eastern states are given in Annexure-I.

Local communities through traditional institutions conserve and manage majority of forests in the region. Though large tracts of forests are protected for practicing shifting agriculture (jhum), smaller areas of forests are also protected as Scared Groves such as those of Khasis and Jaintias of Meghalaya to meet socio-cultural needs; Safety Forests (for village safety and water supply) of the Mizos in Mizoram; Supply Forests and Bamboo Forests for provisioning of raw materials. Similarly, in Arunachal Pradesh there are Anchal Reserved Forests protected for earning economic benefits for community through the sale of forest products.

Table 2: Distribution of Van Panchayats in hilly districts of Uttarakhand

S.No.	Division/District	No. of VPs	Area under VPs (ha)
Garhwal Division			
1	Chamoli	1082	188355.18
2	Dehradun	215	7658.60
3	Pauri	2431	52814.02
4	Rudraprayag	574	20701.60
5	Tehri	1332	13180.00
6	Uttarkashi	644	7264.52
	Total	**6278**	**289973.91**
Kumaun Division			
7	Almora	2199	69853.07
8	Bageshwar	822	38782.92
9	Champawat	629	31232.78
10	Nainital	495	28067.79
11	Pithoragarh	1666	87053.70
	Total	**5811**	**254990.26**
	Total (Garhwal + Kumaun)	**12089**	**544,964.17**

Source : Van Panchayat Nirdeshika (2007) of State Forest Department, Uttarkhand.

Community forestry in the eastern IHR faces challenges from different quarters. At community level factors like eroding traditional institutions, growing inequality, commercialization leading to privatization, and increasing consumerism; increasing control and regulation, matching institutions for CFM, and livelihood issues generally ignored at governance level; and pressure from private sector due to availability of market and development projects.

JOINT FOREST MANAGEMENT IN THE IHR

Following the spirit of the National Forest Policy (1988), the Government of India issued a circular in June 1990 for the involvement of local people in forest protection and management through village level organizations. The Forest Policy also provided guidelines for the sharing of usufructs and the net benefit proceeds from their sale. However, even after two decades of active implementation, joint forest management (JFM) is still evolving with mix results and run in project mode presently under the aegis of FDA at forest division level and a total of 16831 JFM committees are formed (Table 3). However, the

IHR in general, and north-eastern states in particular, where local communities/institutions own and manage 41 to 92% forest area (so called Unclassed State Forests in official parlance), through JFM resolutions have been adopted by the states during 1990s itself; its implementation in Unclassed State Forests (USFs), VPs, and bypassing traditional institutions is often resented by local communities.

Presently there exist three broad types of institutional arrangements of community forestry in the IHR. These are: The age old traditional village institutions prevalent in most of eastern IHR states with complete ownership of forest land under their jurisdiction; the decades old VPs of Uttarakhand where forests are managed by local villagers but the ownership of land is with the state and the forest department provides technical assistance; and the state supported JFM, FDA (Forest Development Agency) and other programmes on community and government forest land from time to time. Though the fourth type in the form of simultaneous agroforestry on private farmland has a vast potential to grow further and provide huge economic incentive at household level, often it is not discussed as a form of community forestry. Some of the specific stories of community led forest conservation based on secondary sources are cited in Boxes 1-7.

Table 3: JFM status in different states of IHR

State	Starting year	No. of JFMCs	No. of families covered	Forest area under JFM (ha)
Assam	1998	503	57341	80000
Arunachal Pradesh	1997	347	23308 persons	90000
J&K	1990	2697	Not available	114100
Himachal Pradesh	1993	1690	265000	420000
Manipur	1990	280	26000	90000
Meghalaya	2003	73	All families	Not available
Mizoram	1990	270	740000	20000
Nagaland	1997	335	85000	20000
Sikkim	1998	155	46000	10000
Tripura	1991	374	33000	Not available
Uttarakhand	1997	10107	500000	544964*

Source: State of Forest Report (2009): Forest Survey of India & *Van Panchayat Atlas, Uttarakhand Forest Department

In the present day context community forestry under all the existing institutional arrangements facing different set of challenges. Traditional community based sustainable forest management practices in the IHR are dwindling particularly in the wake of merging local economies with national economy. In Himalaya its chronic degradation due to over dependence on forest resources for fuel wood, fodder, agriculture and grazing, adverse impacts of climate change, extreme weather conditions, loss of forests due to diversion of forest land for development projects and landslides and landslips are more serious challenges to maintain good forest cover than deforestation *per se.* Further, uncertain environment (project based interventions, etc.), small and unviable areas of community forests, top down centralized policies, lack of resources, lack of accountability with responsibility, man-animal conflict, increasing and uncontrolled biotic pressures on the forests, less effective law enforcement ability of the community organizations, paucity of effective local leadership, poor knowledge for developing entrepreneurship based livelihood options, conflict between policies and laws, in some cases conflict between policies and forest management laws are some of the other issues need to be addressed.

Strengthening community forestry based on lesson learned so far is perhaps the best available option in the IHR to respond to the said challenges along with augmenting local livelihood. Therefore, capacity building and trainings on participatory skills and attitudinal changes for the key stakeholders, more emphasis on protection and conservation based models of forestry than target oriented afforestation, reforms and streamlining of acts/policies/rules etc., appreciation of conservation efforts of communities through rewards, scientific knowledge for optimum outputs from the forests, development of micro-plans/ management plans for all community forests, development of efficient methods of participatory-decision making at local level and possibilities of creating financial incentives through production forestry/carbon forestry etc. will be helpful to better manage the community forests and keep this healthy tradition of participatory forestry alive in the IHR.

Box-1

TRADITIONAL FOREST MANAGEMENT INSTITUTION OF UTTARAKHAND: *LATH PANCHAYATS*

In the mountainous parts of Uttarakhand though till 1865 traditional protection and management of forests was not codified, it was simple, efficient and effective. The stateforward unwritten socio-cultural norms of informal village institution called *Lath Panchayat* through which local communities used to manage the forests in Uttarakhand. The *Lath Panchayat* members would enforce the agreed norms strictly and sometimes even used social power (*lath* i.e. stick) whenever they realized it was absolutely necessary in extreme cases of gross violation of established rules by outsiders or powerful individuals within the village. The Sarpanch or head of the *Lath Panchayat* used to be selected through consensus. Though most of the time the members of *Lath Panchayats* were men, decisions taken by them customarily taken to help women folk as traditionally women of Uttarakhand share almost all work load of fetching firewood, fodder and leaf litter from the forests. The *Lath Panchayats* with the help of entire village community would protect forests particularly that of oak (*Quercus* spp.) from forest disturbances like fire and unregulated grazing. In addition to practices that assisted natural regeneration, saplings/seeds of desired species used to be planted/ sown depending on the climatic condition of the concerned *Lath Panchayat* forest. In most of such forests, cutting of green trees and lopping of big branches were forbidden.

In some *Lath Panchayats* the entire village community would lend support in forest protection activities, in some others each household on rotation basis would share the responsibility for a fixed time period (i.e, for a month or two), and still in few cases *Lath Panchayat*s would appoint local forest guards to perform this duty. Generally the forest guard used to be paid in kind (cereals and pulses) collected from each household. Violators of norms were used to be punished/reprimanded by snatching away their axes, sickles, strings and sometimes in extreme situation were forbidden to take part in any of the village cultural and social ceremonies/activities. The *Lath Panchayats* were known for their sense of justice as these ensured equitable sharing of forest resources among the villagers and thus always commanded respect of the villagers. Though the aim of *Lath Panchayats* was not to generate income from forest resources, income earned through collection of penalties, selling of fallen trees, and wood for agricultural implements used to be spent on various activities and things of common use. Until few decades back such local forest governance supported a robust agrarian economy in Uttarakhand. [*Source: Nagarkoti, D. (1997), PAHAR, Nainital; reproduced from a case study by Semwal et al., 2010, RC, NAEB, New Delhi*].

Box-2

SOCIAL ORGANIZATION AND LOCAL AND NATURAL RESOURCE GOVERNANCE IN NAGALAND

Local communities in Nagaland are socially well organized and indigenous groups have their own social and cultural norms of governance. Traditional knowledge is passed on from one generation to the next through the institution of Morung where normally the elders and young people sit around fire in the evening at a designated place in the village. Formally, the villages across the state are administered by Village Councils (VCs) that in turn constitute Village Development Boards (VDBs) to plan development programmes and schemes for the villages under the Nagaland Village and Area Council Act, 1978. This Act gives powers to the VCs to formulate village development schemes, to supervise proper maintenance of water supply, roads, forests, education and other socio-economic welfare activities. Village councils under this act work in partnership with traditional systems of decision-making as the traditional village heads or the *Gaon Buras* (respected and experienced village elders) are the permanent members of the VCs.

The VC members are chosen by villagers in accordance with the customary practices and approved by the State Government. All residents of the village are the members of the VDB general body. An important provision in the legislation is that the customary law prevails over in settlement of disputes (Article 371A of the Indian Constitution). Villages also have informal village-level forums such as youth clubs, biodiversity protection committees and so on, and majority of tribes are also linked at inter-village level as well where different villages occupied by same tribe come together to form district level organization such as Chakhesang Public Organization, Western Angami Public Organization, Southern Angami Public Organization, etc. These forums are recognized as federation of the village councils under the State Village and Area Council Act, 1978.

[*Source: Neema Pathak (Ed.) 2009. Community Conserved Areas in India- A Directory Kalpavriksha, Pune/Delhi*].

Box-3

TRADITIONAL SILVICULTURAL PRACTICES: A CASE OF WILLOWS BASED FORESTRY IN LAHAUL VALLEY, HIMACHAL PRADESH

In the frigid and xeric climatic conditions of Lahaul valley of Himachal Pradesh, two non native willows viz., *Salix fragilis* and *S. alba* are cultivated through traditional shoot-cutting plantation method in the indigenous agroforestry systems by local people to meet their subsistence needs of fuel wood, fodder and minor timber. Along elevational gradient, the willow based agroforestry systems not only contributes in enhancing forest cover (the density of *Salix spp.* ranges from 57 trees/ha to 365 trees/ha) but also fulfill fuel wood demand sizably. Green bark peeled off from coppices and small branches, twigs, and leaves are used as fodder while the dry leaf litter is used for animal bedding in the cowsheds. Willows are meeting a wide range of local needs including roofing, shelter, roadside shade plantations, and making agricultural implements, baskets, poles for hops and commercial purposes. Generally three years old shoot-cuttings of willows are used for raising new plantations.

Depending upon the altitude of villages, generally 3-5 willow shoot-cuttings (occasionally solitary shoot cuttings are also used in lower altitude villages) of similar height, thickness and age are tied together in a bunch (to withstand damage due to high speed winds and also from complete damage of phloem in case of browsing by livestock) and planted in the months of March and April when the melting snow leaves behind fairly good moisture in the soil. Just after the plantation, auxiliary branches arising along the main trunk are pruned on a bi-monthly basis during early development phase. Shoot-cuttings are regularly irrigated by local farmers at a weekly interval during summer months through ensured water channels in their private farmland. First pollarding is done after three-four year of planting during winter (November to March). At the time of pollarding, 4-5 branches are left intact on the top of main trunk, which are most often used as planting material to raise new plantations. Though cuttings taken from proven genetic material is often advantageous from the point of view of adaptability as the present clone of willow was imported about 150 years ago, and since then the same genetic material is repeatedly yet successfully being used by local farmers. In the Lahaul valley, there is a need to establish nurseries in different altitudinal zones with stock of native and exotic willows required to ensure the availability of quality genetic material and scale up the willows-based forestry system. [*Source: Pers. Comm. Dr. Y.S. Rawat, GBPIHED, Kosi-Almora*].

Box-4

TRADITIONAL FOREST MANAGEMENT IN ARUNACHAL PRADESH

Sustainable forest management is not necessarily associated with any particular protection and management regime. Success and failure can be found out in state, community and even under private management regime. However, studies pouring in from different parts of the globe indicate better management, particularly in-terms of sustainability and equity of forest/natural resources under the participatory regime managed jointly by traditional (community) and formal institutions. In Arunachal Pradesh most of the forests are managed by a number of tribal communities through their respective customary norms and traditional institutions. As opposed to conventional thinking that traditional institutions may not necessarily comprehend the significance of forests and may also lacking in wherewithal needed for scientific management of forests in present times when population is growing and local economies are merging fast with mainstream economy, two landmark rulings given by traditional institution of Nishi community called “Nyel” prove the wisdom and environmental prudence of its members. “Nyel” ruled that community forests can be used only for self use and not for commercial gains and that monoculture plantation in the forests is not good for the health of the forests.

Similarly, another traditional institution of Monpa community of Tawang called “Mangma” not only shows a well defined mechanism of its constitution but also a high degree of understanding among its members in forest resource management. The community forests of Monpas are divided in “*Tsos*” always demarcated along altitudinal gradient to cater to the diverse resource needs of a cluster of villages. The forests are protected by traditional forest protection committee known as “*Tsopa*” comprised of “*Gaon Buras*” from bigger villages and “*Thumis*” from smaller villages with its head called “*Tsorgen*” and the issues related to resource collection and sustainable forest management are deliberated in an assembly of villagers called as “*Mangzom*”. However, in present times due to rapid changes in socio-economic milieu, the traditional institutions may face many challenges. As stated above, the traditional institutions can be reinvigorated if the mechanisms are put in place that help recognize and appreciate local management regimes by larger formal regimes

[*Source: Chatterjee, S., Semwal, R.L. and Dutta, P. WWF-India, Newsletter, 2003*].

Box-5

THE STATUS OF COMMUNITY FORESTRY IN MANIPUR

The total forest area of Manipur is 17, 418 sq km constituting about 77% of the total geographical area of the state (FSI, 2009). Majority of the forest area falls under the category of Unclassed Forests (77%), while rest is managed as Reserved Forests (1456 sq. km) and as Protected Forests (4172 sq. km). Four major forests types viz., Tropical Semi-evergreen, Dry Temperate, Sub Tropical Pine, and Tropical Moist Deciduous are known to occur in Manipur. Agriculture along with forest based livelihoods is the major economic activity of the local people. Teak, pine, oak, and cane, are important forest resources of the state. In addition, cash crops such as rubber, tea, coffee, cardamom, jackfruit and oranges are grown in hill areas. Various government departments are promoting sericulture and horticulture at large scale for the economic upliftment of local people. As per constitutional provisions in Article 371-C, Autonomous District Council status has been granted to Hill Areas of the state and functions as per the Manipur (Hill Areas) District Council Act.

Each village has a Village Authority under Manipur Village Authorities in Hill Areas Act, 1956 and Inter Village Council that facilitates resolving inter village conflicts and could be considered as traditional institutions in the state. In many villages in the state like those inhabited by Nagas, traditional systems of land management regulate resource utilization. The village land is divided in different zones to meet different requirements of the village people such as woodlands, common village land, and homesteads. There are a number of sacred groves with dense forest patches exist in the state. There are various threats such as habitat loss, jhum cultivation, forest conversion for development projects such as hydroelectric projects, frequent forest fires, unregulated grazing, fuelwood collection, timber harvesting, privatization of community land, and unsustainable NTFPs collection that impinge on the sustainable management of forest ecosystems of the state. The government forest department is making concerted effort to promote community forestry through JFM in order to minimize aforesaid threats and enhance forest cover and livelihood options for local communities since 1990

[*Source: Neema Pathak (Ed.) 2009. Community Conserved Areas in India- A Directory. Kalpavriksha, Pune/Delhi*].

Box-6

HAZARD CONVERTED INTO LIVELIHOOD OPPORTUNITY IN PINE FORESTS OF UTTARAKHAND

Chir pine (*Pinus roxburghii*) is prominently present in the forest areas of Uttarakhand in the middle Himalayan region where most of the hilly habitation are concentrated. Uttarakhand forests have more than 3.94 lakh hectares of chir forests. More than 16% of the reserved forest area has been classified as chir pine forest. Every year large quantities of dry chir pine needles fall on the forest floor. These needles are highly inflammable and therefore pose a major fire threat to forests of Uttarakhand. Unregulated forest fires have adverse impact on the biodiversity, water conservation and host of other ecosystem services. The smoke produced during forest fires reduces visibility and adds up CO_2 in the atmosphere and contributes towards global warming and climate change. According to an estimate of the forest department about 10 million tons (@about3 t/ha/year) of chir pine needles fall on forest floor every year. Assuming that even if only 50% of this is available for collection an estimated 5 million tons of dry pine needles would be easily available from reserved forests alone which can be used for various industrial purposes.

Uttarakhand forest department has started innovative scheme to convert this fire hazard into livelihood opportunity for the local people. Under the scheme an memorandum of understanding (MOU) is signed between the DFO of the concerned division and the industry, which wants to use dry chir pine needles as fuel. The industry is allotted specified chir pine area for collection of needles collected through the local villagers at minimum price regulated by the forest department which is Rs. 1/kg at the collection site. The venture has taken off during 2010 fire season in Nainital, Almora and Lansdowne Forest Divisions. Here the industry is making coal briquettes out of dry pine needles to be used as fuel. This arrangement is benefitting all the three stakeholders namely: the local villagers by providing sustainable livelihood opportunities at their door step, the industry by fulfilling its requirement of raw material at affordable price, and the forest department by minimizing fuel loading on forest floor and hence forest fire hazards. The arrangement if implemented at large scale has the potential to create win-win situation for all the stakeholders. Some private entrepreneurs have also expressed their interest in using the pine needles for power generation. With the support of GoI and Uttarakhand Renewable Energy Development

Agency (UREDA) chir pine needle/litter based 120KW power plant has been setup in district Almora and is expected to commission soon to contribute electricity in the national grid. Recently 5 other companies have also been granted permission to collect pine needle and are expected to setup chir pine needle based power plants in different parts of the state to generate about 80 MW electricity. Here also the chir pine needle would be collected from designated forest areas and local villagers will be paid minimum of Rs.1/kg for collected pine needle which would be purchased by the company and process would be regulated through MOU between forest department and the concerened company. Thus this innovative approach adopted by the state forest department has the potential to convert dry and fallen pine needles, a fire hazard, into livelihood opportunity for the local people.

[*Source: Dr. Rajendra Singh Bisht, Conservator of Forests (Research), Uttarakhand*].

Box-7

CHEA'S INTEGRATED INTERVENTIONS STRENGTHENING VAN PANCHAYATS IN UTTARAKHAND

Central Himalayan Environment Association (CHEA; a voluntary organization in Uttarakhand), following participatory approach has been able to identify and prioritize a range of interventions for strengthening of Van Panchayats (VPs) in seven VPs of Lamgarha Block in Almora district of Uttarakhand during a two years pilot phase (2006-2008), supported by the Sir Dorabji Tata Trust, Mumbai. The success of pilot phase has prompted CHEA to upscale its interventions and currently a five year project secured from SDTT is being implemented in 15 VPs of the same area. The integrated interventions have been able to meet various short-term as well as long-term needs of local communities besides reducing pressure on the local community forests. Though a number of measures were taken to facilitate effective implementation of the project activities, some of the key institutional interventions were creation of women Self Help Groups (SHGs) in each VP, a *Van Sansadhan Prabandhan Samiti* (VSPS) that included representatives from all the 15 VPs and dovetailing with some relevant ongoing programmes and projects of government departments/agencies. Among the field interventions, establishment of nurseries of various multipurpose tree species (MPTs), development of fodder grass plots on the VP forest lands and on the raised bunds of farm lands, livestock improvement through artificial insemination, and creation of water harvesting structures have been some of the most successful activities of the initiative. A visible impact is that the communities have been able to appreciate the importance of stall feeding and chopped fodder in minimizing fodder wastage and enhancing palatability of fodder.

The over all impacts of the project activities on the conservation and livelihoods in the selected VPs were: increased sense of responsibility and capacity to protect and manage forests among the village communities; greater involvement of women in the management of VPs and their improved articulation; reduction in unauthorized removal of trees, minimized unregulated grazing and unsustainable harvesting of forest resources; enhanced moisture conservation and rejuvenation of water sources; less number of fire incidences; increased assisted regeneration of forest species; and increasing income through squash preparation from Rhododendron flowers, collection and selling of Myrica (*Kafal*) fruits and honey bee rearing. Availability of fodder grasses near dwellings and production of quality vermin-compost have contributed in reducing women drudgery a bit and also catalyzing the process of improving livestock breed and reducing the number of less productive livestock. An initiative of CHEA is to build capacity of some selected VPMCs in Lamgarha on participatory Carbon measurements in forest biomass. The initiative is to create village level investigators and strengthen participatory research in remote hill villages. Scientists have been training VPMC members in using GPS, sampling methods, and taking correct measurements. The capacity which would help VPs to bring down the measurement cost and secure rewards for their efforts from International Agreement on Climate Change under REDD+ in avoiding deforestation and showcasing them through validated scientific methods. It is envisaged the major outcome of present initiative of CHEA would help stakeholders in Uttarakhand in developing a protocol/package of practice for strengthening of a large number VPs in the state though still there is a long way to go on several fronts that include policy, institutional and scientific aspects to realize the ultimate goal.
[*Source: Semwal, R. L. et al. 2010, RC, NAEB, New Delhi*].

Annexure-I

SOME IMPORTANT LAWS AND ACTS RELATED TO FORESTS AND FORESTRY IN NORTH-EASTERN STATES

The Village Council Act 1978, Nagaland: This is one of the strongest state legislations in the country, providing communities the right to manage their own lands. To be able to do so, the community is free to constitute any appropriate local institution. There are a number of community-owned and declared protected areas in the state.

United Khasi Jaintia Hills Autonomous District Act, 1958: This Act gives recognition to the customary patterns of land holding, however, the management and control of these forests remains subject to the rules made by the District Council.

Mizoram Forest Act, 1955: This Act has provisions for village forest reserves and protected forest reserves, constituted for the benefit of the village community.

Mikir Hills District (Transfer of Land) Act of 1959, and the Meghalaya Transfer of Land (Regulation) Act, 1971: This Act ensure continuity of communal title within a tribal community.

Arunachal Pradesh Anchal and Village Forest Reserve (Constitution & Maintenance) Act, 1984: This Act mandates sharing of revenue from lands at the disposal of the government, and between the Government and the villagers in equal proportion.

Meghalaya Forest (Removal of Timber) (Regulation) Act, 1981 and Arunachal Pradesh Forest (Removal of Timber) Regulation Act, 1983: This Act restricts the removal of timber from the states without permission from the competent authority.

Assam Forest Protection Act, 1986: This Act is another extension of the trend of centralizing forestry management in the state where supervisory officers of the forest department have been equated as police officers.

Assam Forest Authority Act, 1991: Where the forest authority is represented by no less than the Chief Minister, is a clear indicator of the intention to assume the power to control forestry irrespective of traditional practices, land tenure, and ownership patterns in the forest.

The Assam Hill Land and Ecological Sites (Protection and Management) Act, 2006 (2007): This Act prevents indiscriminate cutting of hills and filling up of water bodies in urban areas, which has led to serious ecological problems. Under the bill, the state government can bring any hill under its purview for protection.

4

Structural and Functional Attributes of Forests Along an Altitudinal Gradient in Garhwal Himalaya

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INTRODUCTION

Studies on the functioning of forest ecosystems and forest management have always taken climatic parameters into account as these interact in a complex manner at varying scales. The impact of climate change on species diversity, plant distribution, vegetation zones, primary production and ecosystem processes have been studied by several workers across the world. Changes in climate govern tree phenology (Kramer *et al.*, 1996; Menzel and Fabian, 1999; Linkosalo *et al.*, 2000), forest productivity (McGuire *et al.*, 1993; Joyce, 1995; Aber *et al.*, 2001; Coops and Waring, 2001), growth and yield (Woodbury *et al.*, 1998; Hasennauer *et al.*, 1999) has been well investigated. Productivity of the forests depends on the rate of photosynthesis, which in turn is influenced by the availability of climatic factors, such as ambient temperature and carbon dioxide. Besides photosynthesis, respiration and transpiration rates also affect the plant growth which is dependent on climate. Various phenophases (bud bursting, leaf unfolding, flowering, seed setting and leaf fall) are also governed by the climatic factors. Vegetation response to climate change can be studied at a regional scale using simulation models depicting vegetation parameters or communities across eco-climatic gradients and sampling the important parameters at frequent intervals. Such studies also require climate change scenario at a comparable scale (Lasch *et al.*, 1999).

Phytogeography of the Himalayan region generated much interest right from the beginning of this century or even before, when floristic studies were initiated. It is evident that the Himalayan ranges harbour various elements, viz. Austro-Polynesian, Malayo-Burman, Sino-Tibetan, Euro-Mediterranean and African. About 29% of the endemic taxa of the Indian dicotyledonous flora occur in these mountains. Approximately 3200 species, which account for about 30% of higher plant species

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documented from the Himalaya, are said to be endemic to the region (Singh *et al.*, 2000). The Western Himalayan region shows pronounced Euro-Mediterranean affinities. Some of the Mediterranean elements of the Western Himalayan region are found in drier areas, where the monsoon influence is negligible, e.g. *Quercus ilex, Celtis australis,* and species of *Olea, Acer, Aesculus, Alnus, Fraxinus, Cupressus, Juniperus, Populus, Prunus* and *Pinus* (Singh and Singh, 1982). With increasing aridity in the western Himalaya some of the seral communities/species are likely to shift eastwards. Thus, it has an important bearing in the study of response of forest vegetation to climate change in the region. The present study aims at to document the structural (vegetation composition and biomass) and functional (productivity) attributes along an altitudinal gradient in Garhwal Himalaya with an insight into the patterns of vegetation with reference to temperature at a local scale and its comparison with vegetation patterns reported by earlier workers in Kumaun Himalayan forests.

MATERIALS AND METHODS

Study Area

Five major watersheds, viz. Dharamganga and Dogadda (1600-3400 m asl. each), Bhatwari (1800-3600 m), Asiganga (1600-3200 m) and Gangotri (3000-3700 m) forming a catchment of river Bhagirathi were selected for the present study (Fig. 1). In the study region, differences between mean temperature of the warmest and coldest months range between 10ºC and 19ºC. The summer-winter difference declines up to 1000 m, and then stabilizes at about 10ºC along the remaining elevational transect (Singh *et al.,* 1994). With increase in cloudiness the sun shine duration decreases towards higher elevations. The precipitation effectiveness increases with elevation because of temperature and sunshine decline (Muller, 1982). Corresponding with the upper forest limit of forest vegetation the absolute minimum temperatures at 3600 m elevation are -15ºC and -20ºC, which are less severe than the temperatures reported for continental temperate mountains (Sakai and Malla, 1981; Muller, 1982). The rate of mineralization is strongly influenced by the temperature. In the event of global warming (increased temperature) this rate is likely to change and hence this parameter is considered very important to correlate with other traits of the forest ecosystem.

In each of the five selected watersheds, a series of one hectare plots were selected with a rise of every 100 m altitude from the lower most point up to timberline. For vegetation composition 10 quadrates (10x10 m size) were laid randomly in each site (1 hectare plot) for trees and data were collected following Misra (1968). Only tree layer vegetation was considered in this study. The data were analyzed for density, frequency and abundance (Curtis and McIntosh, 1950) and Importance Value Index (IVI) (Curtis, 1959). Regression equations

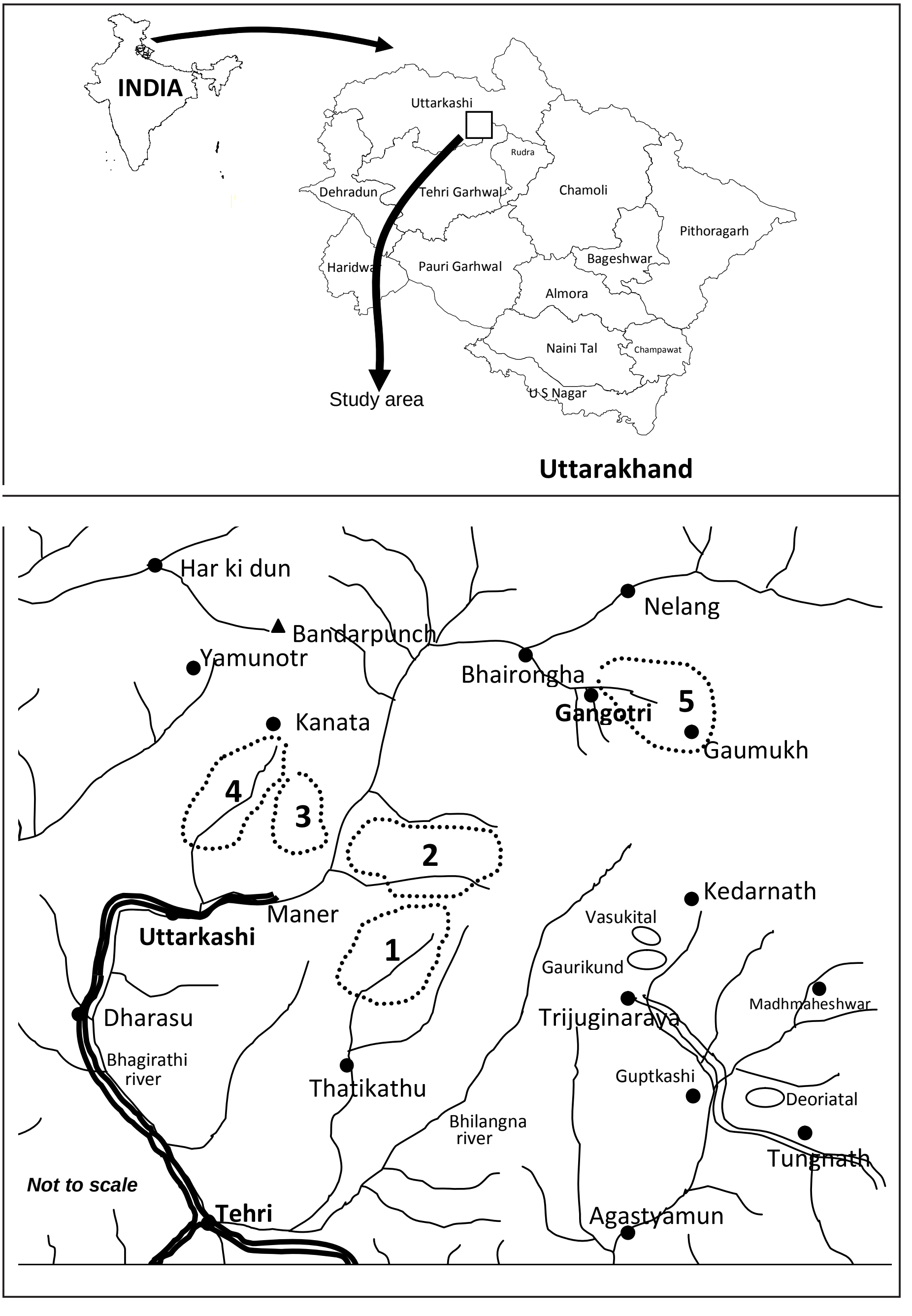

Fig. 1: Map of the study area showing different watersheds in Garhwal Himalaya.
1. Dharamganga, 2. Dogadda, 3. Bhatwari, 4. Asiganga, and 5. Gangotri

were used to calculate the biomass of different species, such as *Quercus semecarpifolia, Abies pindrow, Aesculus indica, Rhododendron arboreum, Symplocos chinensis, Lyonia ovalifolia, Ilex dipyrena, Litsea umbrosa* and *Juglans regia* following Adhikari *et al.*, (1995); *Acer cappadocicum* and interspecies following Singh *et al.*, (1992); *Quercus floribunda, Q. leucotrichophora, Rhododendron arboreum* and interspecies following Rawat and Singh (1988); *Cedrus deodara* following Adhikari *et al.*, (2000); and *Pinus roxburghii* following Singh and Singh (1992). The interspecies regression equations developed by Singh *et al.*, (1992) were used for *Rhododendron campanulatum, Euonymus lacerus* and *Eurya acuminata*, while interspecies regression equations developed by Rawat and Singh (1988) were used for *Machilus duthie* and *Machilus odoratissima*. Regression equations for *Q. floribunda* developed by Rawat and Singh (1988) were used up to 2500 m, while regression equations for *Q. floribunda* developed by Adhikari *et al.*, (1995) were used for the stands above 2600 m. Like-wise the regression equations for *R. arboreum* developed by Rawat and Singh (1988) were used up to 2400 m, while regression equations for *R. arboreum* developed by Adhikari *et al*., (1995) were used for the stands above 2600 m. In addition, new regression equations were also developed for many conifer and deciduous species to determine both aboveground (AB) and belowground (BG) biomass.

Aboveground (AP) and belowground (BP) productivity of each forest type was calculated based on Rawat and Singh (1988), Chaturvedi and Singh (1987), Singh *et al.*, (1992) and Adhikari *et al.*, (1995) reported in Kumaun Himalaya. The biomass accumulation ratio (BAR) was calculated for major forest types, viz. chir pine (*P. roxburghii*), mixed (low altitude), banj oak (*Q. leucotrichophora*), tilonj oak (*Q. floribunda*), mixed forest, horse chestnut (*A. indica*), silver fir (*A. pindrow*), kharsu oak (*Q. semecarpifolia*), maple (*A. cappadocicum*), birch (*B. utilis*) and deodar (*C. deodara*) forests. For other forest types the BAR was calculated as the average value of BAR of selected forests, such as deciduous-broadleaved forest (horse chestnut, maple and birch forests), blue pine (*Pinus wallichiana*) forest (chir pine, silver fir and deodar), mixed-broadleaved forest (banj oak, tilonj oak, horse chestnut and maple forests), oak forest (all oak *spp.*), alder (*A. nepalensis*) forest (maple and birch forests), conifer-broadleaved forest (chir pine, silver fir, deodar, horse chestnut, maple and birch forests), mixed forest (banj oak, tilonj oak, horse chestnut, maple, chir pine, silver fir, deodar forests), toon (horse chestnut and maple forests) and for oak-conifer forest (banj oak, tilonj oak, kharsu oak, chir pine, silver fir and deodar forests). Data on litter fall of different forests was collated from the studies conducted in Kumaun Himalaya (as mentioned for productivity). The aboveground productivity to litter fall ratio was calculated to compute the litter fall of a particular forest. However, to compute litter fall values for other forest types the similar combination was followed as mentioned for productivity.

RESULTS

Species Richness, Density and Total Basal Area

Three major parameters were taken into consideration for describing structural aspects of forests viz., density (trees ha^{-1}), total basal area (TBA, m^2 ha^{-1}) and IVI (Table 1). In Dharamganga watershed 6 forest types were identified. The average density was highest for tilonj oak-mixed and kharsu oak forests (363 trees ha^{-1}), and TBA was highest for tilonj oak forest (55.2 m^2 ha^{-1}). In Dogadda watershed 9 forest types were identified. The average density was highest for banj oak forest (595 trees ha^{-1}) followed by deciduous-broadleaved forest (510 trees ha^{-1}). The TBA was highest for horse chestnut forest (74.5 m^2 ha^{-1}) followed by oak-conifer forest (71.5 m^2 ha^{-1}). In Asiganga watershed 7 forest types were identified. The average density was highest for alder forest (305 trees ha^{-1}; but recorded the lowest TBA =13.4 m^2 ha^{-1}). The maximum TBA was recorded for deciduous-conifer forest (60.8 m^2 ha^{-1}). Bhatwari watershed was mainly dominated by 6 forest types. The average density was highest for tilonj oak and oak-conifer forests (each 270 trees ha^{-1}) and TBA was also highest for both the forests (65.1 and 64.1 m^2 ha^{-1}, respectively). The Gangotri (upper Bhagirathi) watershed was mainly dominated by 5 forest types (Table 1). The average density was highest for deodar forest (37.0 trees ha^{-1}) followed by conifer-broadleaved forest (330 trees ha^{-1}). The TBA was highest for conifer-broadleaved forest (58.4 m^2 ha^{-1}), while the lowest was recorded for birch forest (5.2 m^2 ha^{-1}). Across all the forest types found within the 7 study sites (watersheds), the species richness was highest for deciduous-broadleaved, mixed- broadleaved and tilonj oak forests (Table 1).

Biomass, Productivity and Litter Fall

In the foregoing description total biomass refers to both AB+BG and total productivity refers to both AP+BP unless referred otherwise. The average total AB in Dharamganga watershed was recorded highest for tilonj oak forest (402.9 t ha^{-1}) and minimum for conifer-broadleaved forest (154.4 t ha^{-1}; Fig. 2). Of the total biomass recorded for all the forest types found in Dharamganga watershed the AB ranged from 77 (kharsu oak forest) to 89% (banj oak forest). The average AP was computed highest for chir pine forest (20.0 t ha^{-1} yr^{-1}) and lowest for banj oak forest (5.6 t ha^{-1} yr^{-1}). Of the average total productivity the average AP ranged from 51 (kharsu oak forest) to 74% (banj oak forest). Litter fall was computed between 2.2 (banj oak forest) and 5.5 t ha^{-1} yr^{-1} (chir pine forest).

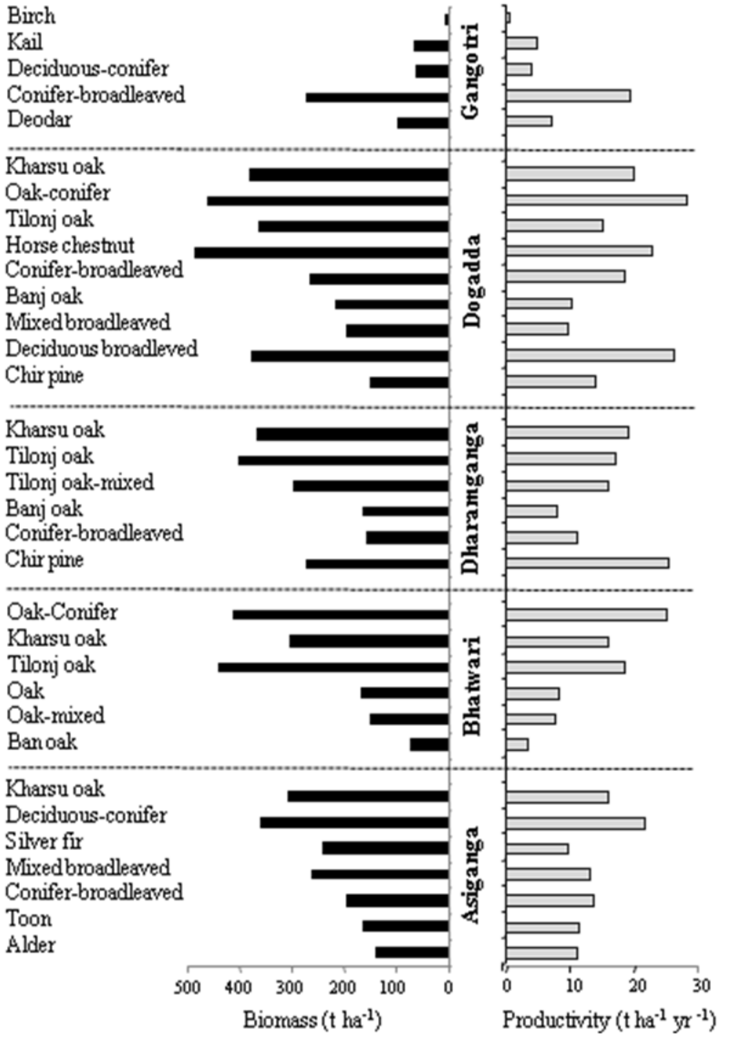

Fig. 2: Biomass and productivity of various forest types in five different watersheds studied in Garhwal Himalaya

Total AB in Dogadda watershed ranged from 150.5 (chir pine forest) to 486.7 t ha^{-1} (horse chestnut forest; Fig. 2). Of the total biomass the AB ranged from 77 (chir pine and kharsu oak forests) to 88% (banj oak forest). The average total AP was computed highest for oak-conifer forest (21.3 t ha^{-1} yr^{-1}) and lowest for mixed-broadleaved and banj oak forests (each 7.4 t ha^{-1} yr^{-1}). Of the average total productivity the average AP ranged from 50 (kharsu oak forest) to 73% (banj oak forest). Litter fall ranged between 2.3 (mixed-broadleaved forest) and 6.9 t ha^{-1} yr^{-1} (oak-conifer forest). The total biomass in Asiganga watershed was found highest for deciduous-conifer forest (361.8 t ha^{-1}) and the lowest for alder forest (137.6 t ha^{-1}; Fig. 2). The AB accounted for 77 to 82% in alder and mixed-broadleaved forests, respectively of the total biomass. The average total productivity was computed highest for deciduous-conifer forest (17.2 t ha^{-1} yr^{-1}) and lowest for silver fir forest (7.5 t ha^{-1} yr^{-1}). Of the average total productivity the average AP ranged from 51 (kharsu oak forest) to 61% (mixed-broadleaved forest). Litter fall ranged between 2.3 (silver fir forest) and 6.9 t ha^{-1} yr^{-1} (deciduous-conifer forest). Total biomass in Bhatwari watershed ranged between 71.5 (banj oak forest) and 439.9 t ha^{-1} (tilonj oak forest; Fig. 2). Of the total biomass the AB ranged from 78 (kharsu oak forests) to 90% (banj oak forest). The average total productivity was computed highest for oak-conifer forest (19.0 t ha^{-1} yr^{-1}) and lowest for banj oak forest (2.4 t ha^{-1} yr^{-1}). Of the average total productivity the average AP ranged from 51 (kharsu oak forest) to 75% (banj oak forest). Litter fall ranged between 1.0 (banj oak forest) and 6.1 t ha^{-1} yr^{-1} (oak-conifer forest). Total biomass in Gangotri (upper Bhagirathi) watershed ranged between 4.9 (birch forest) and 273.2 t ha^{-1} (conifer-broadleaved forest; Fig. 2). Of the total biomass the AB ranged from 75% (birch forests) to 85% (conifer-broadleaved forest). The average total productivity was computed highest for conifer-broadleaved forest (14.7 t ha^{-1} yr^{-1}) and lowest for birch forest (0.3 t ha^{-1} yr^{-1}). Of the average total productivity the average AP ranged from 55% (birch forest) to 68% (deodar forest). Litter fall ranged between 0.1 (birch forest) and 4.7 t ha^{-1} yr^{-1} (conifer-broadleaved forest).

DISCUSSION

The total biomass values reported for conifer forests in the present study are well within the range reported for the other conifer forests elsewhere in the world (*Abies alba* 144.0 t ha^{-1}, Vyskot, 1972; *Picea abies* 202 t ha^{-1}, Devillez *et al.*, 1973; *Pinus taeda* 112 t ha^{-1}, Ralston, 1973) as well as that reported for Kumaun Himalayan conifer forests (*P. roxburghii* 113-283 t ha^{-1}, Chaturvedi and Singh, 1987; Rana *et al.*, 1989). However, the biomass of silver fir forest in the present study was quite low as reported for Kumaun Himalayan silver fir forest (566 t ha^{-1}, Adhikari *et al.*, 1995). Similarly, the values reported for birch forest for the present study is quite low as compared to birch forest of Kumaun Himalaya (173 t ha^{-1}, Singh *et al.*, 1992). The biomass of deciduous-broadleaved forests (*Alnus, Cedrela toona* and deciduous-conifer) reported in the present study is comparable with the values reported for *Alnus rubra* (295 t ha^{-1}, Zavitkovski and Stevens, 1972) and *Fagus sylvatica* (375 t ha^{-1}, Nihlgard, 1972). The values reported for horse chestnut forest for present study are comparable with the Kumaun Himalayan forests (505 t ha^{-1}, Adhikari *et al.*, 1995). Biomass reported for *Q. floribunda, Q. leucotrichophora* and *Q. lanuginosa* in Kumaun Himalayan forests (467, 391 and 294 t ha^{-1}, respectively; Rawat and Singh, 1988), for *Q. ilex* forest (322 t ha^{-1}, Lossaint and Rapp, 1978), for *Q. petraea* forest (314 t ha^{-1}, Duvigneaud *et al.*, 1971), and for *Q. petraea-F. sylvatica* forest (320 t ha^{-1}, Drift, 1981) are comparable with the oak forests presently studied. Biomass of kharsu oak forest of present study is lower than that reported for Kumaun Himalaya (593 t ha^{-1}, Adhikari *et al.*, 1995).

The major environmental factors, such as temperature, moisture, sunshine, cloudiness and soil nutrients have been found to influence productivity of the forest ecosystems in higher elevations of Kumaun Himalaya (Adhikari *et al.*, 1991; Singh *et al.*, 1994). In the present study the productivity (AP+BP) ranged from 0.4-20.0 t ha^{-1} yr^{-1}. The productivity of *P. roxburghii* forest is comparable with the conifer forests of the world (*P. rubens* forest= 11.7 t ha^{-1} yr^{-1}, Gordon, 1981; *P. strobus* forest= 13.5 t ha^{-1} yr^{-1}, Swank and Schruedner, 1974; and *P. roxburghii* forest of Kumaun Himalaya= 9.9-21.2 t ha^{-1} yr^{-1}, Chaturvedi and Singh, 1987). The productivity values for broadleaved-deciduous forests recorded in the present study are comparable with *Fagus crenata* forest (6.5-8.2 t ha^{-1} yr^{-1}, Kakubari, 1977) and *F. sylvestris-A. alba* forest (9.3 t ha^{-1} yr^{-1}, Bindiu *et al.* 1981). Productivity values for oak forests of present study are comparable with *Q. coccinea-Q. alba* mixed forest (12.5 t ha^{-1} yr^{-1}, Whittaker and Woodwell, 1969), *Q. petraea* forest (14.9 t ha^{-1} yr^{-1}, Drift, 1981), *Q. robur* mixed forest (12.1 t ha^{-1} yr^{-1}, Duvigneaud *et al.*, 1971). Values of horse chestnut and kharsu oak forests of present study were recorded lower than the values reported for Kumaun Himalaya (19.6 and 24.6 t ha^{-1} yr^{-1}, Adhikari *et al.*, 1995). Satoo (1970, 1971) reported that in Japan five major forest types, viz., in warm temperate zone the productivity of coniferous forests was 10 t ha^{1} yr^{1}, pine and conifer forests around 10-15 t ha^{1} yr^{1} and evergreen broadleaved forests around 20 t ha^{1} yr^{1}, are more productive, while in cool temperate zone the productivity of deciduous broadleaved forests was very low.

In the present study all the dominant tree species are evergreen with concentrated summer leaf drop throughout the altitudinal range, except the deciduous forests in high altitude regions which shed leaves during autumn.

The total annual litter fall in these forests ranged from 4.2-15.4 t ha^{1} yr^{1} (Singh *et al.,* 1994). The litter fall values reported here are lower than the values reported for Kumaun Himalayan forests and lies within the range reported for warm temperate forests (5.4 - 11.0 t ha^{1} yr^{1}, Bray and Gorham, 1964). The litter fall value of kharsu oak is also comparable with the values 3.8-7.0 t ha^{1} yr^{1} reported for temperate mixed-oak and oak forests (Rapp, 1969; Reiners, 1972; Lang, 1974). Litter fall in silver fir forest recorded here was 2.2 times higher than *A. amabilis - P. menziesii* forest (Fujimori *et al.,* 1976) and 1.4 times more than *A. firma* and *T. suboldii* forests (Furuno *et al.,* 1979). Litter fall value of horse chestnut forest lies within the range reported for *A. rubra* forest (4.5-9.9 t ha^{1} yr^{1}; Zavitkovaski and Newton, 1971), and comparable with *F. crenata* forest (6.6-6.9 t ha^{1} yr^{1}; Tadaki *et al*., 1969).

The relationship between mean annual temperature (MAT) and structural and functional traits in Garhwal Himalayan forests suggests that density and TBA declines at 3200 m and at 9.1°C MAT and the biomass, productivity and litter fall declines at 3400 m and at 8.2°C MAT. However, the values for Kumaun Himalayan forests reported by Singh *et al.,* (1994) were 2400 m and at 12.6°C MAT for the density, biomass and productivity, while at 2800 m and at 10.5°C MAT for the TBA and at 2700 m, and at 11.3°C MAT for litter fall (Adhikari, unpubl.). In nutshell, the preponderance of kharsu oak forests in the higher altitudinal ranges (sub-alpine and timberline ecotone) in Garhwal Himalaya with high density and TBA was found in those sites which are away from the glacial valleys. The germination of seeds in kharsu oak is very difficult, as the sloping habitats can not hold the seed due to their heavy weight and the seed rolls down along the hill slopes. Similarly, litter is either blown by the wind or washed away by rains. However, it was found that the glacial valleys support growth of deciduous species, which are mainly due to their light seed weight and germination capabilities in the nutrient poor soils. Garhwal Himalaya has relatively a mixture of dry and moist temperate climate, which influences the growth and vitality of the forests through the water balance in the watersheds. Therefore, in each watershed of the region the projected changes in the climate may have distinct impact on the forest ecosystems, such as recession of birch forest into alpine meadows and several other changes in composition of mid altitudinal forests.

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Table 1: Tree species richness, density and total basal area of different forest types along an altitudinal gradient (1600-3700 m) in Garhwal Himalaya

Forest type	Altitude (m asl)	Species richness	Density (trees ha^{-1})	Total basal area (m^2 ha^{-1})
Dharamganga Watershed				
Chir pine	1600	1	230	41.4
Conifer-broadleaved	1800	3	170	21.3
Banj oak	1867	4	250	31.4
Tilonj oak-mixed	2200	4	363	33.6
Tilonj oak	2450	5	275	55.2
Kharsu oak	3000	2	362	40.1
Bhatwari Watershed				
Banj oak	1900	4	140	11.2
Oak-mixed	2250	5	175	17.0
Oak	2333	4	177	25.1
Tilonj oak	2600	4	270	65.1
Kharsu oak	3083	3	223	41.3
Oak-Conifer	3250	3	270	64.1
Asiganga Watershed				
Alder	1800	2	305	13.4
Toon	1800	2	120	21.4
Conifer-broadleaved	2167	4	280	29.6
Mixed broadleaved	2200	5	240	35.5
Silver fir	2700	3	260	30.4
Deciduous-conifer	2900	3	260	60.8
Kharsu oak	2940	2	230	36.3
Dogadda Watershed				
Chir pine	1600	4	440	51.2
Deciduous broadleaved	1900	8	510	50.0
Mixed broadleaved	1933	9	423	33.2
Banj oak	2150	4	595	30.3
Conifer-broadleaved	2250	6	405	46.6
Horse chestnut	2400	5	330	74.5
Tilonj oak	2600	8	370	49.2
Oak-Conifer	2800	5	383	71.5
Kharsu oak	3200	2	372	36.1
Gangotri Watershed				
Deodar	3000	1	370	24.8
Conifer-broadleaved	3100	3	330	58.4
Deciduous-conifer	3350	3	250	15.0
Blue pine	3350	2	215	8.8
Birch	3650	2	205	5.2

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5

Regeneration Status of Dominant Tree Species in Sub-Tropical Forests of Manipur

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INTRODUCTION

Trees are the major components of the forests. Composition of the tree species depends on habitat, ecological characteristics, regeneration status, tree species diversity and history of disturbance within the ecosystem. The Himalayan region is known for its rich biological diversity and has always been a botanists' paradise. The Himalayan region is included as one of the nine newly identified biodiversity hotspots (Roach, 2005). In the East Himalayan region, sub-tropical forests constitute one of the most diverse plant communities on the earth. This area also falls within the Indo-Burma biodiversity hot spot recognized by Myers *et al*., (2000). Especially, the north-eastern region of India is significant for biodiversity conservation because of its floristic richness and high level of endemism (Khan *et al*., 1987; Upadhayay *et al*., 2004). The forests of Manipur are also rich in diversity and endemism among the north-eastern region, harbouring over 2,162 species of flowering plants, out of the 17,000 species described from India (Deb, 1961 a & b; Singh *et al*., 1995; Chauhan *et al*., 2000). However, rapid depletion of biodiversity in these forests, particularly due to wanton deforestation such as shifting cultivation, extraction of timber, fuel wood and other forest products has been a major concern to conserve these biodiversity hot spots for posterity.

Seeds and sprouts are the important means of tree regeneration in natural forests. Regeneration through seeds depends on production, dispersal, seed germination, establishment and growth of seedlings. Population structure of trees in terms of seedlings, saplings and young trees can provide adequate information on the regeneration status of forests (Yadava *et al.,* 1991). Limited information is available on population structure and regeneration pattern of tree species in sub-tropical forests of North-east India (Khan *et al*., 1986, 1987;

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Rao *et al.,* 1990; Yadava *et al.,* 1991; Barik *et al*., 1996; Misra *et al*., 2003; Upadhayay *et al*., 2004). The forests in north-east India are exposed to various kinds of disturbances such as felling of trees and burning including age-old tradition of Jhum cultivation (shifting cultivation) which is commonly practiced in the region. The prevailing disturbances may strongly influence the population structure and regeneration of trees in these forests. Therefore the present study aims to analyze the plant species richness and regeneration status of dominant tree species in the sub-tropical forests of Kangchup hills (Manipur), which is subjected to different levels of disturbance.

STUDY AREA

The study site is situated between $24^0$45′-$24^0$51′N latitudes $93^0$48′ and $93^0$55′E longitudes in the Kangchup hills of Manipur state at an altitude ranging from 865 m to 1785 m asl. Five forest sites (i.e. site-I, Protected; site-II, Least disturbed; site-III, Moderately disturbed at lower altitude; site-IV, Moderately disturbed at higher altitude; and site-V, Highly disturbed) were selected representing different degrees of disturbance. These forests falls under type 8 B/C_1 Eastern Himalayan sub-tropical wet hill forests classified by Champion and Seth (1968). Climate of the study area is monsoonal with warm moist summer and cool dry winter. Meteorological data on temperature and rainfall during the study period (1993–1995) indicate that the mean maximum temperature varied from 21.3^0C (January) to 30.7^0C (September) and mean minimum temperature ranged from 3.1^0C (January) to 21.3^0C (September). The average annual rainfall is 1298.5 mm during the study period. The soil of the forest sites are blackish brown in colour, clayey loam and acidic in nature. The organic carbon content in the soil varied from 1.97% to 3.14% across the sites.

METHODS

For study of plant biodiversity, the five selected sites were divided into five parts depending on topography and altitude. Each part was sampled using one 100m × 10m transect containing five (10m x 10m) randomly laid quadrates. From each quadrate, sample species of trees, shrubs, herbs, lianas and ferns were collected and identified from the Regional Botanical Survey of India, Shillong and Kolkata and also from National Botanical Research Institute, Lucknow. The regeneration pattern of tree species across the five forest sites was studied through laying permanent quadrates of 5m × 5m size over a period of two years. The seedling population was divided into three height categories: (i) short seedlings < 10.0 cm ht. (ii) medium seedlings with >10.0 cm to 20.0 cm ht. (iii) tall seedlings with > 20.0 cm to 30.0 cm ht. The sapling population was divided into two categories: (i) young saplings (>30.0 cm ht. but <10.0 cm cbh), and (ii) old saplings (>10.0 cm to 30.0 cm cbh) following (Yadava *et al*., 1991). In each site the different category of size class structure of populations of dominant tree species was studied at 4 months interval by periodic determination of densities of the individuals belonging to five size classes of seedlings and saplings in fifteen randomly laid permanent quadrates. Each individual was marked with aluminum tags and the height was measured periodically (June 1993 to February 1995). The total number of individuals belonging to different categories of seedlings and saplings were counted for each forest sites.

RESULTS

Across the five study site (I-V) a total of 195 species were recorded belonging to 145 genera and 72 families (Table 1). Out of these, 69, 49, 57, 12 and 8 were trees, shrubs, herbs, lianas and ferns, respectively (List of species is available on request to authors).

Table 1: Plant families and number of species in sub-tropical forest of Kangchup hills, Manipur

Family	No. of species	Family	No. of species
Lauraceae	16	Cyperaceae	3
Rubiaceae	14	Haemodoraceae	3
Poaceae	14	Zingiberaceae	3
Euphorbiaceae	10	Aspiadaceae	3
Asteraceae	9	Araliaceae	2
Fabaceae	8	Acanthaceae	2
Fagaceae	6	Caprifoliaceae	2
Urticaceae	6	Gesneraceae	2
Moraceae	5	Myrsinaceae	2
Rosaceae	5	Annonaceae	2
Orchidaceae	5	Apiaceae	2
Verbenaceae	4	Balsaminaceae	2
Lamiaceae	4	Liliaceae	2
Anacardiaceae	3	Piperaceae	2
Betulaceae	3	Pteridaceae	2
Juglandaceae	3	Violaceae	2
Ternstroemiaceae	3	Others	38 (1 each)
Commeliniaceae	3		

POPULATION STRUCTURE AND REGENERATION STATUS

Seedlings and saplings provide an idea of the regeneration of different species in the forest. Study of population structure, on the basis of the occurrence of seedlings and saplings of tree species from study sites can be recognized in the following categories (Knight, 1975): (1) Frequent reproducers/advanced regeneration type in which both seedlings and saplings are found in large numbers; (2) Infrequent reproducer in which both seedlings and saplings are found in low numbers; and (3) slow regeneration type in which only saplings or only seedlings are found (Figs.1-5).

DISTRIBUTION PATTERN OF DOMINANT SPECIES

A total of 15 tree species were selected for seedlings and saplings diameter structure with respect to seasonal changes and of these six species each were represented in their respective forest sites. In site-I, the important species were *Lithocarpus fenestrata*, *Litsaea thomsonii*, *Cinnamomum zeylanicum*, *Lithocarpus dealbata*, *Wendlandia grandis* and *Schmia wallichii*. Among the selected species, *L. thomsonii* exhibited the maximum density of short seedlings, whereas the maximum number of medium and tall seedling, and young sapling classes was represented by *L. fenestrata*. While for *L. dealbata* old sapling class was recorded maximum. In site-II, *L. fenestrata*, *L. dealbata*, *S. wallichii*, *Quercus serrata*, *Quercus griffithii* and *Machilus bombycina* were the dominant species. *L. fenestrata* exhibited greater density for short seedling and old sapling classes. The maximum density of medium and tall seedling classes was recorded by *M. bombycina* and *Q. serrata*. Short seedlings were found absent in *M. bombycina* and *Q. griffithii* during the first growing season and then few numbers was recruited in the second growing season. In site-III, the dominant species were *S. wallichii*, *L. thomsonii*, *W. grandis*, *L. fenestrata*, *C. zeylanicum* and *L. dealbata*. Among the seedling classes, the maximum density of short and medium classes were exhibited by *L. thomsonii*, whereas density of tall seedlings and old saplings was maximum for *S. wallichii* and young sapling class density was maximum for *W. grandis*. The remaining species did not show much difference during the study period. In site – IV, the important species were *Castanopsis tribuloides*, *Engelhardtia spicata*, *M. bombycina*, *Saurauia punduana*, *S. wallichii* and *Drimycarpus racemosus*. *C. tribuloides* exhibited the maximum density of short and medium seedling classes while tall seedling class was recorded maximum for *E. spicata*. The maximum density of young and old sapling classes was exhibited by *C. tribuloides* and *S. wallichii*. In site-V, *C. tribuloides*, *L. thomsonii*, *M. bombycina*, *Eurya japonica*, *E. spicata* and *Glochidion assamicum* were the dominant species. *L. thomsonii* exhibited the maximum population of short seedlings followed by *E. spicata* and *C. tribuloides*. *G. assamicum* was found to be absent in this forest site. The

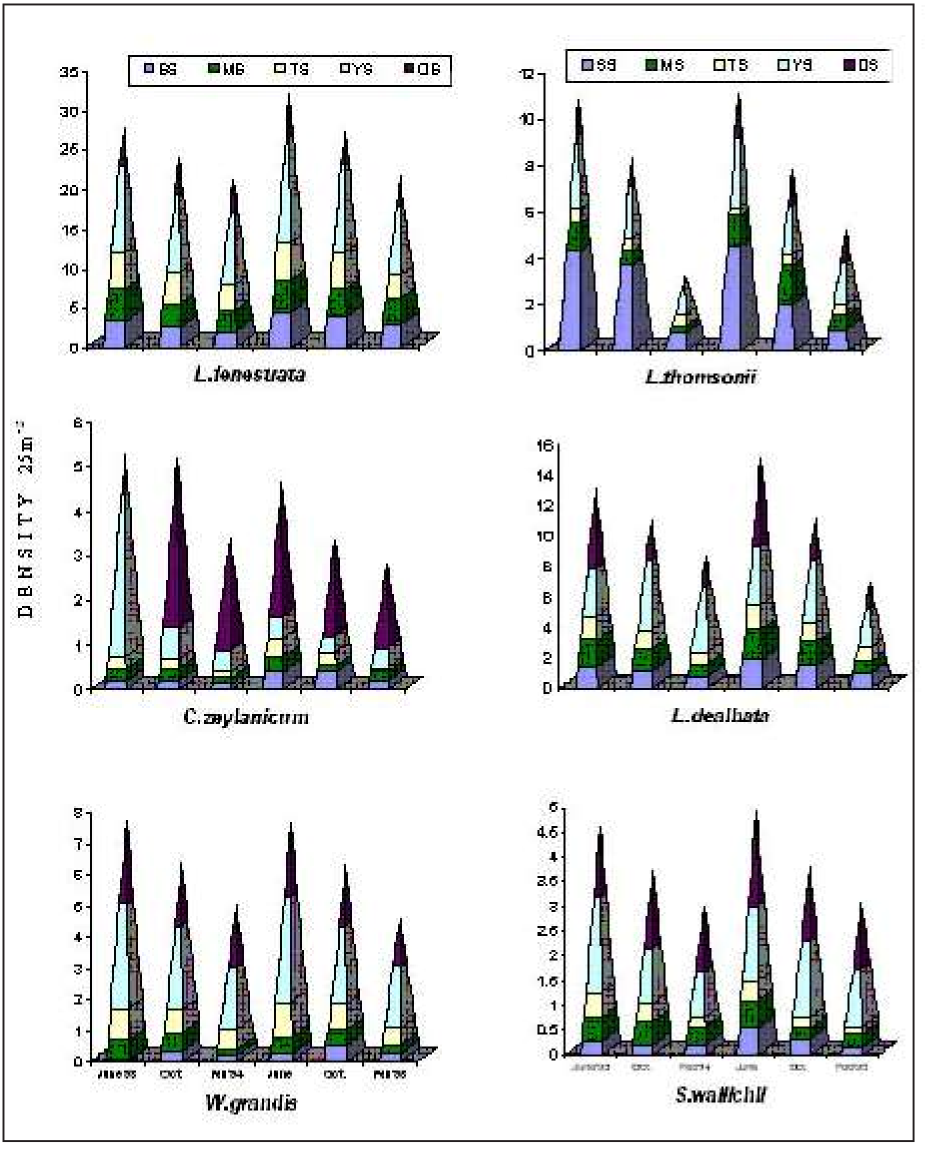

Fig. 1: Population density of important tree species in forest site I.
(SS = Short seedling; MS = Medium seedling; TS = Tall seedling; YS = Young sapling and OS = Old sapling; these abbreviations apply to Figs. 1-5)

maximum population of medium and tall seedling classes was recorded by *C. tribuloides* and *G. assamicum*. In young and old sapling classes, the highest density was observed by *L. thomsonii* and *C. tribuloides*. At the present study site, majority of the species exhibited maximum population of seedling and sapling classes during the wet season (June).

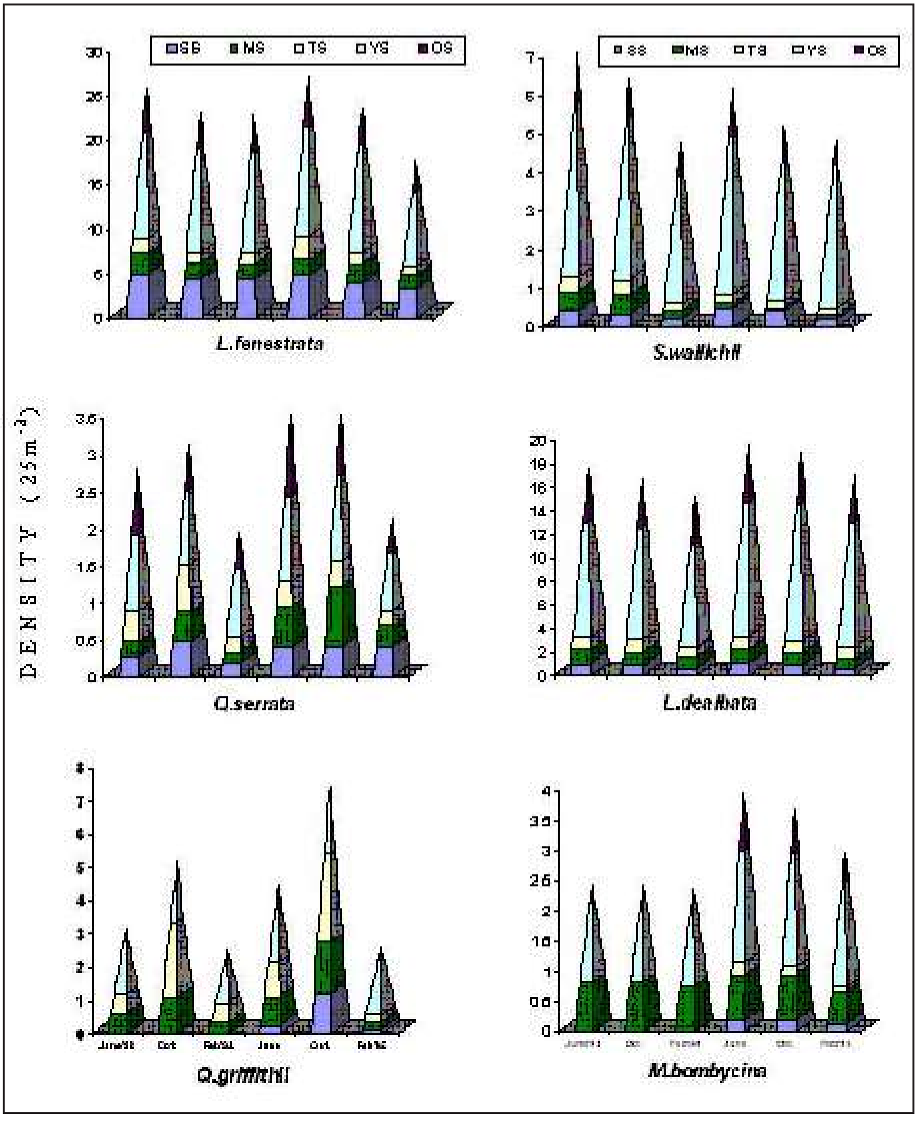

Fig. 2: Population density of important tree species in forest site II

DISCUSSION

The present study reveals that the studied forests are not only rich in plant species diversity but they are also rich in the diversity of families. High species richness recorded for Lauraceae, Rubiaceae and Poaceae families may be because of better seed dispersal, variability in flower form and high adaptive capability. The number of species (195) recorded in the present study was found to be higher than the number of species reported by several workers in

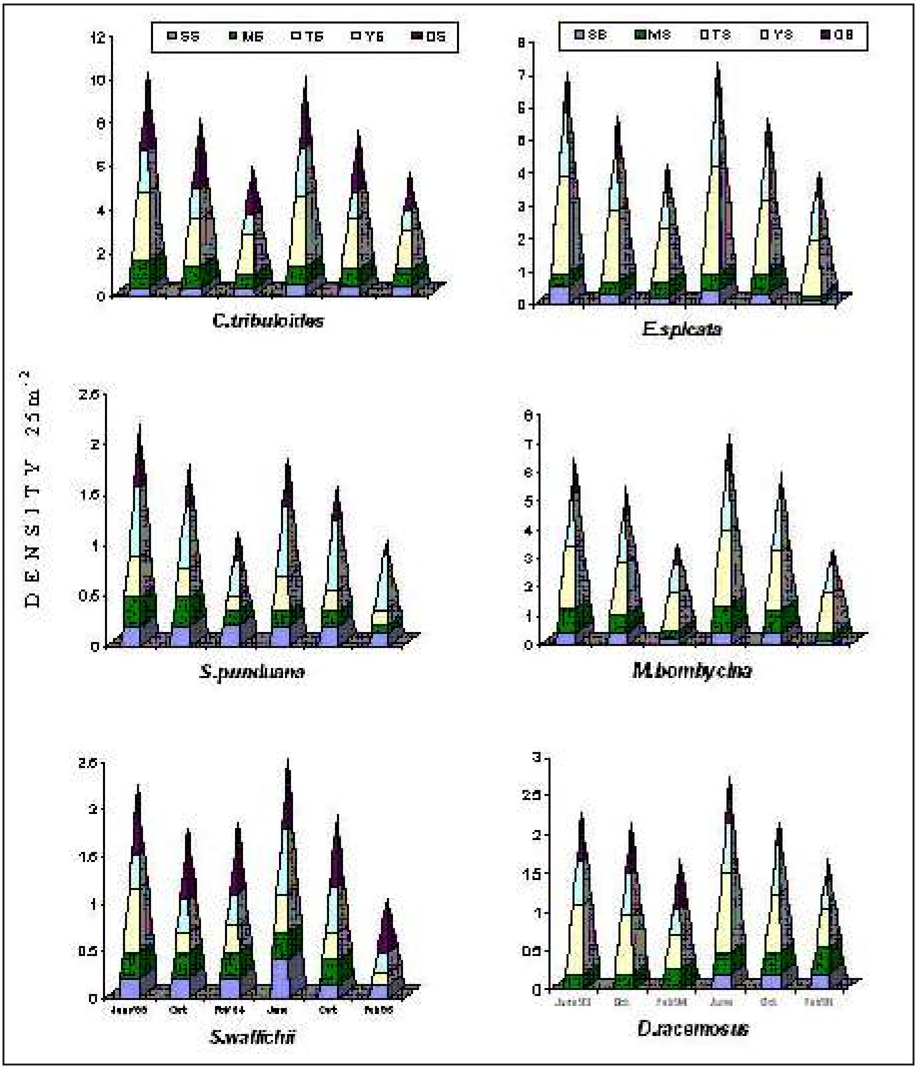

Fig. 3: Population density of important tree species in forest site III

different forest types of India. In this study we found that over all the sapling layer contained more species and was of a higher density than that of seedling layer. Higher number of seedlings and saplings exhibited in *L. fenestrate*, *L. dealbata*, *S. wallichii*, *L. thomsonii*, *C. tribuloides* and *E. spicata* in different sites in both the growing period indicated that these species are frequent reproducers/advanced regeneration type. Such type of classification of tree species was recognized for the vegetation of Barro Colorado Islands by Knight (1975). The species with low seedlings and saplings were: *Lindera pulcherrima*, *Litsaea polyantha*, *Q. griffithii*, *M. bombycina*, *Myrica esculenta*, *Litsaea*

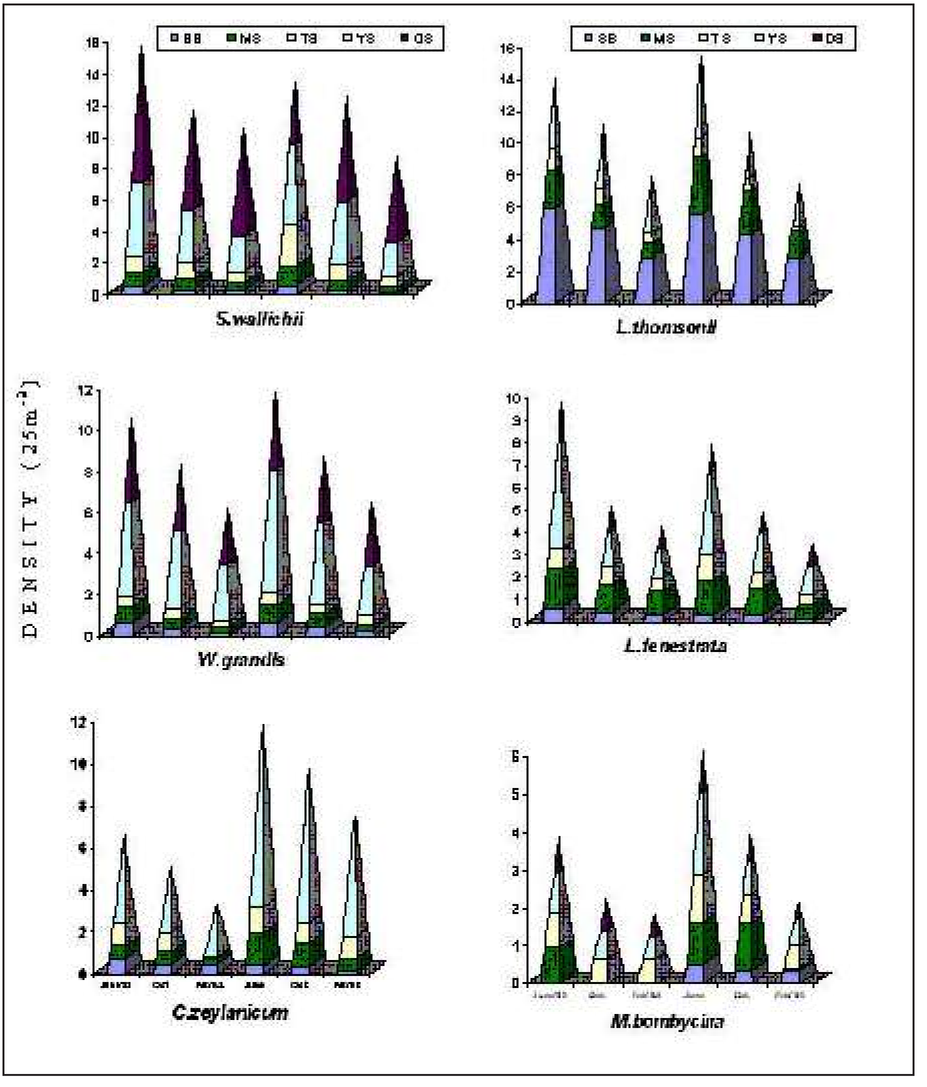

Fig. 4: Population density of important tree species in forest site IV

citrate, *L. dealbata*, *D. racemosus*, *Q. spicata*, *L. thomsonii*, *Ficus pomifera*, *G. assamicum*, *S. punduana* and *Phoebe pallida* in different sites in both the census held across the two study years and may be recognized as smaller reproducers. Such species may be recent invaders and may become canopy/ sub-canopy species at a later stage.

Only saplings were recorded for *D. racemosus*, *M. bombycina*, *Ilea macrophylla*, *E. japonica*, *Q. serrata* and *Litsaea sebifera* in site-I, *Macranga denticulata* and *L. thomsonii* in site-II, *Betula alnoides* in site-III, *P. pallida*

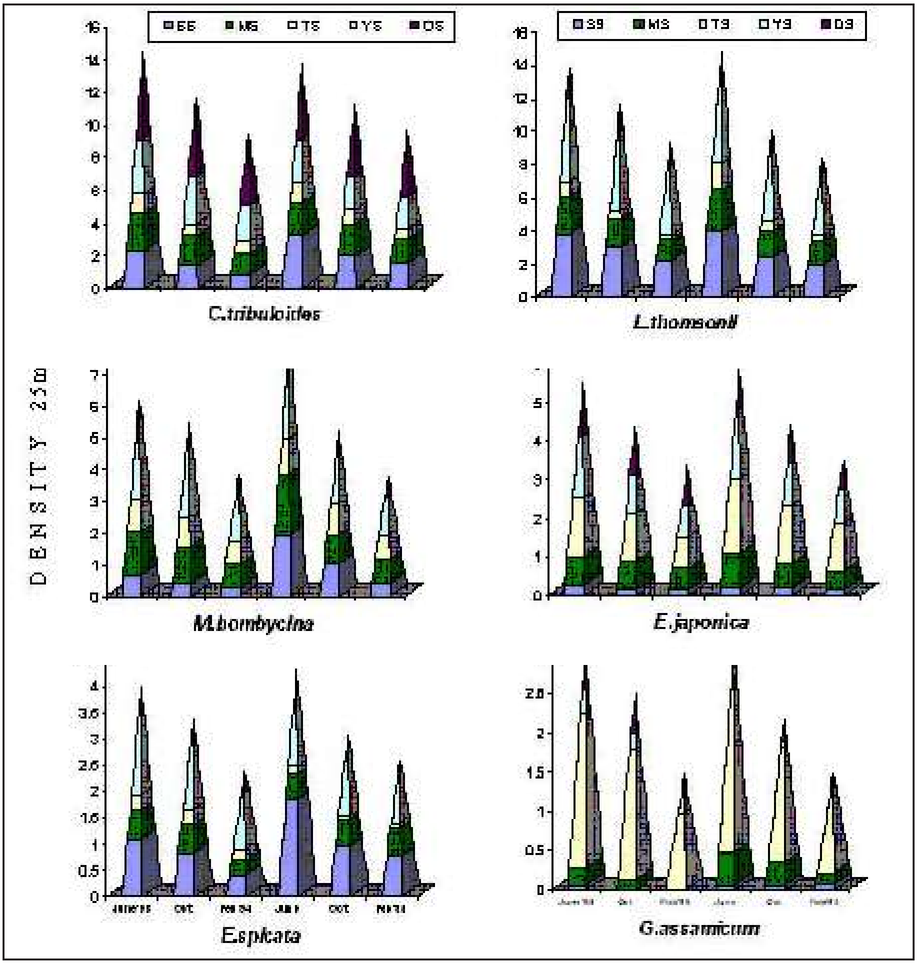

Fig. 5: Population density of important tree species in forest site V

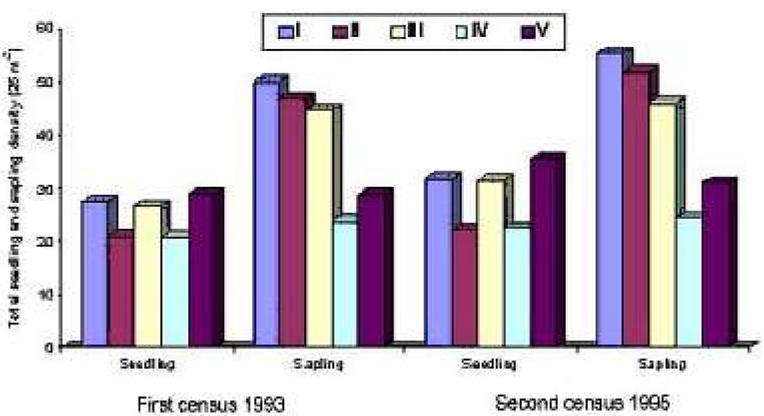

Fig. 6: Total seedling and sapling density / 25 m^2 in five forest sites

and *Alnus nepalensis* in site-IV and *W. grandis* in site-V, respectively in both the census. Absence of seedling of these species may be less number of seeds from few numbers of individual tree species and failure of establishment from seeds. *Albizia chinensis* had no saplings among the different tree species although a higher probability of seedlings in site-V. This indicates that it regenerates only through seeds exhibiting poor regeneration. Kadavul and Parthasarathy (2000) stated that the absence of saplings may either denote failure to recruitment from that seedling population or reflect the recent onset of regeneration perhaps allied to gap formation. Absence of saplings in this forest may be because of the extraction of timber for their commercial purposes by the local inhabitants.

The maximum total seedling density of all the species was recorded in the highly disturbed forest site-V among the different forest sites and followed by site-I, site-III, site-IV and site-II (Fig. 6). Higher seedling recruitment in highly disturbed site may be due to favourable microsites generated by tree felling and burning of the ground vegetation. In highly disturbed site, *L. thomsonii* produced good number of seedlings in comparison to other species and it may continue to dominate in the near future. The lowest total seedling density was observed in the least disturbed site-II. Poor seedling population in the undisturbed site may be due to the lack of threshold light for photosynthesis and a thick layer of litter on the soil surface which is likely to act as a mechanical barrier for seedling emergence. Khan *et al*., (1986) also reported low seedling survival and poor regeneration in the undisturbed "Sacred Groove" of Mawphlang, Meghalaya.

The total sapling density of all the species was recorded in the order of site-I > site-II > site-III > site-V > site-IV in both the census with their respective altitudinal disturbances. Higher population in sapling class of site-I may be due to the well protection by the local inhabitants. The minimum total saplings density was found in the moderately disturbed site-IV at higher altitude. From the results obtained it may be suggested that most of the species exploited because of frequent cutting for commercial logging and collection of charcoal preparation and also for agricultural implements. Biotic disturbances like lopping and trampling may cause lower rates of establishment of young trees. Yadava *et al*., (1991) has also attributed the heavy exploitation of single species to change the community structure in the sub-tropical forests of Ukhrul, Manipur.

The present study indicates that among the woody species, *L. fenestrata*, *S. wallichii* and *C. tribuloides* regenerated well with greater density of seedlings and saplings while *L. dealbata* and *L. thomsonii* are the co-dominant tree species which reproduces a good number of seedlings and saplings. In case of *L. thomsonii* increased level of disturbance favoured regeneration both by seeds as well as coppice. Thus, with the dominance of these species in the present forests they will continue to dominate in maintaining the population of seedlings and saplings of tree species in future. However, efforts are required not only to maintain the regeneration capacity of dominant species but also to enhance the regeneration capacity of species which shows declining trend in the regeneration. The regeneration behaviour of most of tree species seems to be closely linked with the level of disturbance. A detailed investigation would be required in order to ascertain the relationship between the level of disturbance in the forest ecosystem and regeneration of the constituent species.

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Forests and Floristic Diversity of Nagaland

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INTRODUCTION

Nagaland state, is situated in the extreme north-eastern part of India and falls under one of the identified 18 mega hot spots in the world with reference to threats to biodiversity (Meyers, 1988). Vegetation of Nagaland represents the transition zone between the Indian, Indo Malayan and Indo Chinese bio-geographic regions as well as a meeting place of Himalayan mountains with that of Peninsular India and South-East Asia. Many ancient angiosperms and primitive flowering plants are found here and this area is considered as a cradle of flowering plants (Thakhtajan, 1969; Rao, 1994). Several groups of plants of Orchids, Rhododendrons, Ferns, Bamboos, Zingibers and Lichens have expressed their maximum diversity in this state. The state is also known for a great treasure of medicinal plants and faunal elements. Nagaland is considered as one of the centers of origin of rice and secondary centre of origin of citrus, chillies and maize. Patkai hill of Nagaland is particularly rich in biological species, genetic diversity with high endemism. It has about 73% area covered with forests. However, 80% of the land and forests are owned and controlled by the village community (Khels/Clans), and by the individuals. The Patkai and Barial hill ranges of Nagaland has the finest tropical and subtropical evergreen forests and it has also unique broadleaf moist temperate forests with its rich flora and fauna elements of different bio-geographic zones and regarded as bio-geographic gateway.

The biodiversity of the state is essentially due to its unique geographic location where the altitude varies from flood plains (190 m asl) and the high hills of Mt. Saramati (3048 masl). A unique and rich terrestrial diversity of flora and fauna along the different altitudinal gradient also supports diverse agricultural practices with their diverse ethnic groups. A wide variety of plants and animals and interactions between the people and the natural systems has helped in maintaining the richness of species, communities and genetic materials. Indigenous tribal people

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depend on plants and animals for their livelihood and collect resources such as meat, fruits, vegetables, medicines, constructional materials, fibers, etc., from their surrounding environment and have rich indigenous knowledge of use and conservation of these resources (Changkija, 1996).

FOREST TYPES AND VEGETATION

In Nagaland, 52.04% of the total geographical area is under various legal status of forests (Table 1), and the remaining land is classified as agricultural land, miscellaneous tree crops and grooves, cultivable wasteland, cultivable non-forest area, etc. The unique geographical location and wide range of physiographic terrain coupled with climatic and altitudinal variation in Nagaland has resulted into luxuriant and wide variety of flora and forest types. Based on the classification of Champion and Seth (1968), the forests of Nagaland can be classified into seven forest types: (a) Tropical Wet Evergreen Forests; (b) Tropical Semi-Evergreen Forests; (c) Tropical Moist Deciduous Forests; (d) Sub-Tropical Broad Leaved Forests; (e) Sub-Tropical Pine Forests; (f) Montane Wet Temperate Forests; and (g) Sub-Alpine Forests. Flora listed under these forests has been followed from various publications (e.g., Moulik, 1997; Brandis, 1906; Hooker, 1890; Jain and Sastry, 1980; Kanjilal *et al.,* 1940; Nayar and Sastry, 1990).

Table: 1. Status of forests of Nagaland

Legal Status	Forest area (ha)	% of total forest area	% of total geographical area
Reserved Forests	8583	1	0.52
Purchased Forest	19247	2.2	1.16
Protected Forests	50756	5.9	3.06
Wildlife Sanctuary	22237	2.6	1.34
Village Forests			
i) Virgin Forests	477827	55.4	28.82
ii) Degraded	284280	32.9	17.15
Total	862930	100	52.04

Source: Deptt. of Forests, Ecology, Environment & Wildlife, Govt. of Nagaland, 31.01.2008

(a) **Tropical Wet Evergreen Forests:** This forest type once covered the Namsa-Tizit area but is now confined only to a small vestige in the Zankam area (Mon district). These forests are endowed with rich floristic diversity and multi-tiered forests. The dominant tree species in these forests are:

Ailanthus integrifolia, Artocarpus chaplasha, Artocarpus lakoocha, Dillenia indica, Dipterocarpus macrocarpus, Mesua ferrea, Alstonia scholaris, Pongamia pinnata, Michelia sp., *Phoebe* sp., *Sapium baccatum, Shorea assamica,* etc. A characteristic feature of this type of forest is the abundance of climbers and lianas. Various bamboos, orchids, pteridophytes including tall tree ferns also occur among these forests.

(b) Tropical Semi-Evergreen Forests: This forest type is found in the foothills of Assam-Nagaland border in Mokokchung, Wokha, Longleng districts and Niuland area in Dimapur district. Most of the plant species of Tropical Wet Evergreen Forest are found in these forests; however, some deciduous species such as *Tetrameles nudiflora, Lagerstromia speciosa, Bombax ceiba, Albizzia procera, Altingia excelsa, Spondias mangifera, Morus laevigata, Callicarpa arborea, Ficus sp*., etc. are found in these forests. The dominant evergreen species are *Stereospermum chelonoides, A. scholaris, P. pinnata, Aquilaria agallocha, Canarium resiniferum* and *Garcinia spp*. Lianas of family Menispermaceae, Vitaceae and Papilionaceae are common in these forests.

(c) Tropical Moist Deciduous Forests: This forest type is found adjacent to the rivers of Doyang, Dikhu, and also in the foothills of Assam-Nagaland border in Paren and Dimapur districts. *T. nudiflora, M. laevigata, L. speciosa, A. procera, Albizia lebbek, Albizia chinensis, B. ceiba, Canarium bengalensis, Holorhena antidysendrica, Stereospermum chelenoides, Elaeocarpus lanceafolius, S. mangifera, etc.* are the common tree species of these forests.

(d) Sub-Tropical Broad Leaved Forests: This category of forests occupies the hill areas between 500 m and 1800 m asl in all the districts of Nagaland. The vegetation is dense and the species that make up these forests are mostly evergreen, semi-deciduous and degraded bamboos. These categories of the forests are degraded mostly due to human interference such as swidden/Jhum cultivation and extraction of resources. Some important timber species found in these forests are: *A. procera, A. scholaris, Amoora wallichii, Mansonia dipikae, Bauhinia purpurea, Terminalia myriocarpa, A. chaplasha, A. lakoocha, M. laevigata, Garcinia sp., Stereospermum chelonoites, Duabanga grandifollia, Phoebe sp., Juglans regia, Canarium resiniferum, Phoebe lanceolata, Prunus napaulensis, S. mangifera, Spondias axilary, Elaeocarpus sp., Schima wallichii, Ficus sp., Magnolia rubra, Gmelina arborea, Betula alnoides, Mangifera sylvatica, etc*. The climatic condition of these forests is favourable for various bamboos, cane, wild banana, epiphytes like orchids, ferns, mushrooms, bryophytes, lichens and various medicinal shrubs and herbs, etc.

(e) **Sub-Tropical Pine Forests:** This forest type is found in hills with elevation of 1200 m to 2000 m asl in parts of Tuensang, Kiphire and Phek districts of Nagaland. The dominant species in these forests is *Pinus*. The pines are generally associated with species like *Alnus nepalensis, B. purpurea, Quercus sp., S. wallichii, Prunus sp., Betula alnoides, Taxus baccata, Cephalotaxus griffithii, Rhododendron sp., Exbucklandia populnea, Ilex excelsa, Schima khasiana etc.* Dwarf shrubs and undershurbs like *Rubus, Hydrangia, Polygonum sp.,* etc. are abundant in these forests.

(f) **Montane Wet Temperate Forests:** These forests occupy the mountain ranges like Saramati range in Kipheri district, Japfu range in Kohima district, Yakor and Hillipong ranges in Tuensang district, Aghanato range in Zunhepoto in Nagaland (above 2000 m asl). The dominant species are varieties of *Rhododendron spp., Cryptomeria japonica, Ilex excelsa, Schima khasiana, Magnolia campbelii, Exbucklandia populnea, Phoebe lanceolata, Toona ciliata, Quercus sp., Lithocarpus, Acer, Birch* and *Juniperus spp.*

(g) **Sub-Alpine Forests:** The sub alpine vegetation occurs mainly at high altitudes in the ridges of Saramati range and Japfu range. Alpine vegetation such as only few annual short duration grasses and herbs are found in the top hills and in lower area various *Rhododendron, Tsuga* and *Junipers* spp., along with various shrubs and herbs grow. The mountain ranges remain snow capped for major part of the year from October to April. The summer are very brief during which the snow melts and a few annuals, herbs and shrubs along with mosses grow. Sub-alpine vegetation gradually merges into alpine vegetation, which comprises of high altitude grasses and dwarf *Rhododendron* and herbs like *Primula, Anemone, Aconitum, Potentilla spp.,* etc.

ECONOMICALLY IMPORTANT PLANTS

The rich and diverse flora of Nagaland contains a large number of economically important plants such as medicinal, aromatic, ornamental, horticultural, wild edible vegetables and fruits, timber and fodder species. Some important categories of plants documented so far are given in Table 2. Among these plant categories pressure on forests is mainly for timber needs. Some of the valuable timber yielding species those occur in these forests and being commercially exploited are: *A. grandis, A. lucida, A. procera, A. scholaris, A. wallichii, A. chinensis, A. chaplasha, A. lakoocha, A. excelsa, B. ceiba, B. javanica, B. alnoides, C. bengalensis, C. resiniferum, C. tabularis, C. indica, C. toona, D. procerum, D. hamiltonii, D. binectariferum, E. assamicus, E. lanceofolium, E. chinensis, E. acuminata, G. arborea, G. odorata, H.*

antidysenterica, K. calycina, L. spesiosa, L. monopetala, L. polyantha, M. hodgsonii, M. ferrea, M. assamica, M. champaca, M. oblonga, M. kisopa, M. laevigata, M. denticulata, M. pterocarpa, P. acerifolium, P. lanceofolium, P. goalparensis, P. paniculata, P. khesea, P. roxburghii, Quercus sp., S. villosa, S. coccinea, S. chelenoides, S. khasiana, S. walichii, T. myriocarpa, T. nudiflora, etc.

Table 2: Floristic resources of Nagaland

S. No.	Floristic diversity components	Documented spp.
1	Cultivated crops of Jhum fields	74
2	Wild edible fruits	248
3	Wild edible vegetables	128
4	Wild edible flowers	52
5	Wild edible mushrooms	58
6	Domesticated fruits	26
7	Edible roots and tubers	42
8	Edible seeds and nuts	54
9	Medicinal plants	658
10	Bamboo species	62
11	Orchid species	378
12	Cane species	7
13	Lichens	340
14	Ferns	280
15	Indigenous local useful trees spp.	560
16	Commercial timber plants	147
	Total	**3114**

Orchids are among the most important ornamental plants found growing in the forests and have great potential for exploitation as horticultural species. Out of 378 species of orchids (Changkija *et al.*, 1994), which occur in Nagaland, some of the highly ornamental, rare, endangered and endemic orchid species such as *Paphiopedilum hirsutissimum* (Lady's slipper), *Bulbophyllum rothschildianum* (Red chimney), *Ranenthera imschoodiana* (Dancing lady), *Penkhimia nagalandsis* (New genus reported from Nagaland in 2008), *Cymbidium tigrinum, Arachinis cathcartii, Ascocentrum miniatum, Dendrobium wadianum, Galeola lindleyana, Hygrochilus parishii, Thunnia alba, Coelogyne spp., etc.* are endemic in the state.

Nagaland is also known for rich varieties of Rhododendrons. Out of a total of 18 species of Rhododendrons found here *Rhododendron wattii* and *R. vaccinoides* are new species reported for the first time from Japfu hill ranges of Nagaland, and *R. triflorum* var. *bauhiniiflorum, R. johnstoneanum, R. elliotii* and *R. macabeanum* are rare, endangered and endemic. The tallest Rhododendron in the world is reported from the Japfu hills of Nagaland. Hedychiums is another group of plants found growing abundantly all over the state, which has beautiful, fragrant flowers belonging to Family Zingiberaceae. They are also used as cut flowers due to their aesthetic beauty and fragrance which are also used as room freshener by the local communities. Hedychiums in Nagaland are represented by 16 species. Some common species like *Hedychium aurantiacum, H. densiflorum, H. ellipticum, H. gardnerianum* and *H. spicatum* are also cultivated as ornamental plants in gardens and pots. Apart from the above well known ornamental groups of plants, there are several other wild species available in these forests which have beautiful flowers and are easily cultivable. Some of such plant genera are: *Bauhinia, Ensete, Hibiscus, Mussaenda, Prunus, Pyrus, Tacca, Vaccinum,* Ferns, Bryophytes, Dwarf bamboos, various Arecaceae members, etc.

The Nagas in rural areas are solely dependent on the floral resources for their health care and treatment of various ailments. As many as 658 species of medicinal plants found mainly in forests are used for different ailments. Some of these plants are cultivated in house gardens and jhum fields, however, but about 80% of medicinal plant requirements are met through wild collection. They have gained intimate knowledge of the uses of a variety of medicinal plants and this knowledge is inherited from generations through oral tradition. Many of the plants are used in traditional medicinal purposes and among them some are also used as vegetables and fruits. Among the wild edibles a total of 56 wild edible mushrooms are also consumed as vegetables. Many species of bamboo shoots are also consumed as well as fermented for consumption. The natives mostly depend on the wild edible plants as source of vegetables, fruits, tubers, spices and condiment, etc. The knowledge of use of wild plants as vegetables, fruits and medicine are well preserved and practiced by the local communities. Many of these plants are now cultivated in house gardens/ homesteads and swidden/jhum fields, but most of the wild edible vegetables and fruits are still collected from the wild for self consumption and they are also sold in local markets and regarded as delicacies by the people. Some of the species can be listed as follows: the flowers of *Bauhinia, Phlogacanthus thyrsiflorus, Musae spp., Curcuma spp., Crotalaria qudrangularis* are consumed as vegetable and *Gnetum gnemone, Clerodendrum colebrookianum, Huttuynia cordata, Lasia spinosa, Paedera foetida, Urtica dioica, Zanthoxylum* spp., as leafy vegetables.

Nagaland along with other states of North-East India is a major centre of endemism. Chatterjee (1940) observed that about 50% of the endemic taxa of India are confined to North-East (Eastern Himalaya). There are many species which are strictly confined to Nagaland. The geographical position along with climatic condition have created isolated geographical island and the high mountain ranges (Barail and Patkai) along the eastern side and the alluvial plains in the west may act as a barrier for migration of plants. Some taxa exclusively confined to Nagaland are: *Areca nagansis, Begonia wattii, Bulbophyllum rothschildianum, Capillipedium nagense, C. pteropechys, Chaerophyllum orientalis, Clematis meyeniana, C. meyeniana var. insularis, Cocculus prainianus, Coelogyne hitendrae, Corydalis borii, Cotoneaster nagensis, Crotolaria meeboldii, Cyclea wattii, Deyeuxia borii, D. nagarum, Hedychium marginatum, Penkhimia nagalandsis, Pholidota imbricate, Pimpinella evgoluta, P. flaccida, Ranenthera imschoodiana, Rhododendron wattii, R. vaccinoides, R. johnstoneanum, R. elliotii, Silene vegans,* etc. Besides many species hitherto reported to be endemic to Assam, Manipur, Meghalaya and Arunachal Pradesh have also been found in Nagaland.

NEED FOR CONSERVATION

People in Nagaland are engaged in agriculture, hunting and selected logging activities in the forests to supplement their needs and to earn cash income for their livelihood. On the other hand, food and other materials of plant origin are collected in the forests that include edible fruits, seeds, flowers, leaves, tubers, mushrooms, bamboos and bamboo shoots, besides hundreds of medicinal plants, fibers and weaving materials and dying materials, etc. These diverse varieties of minor forest products are valuable for home consumption as well as for sale in local markets. On the other hand, as local population pressure increases and market linkages with the outside world are introduced, loss of indigenous control over collection of valuable forest products ensues. Combination of the rich indigenous knowledge system with scientific support should be utilized to boost the forest management, agriculture, horticulture, soil and water management, etc. to conserve forest resources and generate employment and income avenues for the rural people.

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7

Leaf Phenology of Some Important Forest Trees in Southern Assam

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INTRODUCTION

Phenological studies are important to understand plant responses to various biotic and abiotic factors like competition for light or photoperiod (Write and Van Schaic, 1994), temperature (Arroyo *et al.,* 1981), and precipitation (Opler *et al.,* 1976). Climatic factors such as temperature and precipitation determine seasonality in plant phenology (Frankie *et al.,* 1974, Marques *et al.,* 2004). Study of leaf phenology is important because it reflects the influence of evolution and environment on plant characteristics and in turn has substantial implications for leaf and shoot growth (Reich *et al.,* 2004). Forests with their high level of species diversity display phenological events such as leaf drop, leaf flushing, flowering and fruiting, etc. in relation to time and space (Negi and Singh, 1992; Singh and Singh, 1992; Justiniano and Fredericksen, 2000). Studies in the central Himalayan forests indicate that deciduous species shed their leaves soon after the wet summer or before the onset of dry season, while the evergreen species retain their leaves throughout the winter, and leaf drop is synchronized with new leafing and shoot growth at the onset of dry summer (Ralhan *et al.,* 1985; Negi, 2006). Dhaila *et al.,* (1995) reported that deciduous tree species may or may not initiate growth earlier, but they complete shoot growth significantly earlier than the evergreen species.

STUDY AREA

The present study was carried out in the Loharbond forests at 24°35’04.3" N and 92°44’50.0" E (mean altitude of 53 m asl) in Barak valley, Cachar District of Assam. The area is characterized by wet and warm humid climatic condition with frequent rainfall, which supports tropical wet evergreen forests in the

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region. Rainfall in the region starts in February-March and increases through June to September, with an annual rainfall of about 2514 mm (average of the two study years, 2007 & 2008) as per data collected from nearest weather station located at Tocklai Tea Research Center; Fig. 1). October to January-February usually remain dry. The soil is sandy clay loam in texture and it is slightly acidic in nature with an average of 0.99% of organic carbon content.

Vegetation of the Barak valley is represented by tropical wet evergreen forests, dominated by *Cynometra polyandra*, *Dysoxylum sp.*, *Palaquium polyanthys*, *Trewia nudiflora*, etc. The climate is tropical monsoon type with frequent rainfall and high humidity. One important characteristic of the climate in the study area is occurrence of plenty of rainfall much before the rainy season. The present study describes leaf phenology of some important evergreen and deciduous tree species of Barak Valley (Table 1), in order to show how evergreen species and deciduous species differ from each other in their strategy to impart phenological events. Standard methodology was followed for the phenological observations.

RESULTS AND DISCUSSION

Across the 8 studied tree species the leaf recruitment period was found to be significantly different ($P < 0.05$) for evergreen and deciduous species (3.5 vs. 6.3 months). In the evergreen species, leafing takes place quickly as compared to deciduous species which produced leaves rather gradually. On a fully elongated shoot the leaf numbers per shoot were significantly ($P < 0.05$) greater for deciduous species (average = 23.8) than for evergreen species (average = 8.3). Average shoot length was also significantly greater ($P< 0.05$) for the deciduous species than for the evergreen species (38.8 cm and 7.3 cm, respectively). Among the deciduous species maximum leaf population per mature shoot during rainy season was recorded for *Litsea monopetala* (36.8 leaves/shoot) and minimum for *Lagerstromia speciosa* (11.5 leaves/shoot). For evergreen species maximum leaf population per mature shoot was recorded for *Mesua floribunda* (11.1 leaves/shoot) during April-May and minimum was recorded for *Dipterocarpus turbinatus* (5.5 leaves/shoot) during July-August. Evergreen species retained leaves for a longer period (average = 8.25 month) than the deciduous species (average = 2.5 month), and this difference was significant ($p < 0.05$).

Among the evergreen species maximum leaf expansion rate was recorded for *D. turbinatus* (32.6 cm^2 week/leaf) while minimum was recorded in *Syzygium syzygioides* (0.64 cm^2/week/leaf). Mean leaf expansion rate of evergreen species (27 cm^2/week/leaf) in the present study was significantly ($P<0.01$) higher than that of deciduous species (11.93 cm^2/week/leaf). Leaf expansion period (weeks) was found different from one species to another (Fig. 2). The leaf expansion period for deciduous and evergreen species was significantly different (P<0.05). Similarly, the leaf life span (days) was found different from one species to another (Fig. 3). Among the evergreen species highest leaf life span was recorded in *D. turbinatus* (509 days) and lowest in *S. syzygioides* (270 days). Among the deciduous species, highest leaf longevity was recorded in *L. speciosa* (238 days) and lowest in *Gmelina arborea* (165 days). The average leaf longevity of evergreen species (418 days) was significantly greater (P<0.05) than that of deciduous species (199 days) (Fig. 3). Evergreen species retain their leaves until new leaf initiation in the next spring. In most of the deciduous species leaf shedding begins in the month of October with peak in November–December. All the deciduous species remain leaf less during rest of the winter. The average leaf fall rate of deciduous species (24.2%) was significantly greater (P<0.05) than that of evergreen species (9.9%). Phenophase diagram of the leaves of tree species studied is given in Fig. 4.

Table 1: Attributes of tree species selected for study

Species	Family	Growth form
Dipterocarpus turbinatus	*Diptocarpaceae*	Evergreen
Palaquium polyanthum	*Sapotaceae*	Evergreen
Mesua floribunda	*Clusiaceae*	Evergreen
Syzygium syzygioides	*Myrtaceae*	Evergreen
Litsea monopetala	*Lauraceae*	Deciduous
Toona ciliata	*Meliaceae*	Deciduous
Gmelina arborea	*Verbinaceae*	Deciduous
Lagerstromia speciosa	*Lythraceae*	Deciduous

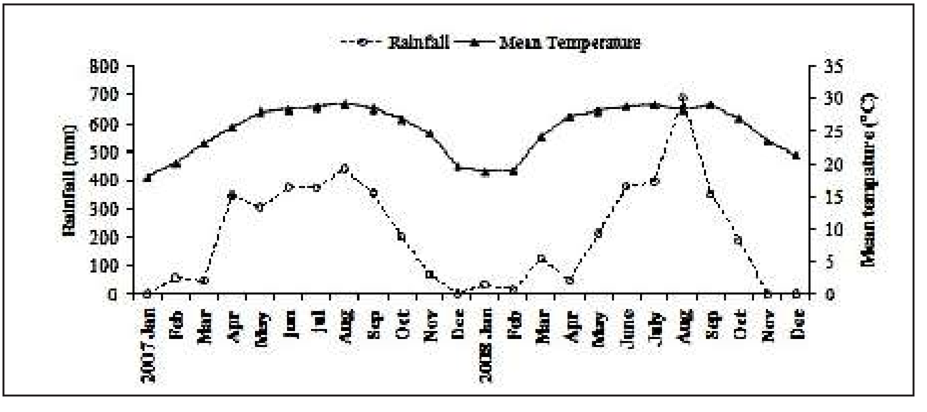

Fig. 1: Mean monthly rainfall (circle with dotted line) and air temperature (triangles with solid line) at the nearest weather station (Source: Tocklai Tea Research Center, Assam)

DISCUSSION

Similar to the earlier reports (Kikim and Yadava, 2001) in the present study the deciduous species produced new leaves during early summer whereas evergreen species initiated leafing late in the season. Early leafing help the deciduous species to avoid the leaching of minerals from the soft leaves by torrential rains (Sarmiento, 1983), and also help maximize the advantage of the most favorable conditions of monsoon period with fully developed foliage (Negi, 2006). Reports suggest that production of new foliage shortly before the rainy season is likely to optimize photosynthetic gain in tropical forests with relatively short growing season (Shukla and Ramakrishnan, 1982; Sundriyal, 1990; Kushwaha and Singh, 2005; Yadav and Yadav, 2008).

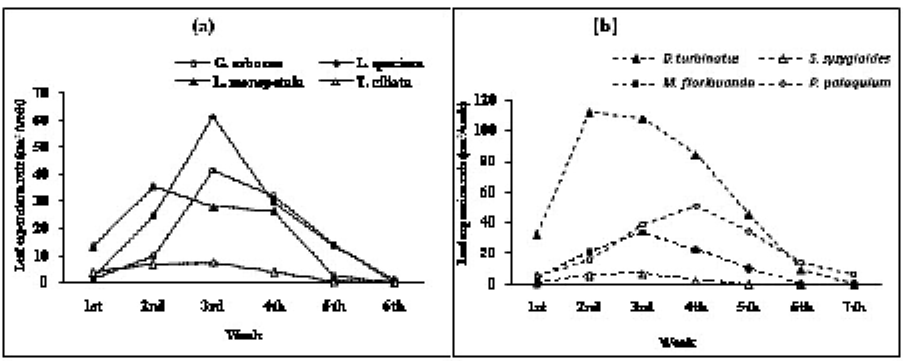

Fig. 2: Leaf expansion period of tree species in Barak valley (a= Deciduous, and b= Evergreen spp.)

However, in some evergreen species like *P. polyanthum* and *D. turbinatus* leaf development was found to be strongly related to rainfall. These species produced new leaves as late as May or June to utilize the favorable moisture conditions of wet summer. Dry summer is the worst time to produce leaves and leaf expansion due to soil moisture limitation; this question how the trees produce leaves during peak summer is still not fully answered (Borchert *et al.*, 2002). The rapid shoot growth, leaf recruitment and leaf expansion in deciduous species may be a significant adaptation attribute, which enable deciduous species to accomplish greater growth earlier in the season compared to evergreen species. This finding is in conformity with the findings of earlier workers in the western Himalayan region (Dhaila *et al.*, 1995; Negi, 2006). Similar to the findings of Ralhan *et al.*, (1985) and Negi and Singh (1992) in the Central Himalaya, in the present study the average leaf longevity of the evergreen species (418 days) was significantly greater ($P<0.05$) than that of deciduous species (199 days). All the studied deciduous and evergreen species show a positive correlation between leaf longevity and leaf expansion rate.

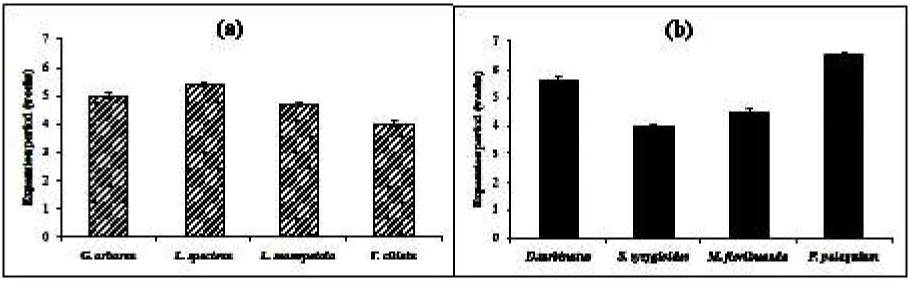

Fig. 3: Leaf life span of tree species in Barak valley (a= Deciduous, and b= Evergreen spp.)

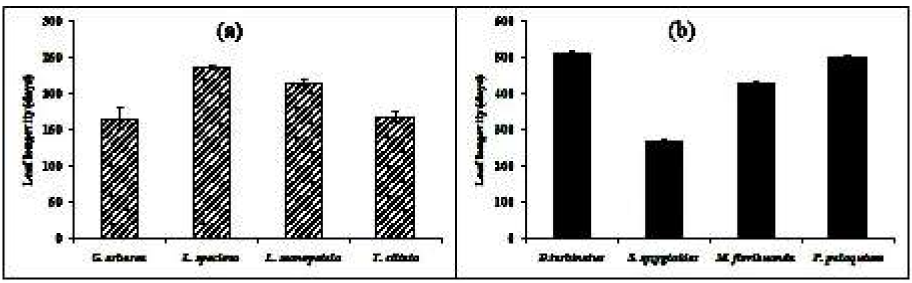

Fig. 4: Phenophase diagram of trees species in Barak valley (a= Deciduous, and b= Evergreen spp.)

Although winter temperature in the study area was not extremely low to hamper the growth in plants, perhaps it is the combined effect of decrease in day length, temperature and lower soil moisture that influences the phenological activities of plants in the region during winter. Bhat (1992) also suggested that leaf fall coincided with short day length and decrease in temperature. The onset of leaf fall initiation was found different across the tree species. This difference in leaf fall may be due to micro-environmental factors (Boojh and Ramakrishnan, 1981; Sundriyal, 1990; Kikim and Yadava, 2001). Singh and Singh (1992) has pointed out that initiation of leaf fall coinciding with the onset of the post-monsoon with low temperature and dry period can be a mechanism maintaining turgidity of shoots. Reich and Borchert (1982) suggested that the leaf fall during the dry season was directly influenced by the decline in soil moisture and increasing water stress conditions. The results are in conformity with Dhaila *et al.*, (1995) who reported that leaf shedding occurred when the radial growth of stems had revived or just prior to this; and also with Singh *et al.*, (1990) who reported that the evergreen species of the Himalaya retained their leaves during the long dry season, until new leaves were formed. New shoot growth seemed to induce leaf shedding in the evergreen species (Ralhan *et al.*, 1985).

This comparative study considering leaf phenological traits of four representative evergreen and deciduous species of Barak Valley suggest that deciduous species may or may not initiate their growth earlier than evergreen species, but deciduous species continue producing leaves coinciding with the availability of soil moisture; long after the evergreen species has stopped producing new leaves. Deciduous species shed all their leaves prior to dry winters, which may allow them to conserve and store water and survive during cold dry winters. On the other hand, the ability of evergreen species to retain leaves during the dry winter season give them an advantage over the deciduous species, because they can maintain growth during winter season and this longer photosynthetic activity enables evergreen species to realize a higher growth and dominance.

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Growth of Conifer Plantations in Himachal Pradesh

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INTRODUCTION

A Pinetum was established in the year 1935 in temperate mid-Himalayan zone of Himachal-Himalaya at Manali with an objective to conserve some of the rare species of conifers found in temperate regions of the world. It was located amidst the reserve forest, on the right bank of river Beas at an altitude of 2050 m asl. The forest type is Deodar with mica schist soil type. The soil of the Pinetum is acidic in reaction with pH 5.3, within safe limit of EC (0.320 dsm^{-1}), very high in organic carbon (1.80%) and available K (532 Kg/ha), and medium in available N (370 Kg/ha) and P (55 Kg/ha). In winter (December – March) the area experiences heavy snowfall thereby dipping the mercury to sub-freezing levels and in summer (April–September) the mean temperature remains around 20 to 25^0C.

MATERIAL AND METHODS

Ten trees, each of the fifteen conifer species (listed in Table 1) were marked and observed for number of branches, dbh, height growth and increment at various age intervals particularly during the peak of their growth phase (63,65,67,69 and 71 years of age) so as to test their adaptability and growth performance under similar edapho-climatic conditions. The growth data was recorded as per standard procedure. The mean annual increment (MAI) was computed by dividing mean growth values by age of the tree at that time.

RESULTS AND DISCUSSION

Data recorded for height, dbh and number of branches showed an upward trend with the increase in age of the tree for all the fifteen species under study (Table 1). At the age of 63 years, *Pseudotsuga taxifolia* showed significantly maximum height (23.20 m) than rest of the species but remained at par with

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Pinus laricio (22.20 m) and *Cupressus torulosa* (22.20 m). *Taxodium distichum* recorded significantly lesser height (7.20 m) as compared to all the fifteen species following *Cupressus glabra* (12.60 m) and *Cupressus obtusa* (13.30 m). At the age of 71 years *Pseudotsuga taxifolia* maintained its supremacy by attaining 33.70 m height followed by *Pinus laricio* (31.70 m) and *Cupressus torulosa* (31.48 m). Similarly, *Taxodium distichum* revealed significantly minimum (10.10 m) height following *Cupressus glabra* (16.00 m) and *Picea excelsa* (19.68 m).

At the age of 63 years maximum dbh was recorded for *Pseudotsuga taxifolia* (45.90 cm), which was significantly at par with *Pinus taeda* (43.39 cm), *Pinus patula* (42.59 cm) and *Pinus laricio* (41.52 cm) (Table 1). On the other hand *Taxodium disticum* recorded significantly minimum dbh (19.44 cm) as compared to all other species under study. Almost a similar trend was observed for dbh at the age of 71 years of plantation where, *Pseudotsuga taxifolia* recorded maximum dbh (55.26 cm) followed by *Pinus taeda* (47.98 cm), *Pinus patula* (46.70 cm), *Pinus laricio* (44.80 cm), *Cupressus arizonica* (43.08 cm), *Larix leptolepsis* (40.87 cm), *Thuja plicata* (40.34 cm) and *Cupressus torulosa* (40.29 cm). *Taxodium distichum depicted* minimum dbh value of 23.33 cm following *Cupressus glabra* (27.15 cm), *Cupressus obtusa* (33.71 cm) and *Pinus ponderosa* (34.23 cm). Data on number of branches at 63 years of age showed highest number in *Pinus excelsa* (81.60) followed by *Pseudotsuga taxifolia* (69.80), *Cupressus arizonica* (52.40) and *Thuja plicata* (52.20). *Taxodium distichum* exhibited minimum (20.20) number of branches than rest of all the fourteen species. Almost similar trend was observed at 71 years of tree age where, *Pinus excelsa* with 112.80 number of branches significantly excelled over all other species (Table 1).

Data recorded for mean annual increment (MAI) of height, dbh and number of branches showed an upward trend with the increase in age of the tree for all the fifteen species under study (Table 2). At the age of 63 years, *Pseudotsuga taxifolia* showed significantly maximum (0.37 m) MAI for height growth than rest of the species. *Taxodium distichum* recorded significantly lesser MAI for height (0.11 m) compared to all the fifteen species, following *Cupressus glabra* (0.20 m) and *Cupressus obtusa* (0.21 m). At the age of 71 years *Pseudotsuga taxifolia* maintained its MAI supremacy and depicted height of 0.47 m. Similarly, *Taxodium distichum* revealed significantly minimum (0.14 m) height following *Cupressus glabra* (0.23 m) and *Pinus excelsa* (0.28 m). At the age of 63 years maximum MAI for dbh (Table 2) was observed for *Pseudotsuga taxifolia* (0.73 cm) and minimum for *Taxodium distichum* (0.31 cm). Almost a similar trend was observed for dbh at the age of 71 years plantation thereby

Table 1: Growth performance of conifer plantations in temperate mid-Himalayan zone of Himachal Pradesh

S. No.	Species	Height (m)					DBH (cm)					Number of branches				
	Age of plantations (yrs.)	63	65	67	69	71	63	65	67	69	71	63	65	67	69	71
1	*Cupressus glabra*	12.60	13.20	13.70	14.40	16.00	21.96	23.12	25.61	26.31	27.15	28.60	29.40	34.70	42.25	45.15
2	*Cupressus arizonica*	20.25	21.00	22.36	25.90	27.42	37.85	38.96	41.37	41.92	43.08	52.40	55.70	59.30	65.55	67.76
3	*Cupressus torulosa*	22.20	23.00	24.30	27.60	31.48	35.04	35.86	36.45	39.78	40.29	46.60	49.56	50.82	57.60	59.58
4	*Cupressus obtusa*	13.30	13.90	14.40	18.00	21.40	27.64	28.41	30.94	33.03	33.71	38.20	43.70	46.82	51.02	53.20
5	*Pinus sylvestris*	19.20	19.82	20.20	22.40	25.62	33.43	34.12	37.00	38.41	39.77	28.80	32.73	33.60	36.53	42.71
6	*Pinus patula*	19.34	20.02	20.70	24.40	26.10	42.59	43.45	44.30	45.60	46.70	40.20	42.31	42.96	43.86	44.75
7	*Pinus taeda*	19.50	20.15	20.70	26.60	30.00	43.39	44.85	45.40	47.51	47.98	21.80	23.40	27.60	30.65	33.80
8	*Pinus ponderosa*	20.00	20.70	21.36	24.75	26.80	29.42	30.50	32.54	33.08	34.23	40.20	41.60	46.75	50.73	53.80
9	*Pinus laricio*	22.20	22.90	24.30	28.60	31.70	41.52	41.88	42.53	44.29	44.80	42.80	46.90	48.95	50.60	51.87
10	*Cryoptomeria japonica*	16.17	18.30	18.86	22.00	26.80	30.75	31.63	35.28	37.18	38.04	31.20	32.72	34.80	39.73	41.90
11	*Thuja plicata*	16.80	17.45	20.20	26.85	30.60	33.85	34.54	37.23	39.59	40.34	52.20	55.90	55.60	70.90	74.66
12	*Larix leptolepsis*	17.40	18.80	19.32	22.40	24.92	34.02	34.60	38.59	39.59	40.87	41.80	44.68	46.93	54.60	55.86
13	*Taxodium distichum*	7.20	7.45	8.36	9.20	10.10	19.44	19.97	21.79	22.77	23.33	20.20	21.40	22.96	29.51	31.76
14	*Picea excelsa*	14.60	15.40	16.56	18.96	19.68	30.06	31.48	33.59	34.80	35.61	81.60	103.25	110.15	109.60	112.80
15	*Pseudotsuga taxifolia*	23.20	24.26	25.45	29.60	33.70	45.90	48.93	51.76	52.53	55.26	69.80	75.90	78.93	93.60	97.62
	$CD_{(0.05\%)}$															
	Species (S)	2.41					7.77					22.37				
	Year (Y)	1.56					1.35					7.15				

Table 2: Mean annual increment in conifer plantations in temperate mid-Himalayan zone of Himachal Pradesh

S. No.	Species	Height (m)					DBH (cm)					Number of branches				
	Age of plantations (yrs.)	63	65	67	69	71	63	65	67	69	71	63	65	67	69	71
1	*Cupressus glabra*	0.20	0.20	0.20	0.21	0.23	0.35	0.36	0.38	0.38	0.38	0.45	0.45	0.51	0.61	0.64
2	*Cupressus arizonica*	0.32	0.32	0.33	0.37	0.39	0.60	0.60	0.62	0.61	0.61	0.83	0.86	0.88	0.95	0.95
3	*Cupressus torulosa*	0.35	0.35	0.36	0.40	0.44	0.56	0.55	0.54	0.58	0.57	0.74	0.76	0.76	0.83	0.84
4	*Cupressus obtusa*	0.21	0.21	0.21	0.26	0.30	0.43	0.44	0.46	0.48	0.47	0.61	0.67	0.70	0.73	0.75
5	*Pinus sylvestris*	0.30	0.30	0.30	0.32	0.36	0.53	0.52	0.55	0.56	0.56	0.46	0.50	0.50	0.53	0.60
6	*Pinus patula*	0.30	0.31	0.31	0.35	0.37	0.67	0.67	0.66	0.66	0.66	0.64	0.65	0.64	0.63	0.63
7	*Pinus taeda*	0.31	0.31	0.34	0.38	0.42	0.69	0.69	0.68	0.69	0.67	0.35	0.36	0.41	0.44	0.48
8	*Pinus ponderosa*	0.32	0.32	0.32	0.36	0.38	0.47	0.47	0.48	0.48	0.48	0.64	0.64	0.70	0.74	0.76
9	*Pinus laricio*	0.35	0.35	0.36	0.41	0.44	0.65	0.64	0.63	0.64	0.63	0.68	0.72	0.73	0.73	0.73
10	*Cryoptomeria japonica*	0.26	0.28	0.28	0.32	0.38	0.49	0.49	0.53	0.54	0.54	0.49	0.50	0.52	0.58	0.59
11	*Thuja plicata*	0.27	0.27	0.30	0.39	0.43	0.54	0.53	0.55	0.57	0.57	0.83	0.86	0.83	1.02	1.05
12	*Larix leptolepsis*	0.27	0.29	0.29	0.32	0.35	0.54	0.53	0.57	0.57	0.57	0.66	0.69	0.70	0.79	0.79
13	*Taxodium distichum*	0.11	0.11	0.12	0.13	0.14	0.31	0.31	0.32	0.33	0.33	0.32	0.33	0.34	0.42	0.45
14	*Picea excelsa*	0.23	0.24	0.25	0.27	0.28	0.48	0.48	0.50	0.50	0.50	1.29	1.58	1.65	1.58	1.59
15	*Pseudotsuga taxifolia*	0.37	0.38	0.38	0.42	0.47	0.73	0.75	0.77	0.76	0.78	1.10	1.16	1.17	1.36	1.37
	$CD_{(0.05\%)}$ Species (S) Year (Y)	0.15 NS					0.28 NS					0.46 NS				

depicting a maximum value of 0.78 cm for *Pseudotsuga taxifolia* and minimum (0.33 cm) for *Taxodium distichum.* Data (Table 2) on MAI for number of branches at 63 years of age showed highest number in *Pinus excelsa* (1.29), and lowest in *Taxodium distichum* (0.32). Almost similar trend was observed at 71 years of age where, *Pinus excelsa* with 1.59 number of branches significantly excelled over all other species, minimum value of MAI for number of branches (0.45) was observed for *Taxodium distichum.*

Results of the study indicated that in spite of similar environment, the tree species exhibited intrinsic ability to achieve differential growth. The better growth potential of some tree species as compared to other ones can be ascribed to better adaptability and utilization of site resources. The inter-specific variation in growth performance of various tree species has also been reported by earlier workers (Bisht and Toky, 1993; Thakur and Mishra, 1998).

CONCLUSION

Observations on height, dbh and number of branches showed an upward trend with the increase in age of the trees for all the 15 species under study. At the age of 71 years, maximum height of 33.70 m was recorded by *Pseudotsuga taxifolia*, which was at par with *Pinus laricio* (31.70 m) and *Cupressus toruolsa* (31.48 m) but showed difference from rest of the species. *Pseudotsuga taxifolia* also exhibited maximum dbh (55.26 cm) followed by *Pinus taeda* (47.98 cm), which was at par with *Pinus patula* (46.70 cm), *Pinus laricio* (44.80 cm), *Cupressus arizonica* (43.08 cm), *Larix leptolepis* (40.87 cm), *Thuja plicata* (40.34 cm) and *Cupressus torulosa* (40.29 cm). The maximum number of branches was observed in *Pinus excelsa* (112.80) followed by *Pseudotsuga taxifolia* (97.62). Species like *Pseudotsuga taxifolia, Pinus taeda, Pinus patula, Pinus laricio, Cupressus arizonica, Cupressus torulosa, Larix leptolepis* and *Thuja plicata* showed better growth under mid-Himalayan temperate conditions of Himachal Pradesh. This long-term data recorded for some important growth parameters for fifteen conifer species will be helpful to select the best performer for massive afforestation programme in temperate region of the world with similar site conditions.

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Soil Carbon Stock and its Role in Carbon Sequestration

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INTRODUCTION

Soil carbon, or soil organic carbon (SOC) as it is more accurately known, is the carbon stored within soil. It is part of the soil organic matter (SOM), which includes other important elements such as calcium, hydrogen, oxygen, and nitrogen. SOM is made up of plant and animal materials in various stages of decay, which depends upon species, spacing, litter quality, decomposition rate, season, etc. It acts both as a sink and source of carbon in response to climate, land use changes and to the rising atmospheric levels (Jobbagy and Jackson, 2000; Kirschbaum, 2000). Carbon sequestration is the facilitated redistribution of carbon from the air to other pools. This would reduce the rate of atmospheric CO_2 increase, thereby mitigating global warming (Anikwe Martin, 2010).

Forestry options are often proposed as important components of carbon sequestration strategies (Pandey, 2002). It has long been established, especially since the Rio summit in 1992 that temperature, soil temperature, rainfall, soil texture, pH and type of vegetation or land cover are the major factors controlling the level of SOC (Krishnan *et al*., 2007). Despite this, most of the estimations of SOC pool at the global level, or at European or Indian scales are based only on the soil type (Rasmussen, 2006). Carbon stock in soil depends largely on the aerial extent of the soils besides other factors such as carbon content, depth and bulk density of soils (Bhattacharya, 2007).

Soil carbon (both soil organic carbon: SOC, and soil inorganic carbon: SIC) is important as it determines ecosystem and agro-ecosystem functions, influencing soil fertility, water-holding capacity and other soil parameters. It is

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also of global importance because of its role in the global carbon cycle and therefore, the part it plays in the mitigation of atmospheric levels of greenhouse gases (GHGs), with special reference to CO_2 (Bhattacharyya *et al*., 2008). To reduce the emission of CO_2, carbon capture and storage (CCS) has been found to be an important option. The technique consists of three basic steps: (i) capturing CO_2 at large and stationary point sources, (ii) transporting CO_2 from a source to sink, and (iii) injecting CO_2 in suitable geological reservoirs or sinks. CCS was generally regarded as an option during the first half of the 21st century, to bridge the gap posed by the urgent need to act against climate change and the time needed to fully develop an important renewable energy (Anon., 2007; Goel, 2007). Soils are the largest reservoirs in the terrestrial carbon cycle. Altogether 3.5% of the earth's carbon reserves are stored in soils compared with 1.7% in the atmosphere, 8.9% in fossil fuels, 1.0% in biota and 84.9% in the oceans. Soil carbon sequestration is an important part of terrestrial C pool. Its size has been estimated between 700 to 3000 Gt C as organic C and 780 to 930 Gt C as $CaCO_3$. Other C pools consist of oceans (38,000 Gt C), fossils C reserves (6, 0000 Gt C), CO_2 in the atmosphere (720 Gt C) and biomass of plants (560 to 835 Gt C biomass) (Bouwman, 1990; Singh, 2009). Current global stock of SOC is estimated to be 1500-1550 Pg. This amounts to twice that in the earth's atmosphere (720 Pg), and more than triple the stock of OC in terrestrial vegetation (560 Pg). The rising concern about the effect on climate change has fuelled a variety of studies over the last decades, attempting to quantify the global SOC. About 40% of the total SOC stock of the global soils resides in forest ecosystem (Eswaran *et al*., 1999). The Himalayan zones with dense forest vegetation cover a fifth part of India and store a third part of the country reserves of SOC which are recognized for their unique conservation value and richness of economically important biodiversity (Sheikh *et al.*, 2009). Soils thus play a key role in the global carbon budget and can have large impact on carbon release under a climate change scenario (Lal *et al*., 1995).

FORESTS AND SOIL CARBON

Carbon management in forests and tree plantations is most common agenda of the 21st century to mitigate global climate change. Tree plantations with fast growing species have a direct impact on the regional rate of carbon sequestration by incorporating carbon into the plant biomass and improving soil organic matter (Bhalla *et al*., 2011). Managing forests may be a useful technique so as to increase SOC status because the presence of trees affects dynamics directly or indirectly. Trees improve soil productivity through ecological and physio-chemical changes that depend upon the quantity and quality of litter reaching soil surface and rate of litter decomposition and nutrient release (Meentemeyer and Berg, 1986). Global warming and its effect on soils in terms of SOC management have led to several quantitative estimates for global C content in the soils (Buringh, 1984; Veleyutham *et al*., 2000). Spatial and vertical distribution estimates of SOC pools and flux are important requirements for understanding the role of soils in the global C cycle and for assessing potential biospheric responses to climatic change (Post *et al*., 2001).

In Indian context, Jenny and Raychaudhuri (1960) studied organic carbon status and reported the effects of climate on carbon reserves in virgin and cultivated soils. Based on different approaches, estimates of total and forest SOC stocks in India are in the range of 23.4 – 47.5 Pg C and 5.4 – 6.7 Pg C (Dadhwal and Nayak, 1993; Gupta *et al*., 1993). Few studies on Indian forest biomass and phytomass carbon pools (Ravindranath *et al*., 1997; Dadhwal and Shah, 1997; Chhabra *et al*., 2002) and litter fall (Dadhwal and Shah, 1997) are available (Table 1). Chhabra *et al.,* (2002) attempted to estimate the SOC based on different forest types. China's SOC storage in a depth of 1 meter is estimated as 69.1 Pg (Pg = 10^{15} g), with an average density of 7.8 kg m^{-2} (Yang *et al.,* 2007). About 48% of the storage was concentrated in the top 30 cm. The SOC density increased from arid to semi-humid zone in northern China and from tropical to cold-temperate zone in the eastern part of the country (Yang *et al*., 2007). Li *et al.,* (2004) studied and estimated the current vegetation and soil carbon storage in China using a biogeochemical model driven with climate, soil and vegetation data at 0.5 latitude-longitude grid spatial resolution. The results indicated that the total carbon storage in China's vegetation and soils was 13.33 Gt C and 82.65 Gt C, respectively, about 3% and 4% of the global total. The national mean vegetation and soil carbon densities were 1.47 kg C/m^2 and 9.17 kg C/m^2, respectively, differing greatly in various regions affected by climate, vegetation, and soil types. Carbon in live vegetation accounts for an estimated 5 percent or less of United Kingdom land carbon. It has been estimated that the vegetation carbon stock of Great Britain (England, Wales and Scotland) is approximately 113.8 ± 25.6 Tg, or millions of tonnes (Milne *et al*., 2001), with vegetation in Northern Ireland containing an additional 3.8 - 4.4 Tg (Cruickshank *et al*., 1998, 2000). In a separate study, the soil carbon stock of Northern Ireland was estimated at 0.4 billion tonnes (Cruicshank *et al*., 1998), with 42% of this was found in peat soils. Bradley *et al*., (2005) assembled a carbon and land-use database for the whole of the UK with soil parameters (i.e. bulk density, organic carbon and texture) at depths of 0–30 cm and 30-100 cm which was used to produce a detailed map of estimated UK soil carbon stocks. Current terrestrial (plant and soil) C is estimated at 2000±500 Pg, which represents 25% of global C stocks (DOE, 1999). The sink option for CO_2 mitigation is based on the assumption that this figure can be significantly increased if various biomes are judiciously managed and/or manipulated. Albrecht and Kandji (2003) revealed that agricultural lands have the potential to remove and store between 42 and 90 Pg of C from the atmosphere over the next 50-100 years and the estimated C sequestration potential of agroforestry systems lies between 12 and 228 Mg ha^{-1} with median value of 95 Mg ha^{-1}. Further they indicated that based on the earth's area that is suitable for the practice (585–1215 x 10^6 ha), 1.1 - 2.2 Pg C could be stored in the terrestrial ecosystems over the next 50 years.

Green house gases (GHGs) are increasing in the atmosphere and causing climate change. Carbon sequestration is the process of removal and storage of carbon from the atmosphere to carbon sinks (such as oceans, forests or soils). Forests play a major role towards increasing the global carbon sequestration. Miscellaneous forests are spread over an area of 40.7316 M ha, and their soils have maximum SOC store (6,469.80 Mt) while SOC store is the least (0.82 Mt) in *Dipterocarpus macrocarpus* forest with 0.0068 M ha area (Melkania, 2009). Among the states, Arunachal Pradesh has maximum SOC store (1702.08 Mt) and least (2.42 Mt) in Dadra and Nagar Haveli (Melkania, 2009). The soil is the largest terrestrial pool of OC, with global estimates ranging from 1115 - 2200 Pg of carbon (Batjes, 1996), 1576 Pg of C (Eswaran *et al.,* 1999) and 1220 Pg of C (Sombroek *et al.,* 1993). In the soil under tropical rain forests this pool is about equal to that of above ground biomass (Sombroek *et al.,* 1993). Jha *et al.,* (2003) estimated 9, 815. 95 Mt of soil C store in forest soils as per 1994 forest stands under 19 species in India. However, Spruce (*Picea smithiana*) forest soil has the maximum C store (386.0 t ha^{-1}) while Khair *(Acacia catechu*) has the least (51.93 t ha^{-1}). In view of this, soil conservation practices should be strengthened so that carbon store may not deplete especially from mountain forests considering the following:

(i) Altitude plays an important role for the carbon stock because forest density and total basal cover decreases with increasing altitude; (ii) Soil physical properties such as bulk density, particle size and texture are important parameters to study soil carbon stock; (iii) Forest type influence soil organic matter and ultimately soil carbon; (iv) Broad leaved species absorb more carbon than conifers; (v) Management of vast areas of Himalayan forests at lower elevations can be regarded as major sinks of mitigating atmospheric CO_2 and can sustain the soil health by improving the various soil quality parameters; and (vi) Ability of soil to stabilize soil organic matter depends negatively on altitude and calls for comprehensive theoretical explanation.

Table 1: Quantity of soil carbon stock under different forests and soil types in India

Forest type	Carbon stock (t C ha^{-1})	Source(s)
Oak (*Quercus leucotrichophora*) forest, Pauri Garhwal Pine (*Pinus roxburghii*) forest, Pauri Garhwal	64 - 72 49.6 – 60.0	Singh *et al.*, (2011)
Oak (*Q. leucotrichophora*) forest, Tehri Garhwal Pine (*P. roxburghii*) forest, Tehri Garhwal	60.8 - 185.6 124 - 141	Sheikh *et al.*, (2009)
Giri catchment, HP (<1000 m - >2500 m)	54.34 - 97.31	Negi & Gupta, (2010)
Montane forest (>1400 m asl) Montane grassland (>1800 m asl) Other dense evergreen forests Secondary/distributed evergreen forests Moist deciduous forest, dense or disturbed Dense dry deciduous forests Degraded forests, pastures, wastelands	110.2 82.6 64 63.2 73.1 65 45.1	Bhadwal & Singh (2002); Krishnan *et al.*, (2007)
Indian Red soil Indian Laterite soil Indian Saline soil Indian Black soil	41.2 120.4 13.2 18.0	Jha *et al.*, (2001)
National average of Indian soil	182.94	Jha *et al.*, (2003)

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10

Carbon Accumulation in Community Managed Forests: A Case Study in Kumaun Himalaya

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INTRODUCTION

Forests of Uttarakhand are the repositories of great biological diversity and provide ecological stability, timber, fuelwood, fodder and green manure which are critical to the household economy of the local inhabitants. Eight out of the 16 forest types existing in India are found in Uttarakhand (Champion and Seth, 1968). Forests in Uttarakhand are managed by three different agencies: Reserved forests under the control of Forest Department; community forests under the control of Van Panchayats (VPs); and civil soyam forests under the control of Revenue Department. Of the total forested area of Uttarakhand approximately 84% is either under reserved forests or civil and soyam forests and the rest 16% of the forests area is under community forests. The capacity of the community forests managed by the VPs to meet the daily needs of local people of fuelwood, litter, timber, fodder and non-timber forest products (NTFP's) and the maintenance of the flow of ecosystem services depends on strengthening of these VPs. Singh (2007) has reported that a mature forest in the Himalayan region stores approximately 200 to 300 tonnes of carbon per hectare. Similar studies have been conducted by Jina *et al*., (2008) and Singh (2009) in this region.

Global climate has always been changing naturally. However, the changes witnessed in the last 50 years have been dramatic, and scientists attribute the change to human induced factors linked directly to increased levels of CO_2 and other greenhouse gases emitted from burning of fossil fuels, deforestation, and other human activities. According to Janzen (2004), the concentration of atmospheric CO_2 has increased by over 30% since pre-industrial levels and it is expected to exceed 500 ppmv by 2100. Every year about 8 billion tonnes of carbon is released into the atmosphere contributing to global warming. When

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forested lands are cleared or converted into other land uses such as agriculture land, the carbon earlier stored in above and below ground biomass and in the soil is released back to the atmosphere. Thus loss of forests which could store carbon is a significant contributing factor to climate change impacts. However, the possibility of expanding carbon storage in forests has been identified as a potential measure to mitigate climate change by sequestering atmospheric carbon dioxide (FAO, 2001). Conversion of pasture lands, agricultural fields and degraded forests into intact forests leads to more sequestration of CO_2 from the atmosphere. Forests are a much cheaper and easier way to store carbon than industrial capture and storage. Reducing emission by avoiding deforestation and forest degradation (REDD+) has been considered an effective solution to combat the atmospheric rise of carbon dioxide. The general goal of sequestration activities is to maintain ecosystem in the sink phase. Managed forests sequester more carbon than unmanaged forests nearing their climax stage as decay, burning, and die-back are balanced by the growth of plants (Upadhyay *et al*., 2005). Carbon sequestration can be achieved effectively through forest management and conservation practices. If the payment for carbon credit is made to these communities, added benefits may provide communities relying on the forests incentive to halt deforestation and opt for longer term benefits (Kagi and Schmidtke, 2005).

THE CARBON MARKET

It is widely accepted that global climate change would have adverse impacts on the socio-economic development of many nations. Mitigation of the adverse effects of climate change holds a high priority on the international agenda. Carbon credit trading is a market-based mechanism for efficiently allocating emission reductions and sink enhancements among different sources and sinks with different marginal costs. It ensures that the actual emission reduction or sink enhancement is undertaken by sources or sinks that have the lowest-cost opportunities to reduce emissions or enhance removals by sinks. Carbon trading under the Kyoto Protocol as well as outside the protocol is growing rapidly from a small base and is expected to increase dramatically under present trends. In addition to markets operating under the Kyoto Protocol, there are several other distinct carbon schemes or markets in operation at present. Thus, rather than a single carbon market several carbon markets operate simultaneously with linkages among them. These all schemes use market-based mechanisms to allocate and trade carbon credits that represent a reduction of CO_2 emission. Carbon transactions are defined as purchase contracts in which one party pays another party in return for GHG emission reductions or for the right to release a given amount of GHG emissions that the buyer can use to meet its compliance on climate change mitigation objectives. Payment can be made using equity, debt, convertible debt or warrant, or in-kind contributions such as providing technologies to abate GHG emissions. Carbon transactions can be grouped into two main categories: allowance-based and project-based. Transactions can also be categorized if it is intended to meet emission limits under the Kyoto Protocol. Carbon markets can be a cost effective way to meet a state or national GHG emission goal. The key to keeping costs low is to allow all potential emission reductions or offset practices, particularly those that can achieve these reductions or offsets at low costs. The costs of sequestering soil carbon and reducing agricultural CH_4 and N_2O emissions are likely low to be relative to the costs of emission reductions from fossil fuel combustion.

FOREST MANAGEMENT AND UTILIZATION BY VILLAGE COMMUNITIES

Most of the Van Panchayats in Uttarakhand were initiated after the notification of Van Panchayat Act in 1931 on degraded forest sites under the control of the State Revenue Department. According to recent estimates, there are about 12,089 Van Panchayats spread over an area of 5,44,965 ha in Uttarakhand. The area under each VPs ranges from less than a hectare to over 2000 ha. A major objective of VPs is to rejuvenate and manage patches of civil soyam forests for local use. It also prevents neighbouring villages from intruding into this zone, once formally demarcated as a VP forest. Van Panchayat ensures that their forests are protected from illegal lopping, animal grazing, or forest fires through certain village-level rules and regulations. Penalties are levied on people found indulged in illegal extraction of forest resources. The penalty rates vary for illegal fodder and litter collection, timber and fuelwood extraction, grazing livestock, etc. Strong rules and regulations and effective enforcement have avoided forest degradation and deforestation in many of these VPs in the state (Negi, 2008). The main products include timber, fuelwood, fodder, litter and NTFP's. A decision to harvest is taken by the community members together in village meetings and the forest is opened for collection of forest produce for a defined time period. Every household pay a small fee for collection of the forest products. On special occasions such as during marriages, religious ceremonies, etc. villagers can harvest more fuelwood for the same price. Products extracted collectively after a thinning or clearing operation are distributed equally amongst villagers. Community members may sell their personal excess of these products to the villagers, but the products may not be sold commercially outside the village.

Table 1: Total tree carbon stock and carbon sequestration rate in Anriyakot and Bhatkholi VPs in Lamgara block of Almora district

VPs/Site	Carbon stock in 1st year (B_1) (t ha^{-1})	Carbon stock in 2nd year (B_2) (t ha^{-1})	Carbon sequestration rate $\Delta B=B_2-B_1$ (t ha^{-1} yr^{-1})
Anriyakot VP Forest			
Site 1	77.53	81.16	3.63
Site 2	78.69	84.13	5.44
Site 3	18.92	22.07	3.15
Site 4	49.04	52.43	3.39
Mean			3.90
Bhatkholi VP Forest			
Site 1	26.37	31.67	5.30
Site 2	29.54	32.82	3.28
Site 3	17.76	19.79	2.03
Site 4	12.78	15.79	3.01
Mean			3.41

CARBON SEQUESTRATION IN COMMUNITY MANAGED FORESTS

The present case study conducted in two VPs (Anriyakot and Bhatkholi) in Almora district of Uttarakhand illustrate that community forest management can be a viable strategy for reducing permanent emissions by deforestation activities. The data reveal that the mean carbon sequestration rate for India (3.7 t ha^{-1} yr^{-1}) and Nepal (1.88 t ha^{-1} yr^{-1}) are close to 2.79 t ha^{-1} yr^{-1}or 10.23 CO_2 t ha^{-1} yr^{-1} under normal management conditions (Banskota *et al.*, 2007). This is the situation when local people have extracted various forest products to meet their subsistence needs. The mean carbon sequestration rate in the present study in Anriyakot VP forest was 3.90 t ha^{-1} yr^{-1}, while in the Bhatkholi VP forest it was 3.41 t ha^{-1} yr^{-1} (Table 1). The Anriyakot VP accumulates a total of 140.87 t C and Bhatkholi VP accumulates 170.5 t C annually. Taking average price of carbon offsets as US$ 12/t the carbon stocked in Anriyakot and Bhatkholi VP forests was worth US$ 1690.44 and US$ 2046, respectively. The situation in other VPs in Uttarakhand is more or less similar. In the Himalayan region each villages have approximately 50 households. It was assumed that at least 2-5 ha of forest are required per household to meet their daily needs of fodder, fuelwood and other products. Only about 748 VPs out of 12,089 (6.19%), mostly in Chamoli, Pithoragarh and Almora, have enough forest resources to meet their household needs. Giving each VP an adequate forest area, regulations about the protection of government forests can be enforced effectively. Selling of carbon from their forests can provide a considerable income to the VPs. The inclusion of forest conservation activities in international agreements and protocols will give incentives to the local population to get certified emission reductions for their efforts to conserve the forests. This would not only provide resources for sustainable livelihoods and improved lifestyles, but also encourage the marginalized people of the region to make a meaningful contribution to reducing global emissions and forest conservation (Tewari *et al*., 2008). Carbon revenue could be an important source of income and financial incentive that will assist communities further in better conservation practices and in promoting local community development in this region.

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Carbon Stock in Oak Forests : A Pilot Study in Central Himalaya

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INTRODUCTION

Forests play an important role in regional and global carbon (C) cycles because they store large quantities of C in vegetation and soil, and are sources of atmospheric C when they are disturbed by human or natural causes (Brown *et al.,* 1996). They act as atmospheric C sinks during re-growth after disturbance, and can be managed to sequester or conserve significant quantities of C on the land (Brown *et al.,* 1996). Forests are among the most productive terrestrial ecosystems, which along with their long-lived woody character make them attractive for climate change mitigation (Nabuurs *et al.*, 2007). Globally, forests represent an important C store, containing an estimated 638 GtC in their ecosystem as a whole, with 283 GtC in biomass alone (FAO, 2005).

Carbon is stored in various pools in a forest ecosystem: above- and below-ground living biomass, including standing timber, branches, foliage and roots; and necromass, including litter, woody debris, soil organic matter and forest products (Malhi *et al.*, 2002). To accurately and precisely measure the C in forests is gaining global attention as countries seek to comply with agreements under the UN Framework Convention on Climate Change (Brown, 2002). By increasing inventories of "trapped C", C is removed from the atmosphere and not released again; forest managers may be able to help buffer the effects of C emissions elsewhere. With the intense focus on the increasing levels of atmospheric CO_2 and the potential for global climate change, there is an urgent need to assess the feasibility of managing ecosystems to sequester and store C (Johnson and Kern, 2002). If the existing C pools in different forest types can be estimated, it can be used in making decisions about C management within forests. To contribute to reduction of GHG emissions, and to partly offset

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deforestation, the Kyoto Protocol explicitly considered reforestation and afforestation activities for C sequestration accounting (IPCC, 2007). The recognized importance of forests in mitigating climate change has led countries to study their forest C budgets and initiate the assessment of enhancing and maintaining C sequestration of their forest resources. Afforestation and reforestation are seen as potentially attractive mitigation strategies, as wood production and C storage can be combined.

ROLE OF HIMALAYAN OAK FORESTS IN CARBON STORAGE

The Himalayan ecosystem services are vital for the entire globe. Forests of the Himalayan mountains comprises a critical component of the ecosystem serving as robust C sinks and conserving soil, water and biodiversity and building up a specific micro-climate contributing to cooling the globe in general, and the Himalayan region in particular. Oak (*Quercus leucotrichophora*) forests are the major climax vegetation of the mid-altitude Himalayas, and also a major source of livelihoods of the inhabiting communities (Singh and Singh, 1992). Oak forests, are rich repository of C both in vegetation biomass and soils. As the Oak forests serve as source of livelihoods, they are subjected to various kind of anthropogenic interference (e.g., extraction of fodder, fertilizing leaf litter, fuel wood and wood for agricultural implements, NTFPs etc.), which leads to significant reduction in their environmental services, including their role in C sequestration. Recurrent fire is another major disturbance that alters the structure and function of these forests considerably (Semwal and Mehta, 1996). These anthropogenic disturbances not only influence the soil, nutrient and water conditions but also influence micro-climatic conditions. In the Himalayan region, the chronic form of disturbances is unabated in which people remove the forest biomass by means of grazing, lopping, surface burning and litter removal. Biotic interference in forests has also caused remarkable changes in the vegetation and species composition (Singh, 1998). Studies are therefore required to estimate the impact of forest degradation in C stocking capacity of forests. Carbon stocking in soil of the Oak forests is still least understood across the disturbance gradient in this region.

SOIL CARBON STOCK IN OAK FOREST SOIL

A study was therefore carried out in two Oak (*Quercus leucotrichophora*) forests; one located at Bans Patan and other at Simsimani in Pithoragarh district of Kumaun Division of Central Himalaya. Both areas lie in temperate region and have almost similar physiographic and edapho-climatic conditions. The forest of Simsimani is highly disturbed, due to high grazing pressure, leaf litter collection and tree lopping for fodder. The forest at Bans Patan is virtually undisturbed and it has been protected nearly for 40 years. In these forest sites the mean monthly maximum temperature ranged from 13.0 to 23.7°C. The mean monthly minimum temperature varied between 4.9 and 16.6°C. Snowfall is frequent during the winter months (December-February). Across both the forest sites tree layer composition was computed lying quadrates of 10x10 m size randomly in October. Forest community structure was determined according to Zobel *et al.*, (1976) and Subedi *et al.*, (2010). Soil organic carbon and other physico-chemical properties were measured up to 15 cm depth following Pearson *et al.*, (2007).

Physico-chemical characteristics of soil in both the forest sites are given in Table 1. The natural forest site (Bans Patan) was better in soil moisture, organic C, N, P and K. The soil organic C stock was as much as two times greater in natural Oak forest as compared to the degraded Oak forest (23.1 vs. 11.5 t/ha). In the natural forest site Oak trees measuring up to 174 cm DBH were found whereas in the disturbed site the maximum DBH was recorded only 95 cm. In the disturbed site density of Oak trees was recorded 160 ind./ha, whereas it was about ten times more at the natural forest site. Species richness of the disturbed site (11) was markedly lower as compared to natural site (17). Carbon stocked in dead wood and stump biomass in the natural forest site was recorded 16.5 t/ha, which was absent in the degraded forest site as the dead wood is collected by the people for fuelwood and other purposes frequently. This study thus indicated that disturbance in climax Oak forests due to various anthropogenic activities substantially affects the C stocking capacity in soil and the forest floor and in turn the C sequestration in both vegetation and soil pool in the forests. Attempts are therefore required to avoid degradation of climax Oak forests of the region and allow regeneration of these forests as a climate change mitigation strategy.

Table 1: Soil physico-chemical parameters measured in two oak forests

Parameters	Disturbed Forest	Natural Forest
Moisture content (%)	6.0	12.0
pH	5.44	5.93
Total Nitrogen (%)	0.14	0.98
Organic Carbon (%)	1.314	1.820
Phosphorus (kg/ha)	15.13	22.41
Potassium (kg/ha)	172.48	201.6

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A Note on CO_2 Mitigation Potential of Himalayan Forest Ecosystems

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INTRODUCTION

Man is accelerating the rate of increase in atmospheric CO_2 concentration through fossil fuel burning, land-use changes and agricultural activities, raising the problem of global warming (Upadhyay *et al.*, 2005). In the last 100 years, the mean surface temperature has risen by 0.4-0.8ºC globally due to 29% rise in CO_2 concentration (Lal, 1999; IPCC, 2001). Already documented increase in global mean temperature by 0.74°C is an alarming situation, and hence climate scientists are focusing on an urgent action to curb global warming (IPCC, 2007; Kerr, 2007). Indian Himalayan region is also experiencing rise in atmospheric temperature. According to a study, the average temperature has increased by 0.6^{0}C over the period 1960–2000 in the high altitudes of Uttarakhand (Singh *et al.*, 2010). The intense warming may have deleterious effects on the Himalayan environment in the form of rapid retreat of Himalayan glaciers and diminishing snow fields (Dyurgerov and Meier, 2005; Singh *et al.*, 2010). This rise in temperature may affect the permafrost layer in the Himalayas and can also have impacts on slope stability, erosion processes, hydrology and the ecology, with succeeding implications for people depending on these areas for their livelihoods (Eriksson *et al.*, 2009). Deforestation and forest degradation alone gives rise to 17.4% of the world's greenhouse gas emissions (Subedi *et al.*, 2010). There is more alarming situation in tropical and subtropical forests where carbon stocks are decreasing at a frightening rate of 1-2 billion tons a year (Subedi *et al.*, 2010). Since the livelihood of poor and socially marginalized people is wholly or partially dependent on the forests in this region, therefore some initiatives in forest conservation and enhancement can help to address this situation.

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IMPACT OF CLIMATE CHANGE ON FOREST ECOSYSTEMS

It has been projected by a few workers that in the face of climate change shifts in forest boundaries by latitude and upward movement of tree lines to higher elevations; changes in species' composition and vegetation types; and an increase in net primary productivity would happen (Ramakrishna *et al.*, 2003; Xu *et al.*, 2007). Alpine plant species on mountain ranges with restricted habitat availability above the tree line will experience severe fragmentation, increased soil erosion, habitat loss, or even extinction if they do not move to higher elevations, particularly after an increase of 2ºC (Dirnbock *et al.*, 2003; Xu *et al.*, 2007). According to Cannone *et al.*, (2007), climate change is very rapidly affecting the alpine vegetation of Indian Himalaya. Alpine areas are particularly vulnerable to hydrological disturbances. Because of enhanced hydrological cycles (due to the rapid snow melt and more precipitation) and resultant increased surface instability and disturbance, unexpected changes in vegetation may occur. Change in temperature will narrow down seasonal temperature variation in Himalayas within an annual cycle. This will result in fall in the number of species of deciduous forests (which need a proper seasonal temperature to shed and regain leaves), and will promote only evergreen forests resulting in the loss of biodiversity (Singh *et al.*, 2010).

MITIGATION STRATEGY - CARBON SEQUESTRATION

Carbon sequestration refers to the long-term storage of carbon in the terrestrial biosphere so that the buildup of CO_2 in the atmosphere will be reduced or slowed down in order to improve environmental conditions and check the processes of environmental degradation (Yadava, 2011). A great significance of forests lies in regional and global C cycles because they store large quantities of C in vegetation and soil; exchange C with the atmosphere through photosynthesis and respiration; are sources of atmospheric C when they are disturbed by human or natural causes; become atmospheric C sinks during re-growth after disturbance; and can be managed to sequester or conserve significant quantities of C on the land (Brown *et al.*, 1996). In the context of climate change, forest ecosystems are of worth consideration because they can act as sources as well as sinks of CO_2, the most copious greenhouse gas (Haripriya, 2002). According to Ravindranath *et al.*, (2008), the amount of carbon stock in Indian forests in both soil and vegetation ranges from 8.58 to 9.57 Gt C.

ROLE OF HIMALAYAN FOREST ECOSYSTEMS IN CARBON SEQUESTRATION

Forest sinks represent easier solution to the stocking of the atmospheric carbon. Ecosystems services of Himalayan forests, such as carbon sequestration and hydrologic regulation are considered far more than the value of biomass extracted from them (Singh, 2002). Carbon sequestration in relatively undisturbed forests in Uttarakhand, such as sal (*Shorea robusta*), pine (*Pinus roxburghii*) and oak (*Quercus* spp.) forests, generally ranges between 4.0-5.6 t C ha^{-1} yr^{-1} (Singh, 2007), which is close to values reported for tropical forests. Annually, the amount of carbon accumulated in total forest biomass in the Uttarakhand state is approximately 6.61 mt, valuing Rs. 3.82 billion at the rate of US$ 13 per t carbon (Singh, 2002). Soil carbon pool on deep soil sites is as large as the biomass carbon pool, but it is quite tough to estimate the rate of sequestration in the deep soil. However, loss of soil carbon following the cutting of forests can be considerable in Himalaya because of immature topography, steep slopes and high geological activity. According to a preliminary study carried out in Lamgarha block of Almora District, forest degradation can lead to soil loss at the rate of up to 3 t C ha^{-1} yr^{-1} (Singh, 2007).

In the Indian Himalayan region, it is estimated that forests accumulate about 65 mt carbon annually in aboveground biomass alone, which is estimated as US$ 843 million or Rs. 37.5 billion (Singh, 2007). Rough estimate of total carbon pool (forest biomass + soil) in the entire forest area of Indian Himalaya is about 5.4 billion t C (Singh, 2007). These are the values which are approached only by old growth forest stands, which still remain in remote mountain areas. There is high opportunity for enhancing the potential of Himalayan region to store carbon, in vegetation and also through improved management of degraded lands (Upadhyay *et al*., 2005), and old growth forests should be valued from this standpoint, apart from their importance for biodiversity. Case study in well managed community forests have shown that 3.7 t C/ha is stocked annually (Singh *et al.*, 2010). C stock estimation in western Himalayan forests has also been undertaken recently (Sharma *et al.*, 2011).

CONCLUSION

Himalayas are home of rich biodiversity which strongly need attention. Climate change is posing a challenge before us both at local and global level. Especially when we talk about Himalayan region, the problem is more severe because impacts are rapid and irreversible. With increasing magnitude of climate change, the need for planned adaptation becomes more acute. There is a strong need of adequate information on the status of biodiversity, trends in environmental change including climate change, and its potential impacts on biodiversity, human resources, expertise, institutional capacity, political commitments and the financial resources for planned adaptation measurement. Some important information on climatic parameters, physical and biological conditions, and socio-cultural and livelihoods situations in the Himalayas is necessary for generating consistent representative data. The information generated then could be used for sustainable development and for responding to climate change impacts (Xu *et al.*, 2007; Eriksson *et al.*, 2009).

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Sustaining Himalayan Ecosystems : Adaptation and Mitigation Actions for Climate Change

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INTRODUCTION

Extending for about 2500 km from east to west, Himalayan arc covers more than 10^0 of latitudinal expanse (between 27 and 38^0 N latitude). This youngest and fragile mountain system on the earth has direct influence on climate, regional hydrology and environment of Indian subcontinent. Altitude varies considerably and locally exceeding 5000 - 6000 m asl resulting in highly diverse ecological conditions. Himalaya is a geodynamically unstable mountain chain with youthful topography. The Himalayan ranges have not only contributed to monsoonal pattern of rainfall, they also have extended profound influence on other climatic patterns and biogeography of the continent. It has been reported that in the least disturbed Himalayan forests carbon sequestration rates in total biomass range between 4.0 and 5.6 t C $ha^{-1}yr^{-1}$, and the Indian Himalayan forests sequester about 65 million t of carbon annually in above ground biomass alone (Singh, 2007).

PROJECTED TEMPERATURE AND RAINFALL IN HIMALAYAN REGION

Climatologically, the entire Indian region is divided into the western Himalayas, north-west, north-east, northern-central region, eastern coast, western coast, and the interior plateau. Climate change information obtained from PRECIS driven by IPCC A1B scenario the Ministry of Environment & Forests (2010) has projected that the annual rainfall in the Himalayan region is likely to vary between 1268±225.2 and 1604±175.2 mm in 2030s. The projected precipitation is likely to increase by 5% to 13% in 2030s with respect to 1970s. The number of rainy days in the Himalayan region may increase by 5–10 days on an average in the 2030s. In the eastern part of the Jammu and Kashmir this increase will be more than 15 days. The intensity of rainfall is likely to increase

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by 1–2 mm day^{-1}. The mean annual temperature in the Himalayan region is projected to increase from 0.9±0.6^{o} C to 2.6±0.7^{o} C in the 2030s. Temperature will also show a rise in all seasons. The analysis of the model runs indicate that both the daily extremes in surface air temperature, that is, daily maximum and daily minimum may intensify in the 2030s. In the Himalayan region, minimum temperatures are projected to rise by 1^{0} C to 4.5^{0} C, and the maximum temperatures may rise by 0.5^{0} C to 2.5^{0} C.

EXPECTED IMPACT OF CLIMATE CHANGE IN THE MOUNTAIN ECOSYSTEMS

Ecologically sensitive mountainous areas like the Himalaya are prone to adverse impacts of global climate changes on account of both natural causes and anthropogenic emissions across the globe as well as those arising out of unplanned developmental activities in the region. Himalayan ecosystem resources are critical on the face of natural disturbances, anthropogenic activities and climate change (DST, 2010). The upper limit of forest growth in Central Himalaya generally stretches between 3000 and 3500 m asl. As a consequence of change in temperature and rainfall pattern, the ranges of both animal and plant species will change. As the earth warms, the species tend to shift their distribution towards higher latitudes and altitudes. For each 1^{0} C of warming tree ranges in the northern hemisphere have the potential to expand 100 km northwards while southern boundaries retreat. This is a process which has been tracked since ice age. With current level of increase in mean annual temperature over various parts of the Himalaya, an upward movement of plants is expected (Grabherr *et al.*, 1994; Pauli *et al.*, 2001). Research carried out elsewhere have shown that the community composition has changed at high alpine sites, and tree line species have responded to climate warming by invasion of the alpine zone or increased growth rates during the last decades (Paulsen *et al.*, 2000). The study by Borgaonkar *et al*., (2010) has reported an unprecedented enhancement in growth during the last few decades in the five tree-ring width chronologies of Himalayan conifers (*Cedrus deodara* D.Don; *Picea smithiana* Boiss) from the high altitude areas of Kinnaur (Himachal Pradesh) and Gangotri (Uttarakhand) regions. Change in plant phenology may be one of the earliest observed responses to rapid global climate change and could potentially have serious consequences for the plants and animals that depend on periodically available forest resources. The phenology and development of most organisms generally follow a timescale, which is temperature dependent (Allen, 1976). Species in some ecosystems are so strongly adapted to the long-prevailing climatic pattern that these are vulnerable even to modest changes. Little is known about the reproductive cycle and ecological factors necessary for flowering and reproduction in individual species. Increase in the level of carbon dioxide in the atmosphere and consequent global warming may also have a profound effect on the flowering time of plants.

Indications of climate change have already begun to appear in the Indian Himalayan Region (IHR) in the form of shift in the arrival of monsoon, long winter dry spells (5 - 6 months as experienced in 2008–09), increased frequency of forest fires during winter, the early flowering/fruiting of native trees, such as *Rhododendron* spp. and *Myrica esculenta*, etc. One systematic study, which deals with the impact of climate change on the phenophases of 11 multipurpose tree species (viz., *Grewia optiva*, *Morus alba*, *Bauhinia variegata*, *Robinia pseudoacacia*, *Melia azedarach*, *Dalbergia sisoo*, *Toona ciliata*, *Celtis australis*, *Gmelina arborea*, *Sapindus mukurosii* and *Albizia stipulata*), pertaining to Himachal Pardesh (western Himalayas) concluded that the substantial shift in critical phenophases, including leaf emergence, flower initiation and growth period in a span of eight years seems to be associated with climate change, and there is every reason to believe that advancement in phenophases of these tree species might be the result of climate change at the regional level (MoEF, 2010). Future shifts in the natural ranges of trees and forest communities could have both positive and negative effect on goods and services provided by the forests. Because of their mobility, animals are generally at less risk as they are able to disperse to habitats which are more favourable. Plants on other hand are stationary and must rely on dispersal of seeds from areas, which are no longer favourable to new areas resulting in gradual shift in their new ranges (Singh *et al*., 2010). As per the recent study of MoEF (2010), the IBIS model was used for assessing changes in vegetation and net primary productivity in forests in the 2030s. The Himalayan region considered in the study includes the states of Jammu and Kashmir, Uttarakhand and Himachal Pradesh. Of the 98 IBIS grids covering this region, 56% of the grids are projected to undergo change in the 2030s. The net primary productivity is projected to increase in the region by about 57% on an average by the 2030s.

IMPACT ON NATURAL ECOSYSTEMS AND BIODIVERSITY

There is now a growing realization that conservation and rational use of biodiversity in the Himalayan region could bring enormous economic benefits to the inhabitants and contribute to the sustainable development of region. More than 80% of the population in the region is involved in agriculture, animal husbandry, forestry and other biodiversity dependent vocations. There is need to identify the climatic amplitude of the species that are of economic interest and are classified as rare and threatened growing in the Himalayan region, and conserving them in the protected areas with larger climatic amplitude so that species are able to shift their distribution ranges naturally in the event of changing climate (DST, 2010).

The IPCC Third Assessment Report (TAR) (IPCC, 2001), identified mountain regions as having experienced above-average warming in the 20th century, a trend likely to continue. Related impacts included an earlier and shortened snow-melt period, with rapid water release and downstream floods which, in combination with reduced glacier extent, could cause water shortage during the growing season. The TAR suggested that these impacts may be exacerbated by ecosystem degradation, pressures such as land-use changes, over-grazing, trampling, pollution, vegetation destabilization and soil losses, in particular in highly diverse regions such as the Caucasus and Himalayas. Upper tree lines, which represent the interface between sub-alpine forests and low-stature alpine meadows, have long been thought to be partly controlled by carbon balance. In many mountains, the upper tree line is located below its potential climatic position because of grazing, or disturbances such as wind or fire. In other regions such as the Himalaya, deforestation of past decades has transformed much of the environment and has led to fragmented ecosystems. Although temperature control may be a dominant determinant of geographical range, tree species may be unable to migrate and keep pace with changing temperature zones (Singh *et al.*, 2010).

SUSTAINABLE FORESTRY IN HIMALAYA

Sustainable forestry in the Himalayan region has been identified as a part of desirable adaptation policies to improve regional sustainability in the National Mission for ‘Sustaining the Himalayan Ecosystems’, one of the eight missions under Prime Minister’s National Action Plan on Climate Change. It calls for a combination of both standard silvicultural knowledge and involvement of communities with traditional ecological knowledge available in the realm of forest management. It is known that introduction of socially valued species with ecological keystone value, along with socially valued ecosystems (e.g. sacred groves) and socially valued cultural landscapes for implementation of JFM has facilitated biodiversity conservation linked sustainable forestry practices in certain parts of the ecosystem. Further extension of such traditional practices of forest management to larger parts of the Himalaya will be explored under the Mission (DST, 2010).

REDD + INCENTIVES FOR COMMUNITY FOREST MANAGEMENT IN HIMALAYA

Reducing emissions from deforestation and forest degradation (REDD+) in developing countries and role of conservation (collectively known as REDD+) under UNFCCC is a process to pass financial incentives to the communities for halting deforestation and encourage forest conservation thereby enhancing forest carbon stocks. Forest dwelling communities in India have been successful in transforming the deteriorating state of their natural forests to sustainable management, thereby avoiding deforestation and the subsequent release of CO_2 emissions into the atmosphere. Government of India while submitting it view on implementing REDD+ opined that REDD plus in India will be taken at locations that cover different forest types and socio-geographic regions of the country (UNFCCC, 2011). For example, projects in conservation can be taken up in western Himalayan region comprising states of Uttarakhand, Himachal Pradesh and Jammu and Kashmir. In Uttarakhand there are 5,449.6 sq km forests (15.73% of total forest cover) under Van Panchayats (Uttarakhand Forest Deptt. 2010). There is excellent scope and opportunity for integrating the REDD+ initiative within the community controlled/managed forest and JFM activities. For this purpose, methodologies and modalities for a procedural framework will need to be worked out to ensure people's participation and sharing of the benefits accruing from REDD plus incentives. REDD+ programmes in Himalayas have the potential to contribute towards adaptation to climate change for forests and communities as well. A well designed REDD+ project could also lead to a substantial climate change mitigation opportunities in the Himalayan region.

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Markets for Ecosystem Services: Operationalizing REDD+ in Uttarakhand

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INTRODUCTION

Reduced Emissions from Deforestation and Forest Degradation (REDD+) is an innovative attempt to compensate developing nations to curb greenhouse gas (GHGs) emissions from deforestation and forest degradation activities. The concept has found a lot of momentum in countries in Africa and Latin America. In Asia, the same can be said about Indonesia, Lao PDR, Nepal and Vietnam which have demonstrated significant advances on this front. The excitement surrounding REDD+ in India was echoed with the Ministry of Environment and Forests releasing its publication "India's Forest's and REDD+" in May, 2011 highlighting the implications of REDD+ for India. This article presents the findings of a scoping study conducted in and around the Toli village within the Lamgara block in the Almora district of Uttarakhand Himalaya on how REDD+ can be used to address forest degradation. It comes at a time when carbon forestry is increasingly being viewed as a viable livelihood option for communities living in tropical/semi tropical areas. The study approaches REDD+ from a community forestry perspective and tries to build on to the current available discourse on the subject. It ends with a critique and commentary of market mechanisms in nature conservation and presents a set of recommendations on how the implementation of REDD+ can take place in Uttarakhand. If climate change due to an increase in CO_2 levels is a recognized problem than forests could provide the most practical and cost-effective solution by sequestering that CO_2. There have been several attempts to study the amount of CO_2 released into the atmosphere as a result of deforestation and forest degradation and different numbers have been put on the table vis-à-vis 20% (IPCC, 2007); 25% (FAO, 2005) and 12% (Werf *et al.*, 2009) which makes it extremely crucial that we manage our forest resources sustainably. "REDD is a mechanism to create an incentive for developing countries to protect, better

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manage and wisely use their forest resources, contributing to the global fight against climate change...” (www.unredd.org). It works by making forests more valuable when they are standing rather than being cut down by creating a financial value of the carbon stored in the trees. It has been estimated that a REDD+ programme for India could provide a basis to capture more than 1 billion tonnes of CO_2 over the next three decades and provide over USD 3 billion as carbon service incentives (Kishwan and Pande, 2011). The incentives received from REDD+ would be passed on to the local communities involved in the protection and management of forests which in turn will ensure sustained protection of the forests against deforestation. REDD+ is also expected to have a net positive impact on local communities, tribal communities and forest dwellers as implementation will result in creation of livelihoods and also help remove social inequality.

Forest disturbances have been broadly classified into “common type” and “chronic type” (Singh, 1998). The common forms of acute forest disturbance involve selective logging or clear-cutting, which allows the forest to regenerate by natural means. On the other hand, the chronic form of disturbance, which is subtle and slowly creeping, but equally destructive, is a much less-recognized problem (Singh, 1998). Environmental degradation caused by chronic human disturbance is often discontinuous and non-linear, like the sudden change of state of liquid from water to stream (Myers, 1995). Some of the direct causes of forest degradation in the Himalayas have been attributed to disturbances in the undergrowth through removal of leaf litter (used as compost fertilizer); low-intensity fires both accidental and intentional; soil compaction by grazing cattle and damage to tree seedlings through grazing (CEDAR, 2011).

THE TOLI VILLAGE AGRO-ECOSYSTEM

Geographically, Toli village belongs to the Lamgara block in the Almora district, Uttarakhand state in India. Uttarakhand is a state in the Northern part of India, covering an area of 53,566 km^2, 93% of which is mountainous with most of the Northern parts of the state belonging to the Greater Himalaya mountain ranges (Government of Uttarakhand, 2010). More than 60% of the land is covered with forests and it is home to more than 1 million people (Government of Uttarakhand, 2010). Poor mountain farmers with average landholdings well below 1 hectare per household are highly dependent on forest resources for subsistence living (Singh *et al.,* 2011). The Toli village agro-ecosystem is an area which has seen a lot of disturbances over the past few years. Although degradation emerges as the most obvious issue in the area (ICIMOD, 2010), problems of landslides, decreasing agricultural productivity and the drudgery of the women folk cannot be ignored as they seem to be interrelated. Studies conducted by Central Himalayan Environment Association (CHEA), Nainital and International Centre for Integrated Mountain Development (ICIMOD), Nepal show that forest degradation is common in van panchayats (VPs) where the average VP area per household is less than 1.5 hectare (ICIMOD, 2010). In the case of Toli village it works out to be 0.53 hectares per household. The report also estimates that 0.8 hectares of VP forest land in Toli village is already under degradation (ICIMOD, 2010). However, if the minimum area required for sustainable use of forests is 1.5 hectares per household (ICIMOD, 2010), than the future of this forest does not look very encouraging. Furthermore, there are other studies which estimate an area between 3 ha – 5 ha is required per household for sustainable management of forest resources (Bisht, 2005). Transect walks across the Toli village and data collected during PRA exercises have highlighted other additional disturbances such as increase in the number of landslides and damage to property which are most likely fallout of the poor quality of forests. These viewpoints are based on similar studies carried out elsewhere, visual experiences and from discussions held with the community. However, detailed hydrological studies would have to be conducted in the area to further verify these claims.

METHODOLOGY

Research began by interaction with G.B. Pant Institute of Himalayan Environment and Development (GBPIHED), Almora and CHEA, Nainital. Project details were obtained on the village panchayat's of Lamgara block in Uttarakhand and the Kyoto Think Global Act Local Project (ICIMOD, 2010). In order to identify the problem of forest degradation, an analysis of secondary literature was used (ICIMOD, 2010; CHEA, 2011). For the use of the most appropriate strategy and method to estimate project level REDD+ carbon benefits which forms a part of the analysis, the decision tree to identify the REDD+ project types available in 'Standards and methods available for estimating project-level REDD+ carbon benefits: reference guide for project developers' was used (Estrada, 2011). However, before moving on further, it became essential to obtain the free prior and informed consent (FPIC) of the communities involved in the research as advocated by the United Nations. Interactive steps for a REDD+ process to respect the rights of communities to FPIC was used as described in Anderson (2011). The voluntary carbon standard (VCS) was used for analyzing the different aspects of project development, e.g., estimating baselines, leakage, etc., and the VCS programme establishes different verification requirements for projects according to their sizes and was initiated by the Climate Group, the International Emissions Trading Association and the World Economic Forum in 2005.

Data was collected using qualitative and quantitative methods. Participatory Rural Appraisal (Chambers, 1994), and focused group discussions were used to collect qualitative data while quantitative data was collected using household surveys to map the communities dependence on biomass from the village forest. Google Earth was used for obtaining aerial views of the van panchayat forest. The analysis of data has been done in three parts namely, the free and prior consent of the communities to go ahead with this sort of a carbon forestry project (REDD+); mapping the carbon inflow from the VP forest into the community and how this dependence can be reduced using alternative methods such as bio gas and pine briquetting etc. to meet local demands.

FINDINGS AND ANALYSIS

After an analysis of the data collected during PRA exercises, it was evident that the community as a whole was willing to participate in a REDD+ project. Although, there were certain doubts and differences, as a whole the community's stand was positive and enthusiastic towards implementation of a REDD+ project in the van panchayat forest. The household surveys were helpful in giving a better understanding of the carbon inflow into the Toli village forest (annually estimated at 973 tonnes of carbon is required annually in the form of pine needles, fuel wood and fodder). The focused group discussions helped to explore means and ways in which the community's dependence on carbon from forests could be reduced. Some of the alternative methods discussed were biogas units and pine briquettees to meet cooking needs; regulated grazing; high quality fodder grass; social fencing and tree plantation activities. Installation of five biogas units in adjoining villages having the same climate and topography have demonstrated an ability to provide eco-friendly gas for 60–90 minutes/day/family thus reducing fuel wood extraction by 15-20 kg/day (CHEA, 2011). Using the same logic, twenty biogas units in a village of 202 families as in the case of Toli have the potential to reduce 140 tonnes of CO_2 annually. When the data was collected and analyzed following Estrada (2011) against the different criteria of a REDD+ project, it was observed that project seems to comfortably meet four of the nine criteria of REDD+ and requires more work on four of the other criteria as illustrated in the Table 1 below. The only criterion the project doesn't meet is that of co-benefits and adaptation as this criterion is not required under the VCS system of crediting.

CRITIQUE AND COMMENTARY

In their seminal essay, "Payments for Ecosystem Services and the Challenges for Saving Nature" (Redford and Adams, 2009) highlight some important issues related with novel approaches to conservation such as PES and REDD+. They are skeptical about the fact that economic arguments about the services valued by humans will overwrite and outweigh non economic justifications for conservation in a world where there is a relentless pursuit of economic logic. They argue for multiple approaches to conservation over singular ones as being more resilient and persuasive (Redford and Adams, 2009). They go on to highlight the problems associated with the valuation of ecosystem services as markets exist only for a range of ecosystem services (e.g., carbon sequestration, watershed services etc.) which means that services for which there are no markets or those which cannot be valued would be neglected. There are also some unanswered design issues for REDD+ which need to be addressed. The REDD+ text in the Cancun Agreement fall short on several aspects which need to be addressed before REDD+ can be supported by member countries. To begin with, there is no universally agreed definition of some of the key terms and other activities included under the REDD+ framework. The term "forest degradation" has not yet been defined. Other crucial concepts to operationalizing of REDD+ such as "sustainable management of forests" and "conservation" also remain undefined (Austin *et al.*, 2010). There also seems to be a lack of guidance with regards to setting of reference levels for countries in the Cancun Agreements (Austin *et al.*, 2010), and a big question mark on the issue of financing the REDD+ activities amongst the developed countries as no consensus on the same has been reached at as yet. The reasons being attributed to this disagreement are the outstanding methodological questions about what the "result-based" approach would include (Austin *et al.*, 2010).

Table 1: Summary of the different REDD+ criteria and to what extent they are met vis-à-vis the Toli village VP

S. No.	Criteria	Meets criterion	Needs more work	Doesn't meet criterion
1	Estimating baselines	√		
2	Additionality		√	
3	Estimating project emissions	√		
4	Leakage		√	
5	Monitoring	√		
6	Addressing non-permanence		√	
7	Estimating net carbon benefits	√		
8	Dealing with uncertainty		√	
9	Co-benefits and adaptation			√

CONCLUSION AND RECOMMENDATIONS

The study validates the sound reasons to undertake Carbon Forestry projects such as REDD+ in the Toli village community forest for not only addressing the issue of forest degradation but also to promote sustainable development in the village. From analysis of data on the different REDD+ criteria, one can conclude that REDD+ has the potential of being successfully implemented in the Toli VP forest barring a few constraints which will be highlighted hereafter. Some of the strengths of the project can be attributed to a strong political will to implement REDD+ in the country; availability of data and a willing and active community. On the other hand weaknesses include lack of practical experience in the area and the small scale of the project.

After having looked at both sides of the debate and in lieu of the prevailing socio-ecological climate in India, a set of recommendations can be put forth which would better facilitate the implementation of REDD+ not only for the Toli VP but also for other such projects to follow in India. A bottom-up approach can play a very important role in determining the success of the project since the community forms an integral part of project implementation. There is also a need to create a sense of ownership amongst all stakeholders; streamline governance and minimize delays in order to ensure smooth implementation of REDD+.

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Climate Change Database, Kullu Valley, Himachal Pradesh

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INTRODUCTION

Himachal Pradesh is well known for its unique topography, large altitudinal range (200-7,000 m), unique climatic conditions and diverse habitats. The state is blessed with abundant water resources in its five major rivers i.e., Chenab, Ravi, Beas, Satluj and Yamuna, which emanate from the Western Himalaya and flow through the State. These snow fed rivers and their tributaries carry copious discharge throughout the year and flow with steep bed-slopes, which can be exploited for power generation. The State is well known for representative, natural, unique and socio-economically important biodiversity. It supports over 3,200 species of Angiosperms, 643 species of medicinal plants (Samant *et al.*, 2007) and over 300 species of wild edibles (Samant and Dhar, 1997). The land use pattern showed that nearly one fourth of the total geographical area (i.e., 55,673 km^2) of the State is under wasteland, permanent pastures cover 20.7%, barren land, 3.5% and un-cultivable agricultural land, 2.1% (Source: Statistical Hand Books, Shimla). The biodiversity rich areas of the State have been declared as Biosphere Reserve, National Parks and Wildlife Sanctuaries for the conservation of ecosystem, habitats and species (Gulati *et al.*, 2004). Apart from rich biodiversity, the State is also rich in horticultural and agricultural crops, traditions and cultural heritage. Most population of the State lives in the rural areas and largely dependent on forest resources for medicine, wild edibles, fuel, fodder, timber, house building, making agricultural tools, religious and various other purposes. Due to over exploitation and habitat degradation the economically important resources are decreasing fast. Further, population explosion, urbanization, forest degradation, construction of roads and hydro-electric projects, industrialization, forest fire and biomass burning, tourism beyond carrying capacity, etc. have caused a great threat to the environment. These factors are the major contributors

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towards climate change locally. Therefore, there is a need to: (i) collect weather data from different sources; and (ii) analyze and synthesize weather data for understanding the climate change. In the present study, weather data (i.e., temperature, relative humidity and rainfall) for Manali (1980 m asl), Bhunter (1100 m asl) and Larji (957 m asl) stations of Kullu valley for the period of 1986-2005 have been collected from the office of Bhakhara Beas Management Board, Mandi (H.P.) and analyzed.

TEMPERATURE

Analysis of meteorological data indicated that at Manali, maximum temperature i.e., 36°C was recorded during 1994 and minimum temperature i.e., -9°C during 1989 (Fig. 1). At Bhunter, maximum temperature i.e., 40°C was recorded during 1988 and minimum temperature i.e., -3.4°C during 1992 (Fig. 2). At Larji, maximum temperature i.e., 46°C was recorded during 1995 and minimum temperature i.e., -4°C during 1996 (Fig. 3). In general, during 1986-2005 mean annual temperature varied across all the stations and from one year to other.

Fig. 1: Temperature at Manali during 1986-2005

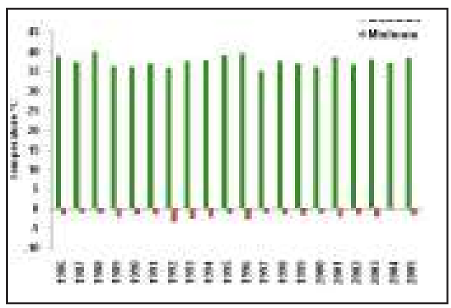

Fig. 2: Temperature at Bhunter during 1986-2005

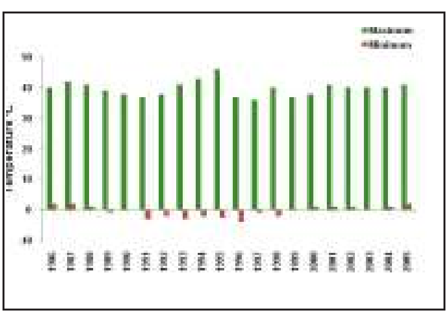

Fig. 3: Temperature at Larji during 1986-2005

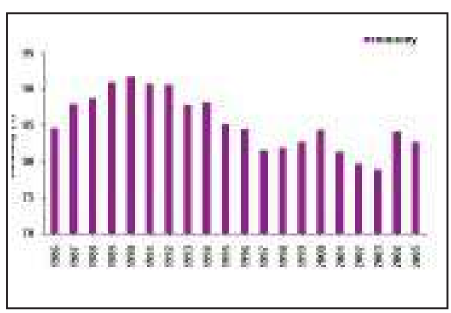

Fig. 4: Humidity (%) at Manali during 1986-2005

RELATIVE HUMIDITY

At Manali, relative humidity was maximum (91.6%) during 1990 and minimum (78.8%) during 2003 (Fig. 4). At Bhunter, relative humidity (83.8%) was maximum during 1998 and minimum (77.9%) during 1991 (Fig. 5). At Larji, relative humidity was maximum (93.3%) during 2004 and minimum (79.0%) during 1987 (Fig. 6). In general, during 1986-2005 relative humidity varied across all the locations and from one year to other.

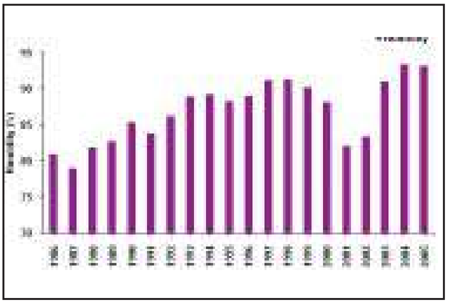

Fig. 5: Humidity (%) at Bhunter during 1986-2005

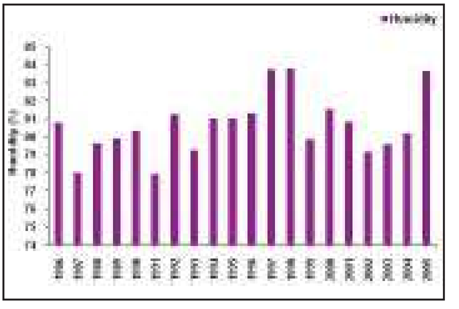

Fig. 6: Humidity (%) at Larji during 1989-2005

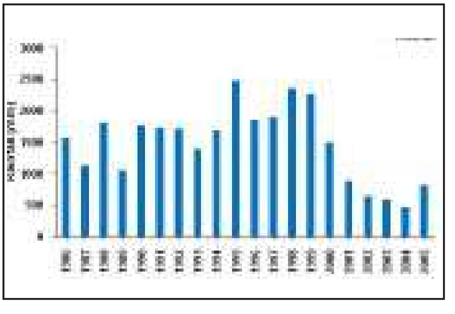

Fig. 7: Rainfall at Manali during 1986-2005

Fig. 8: Rainfall at Bhunter during 1986-2005

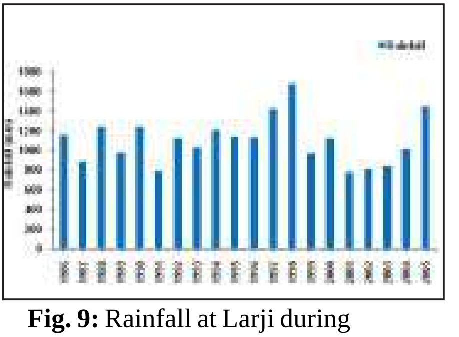

Fig. 9: Rainfall at Larji during 1986-2005

RAINFALL

At Manali, rainfall was maximum (2479.6 mm) during 1995 and minimum (239.4 mm) during 2004 (Fig. 7). At Bhunter, rainfall was maximum (1376 mm) during 1988 and minimum (756 mm) during 2000 (Fig. 8). At Larji, rainfall was maximum (1677.1 mm) during 1998 and minimum (776.7 mm) during 2001 (Fig. 9). In general, during 1986-2005, in all the sites, there was not a definite pattern of rainfall was found.

The data on temperature, relative humidity and rainfall indicate that there is no any definite pattern; it fluctuates from one year to another. This fluctuation in weather conditions may cause changes in vegetation patterns, natural resources and overall environment. From the present study, it is clear that there is a need to monitor weather data regularly and correlate it with the adaptation strategy of the local inhabitants and changing patterns of vegetation, which play an important role in governing the local environment. This study will help in making adequate planning for the environmental management of the Kullu valley.

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Resource Utilization by the Local Communities Around a Protected Forest in Western Himalaya

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INTRODUCTION

Dependence of human beings on natural resources is a common feature among tropical third world countries, especially in the absence of other resources (Mac Halis and Tichnell, 1985; Kothari *et al*., 1989). In case of most of the Himalayan districts of Garhwal and Kumaun region, where forest biomass is the major source of energy, livelihood of the people is closely driven by the forest resources. The total 51 million population (6% of India's population) of the Indian Himalayan region largely lives in rural areas where their livelihood mostly depends upon the natural resources available in the nearby areas (Badola and Hussain, 2003). The ecosystems in Himalayan region are very fragile and subsistence agriculture is the backbone of local people (Tiwari, 2003). Extraction of fodder from forests is very high (62%) compared to extraction from agro forestry system and low altitude grassland and crop residues (38%) (Singh and Pande, 1988). The per capita annual consumption of dry wood in various parts of Himalaya has been reported to be much higher, ranging between 500 and 1200 Kg (Campbell and Bhattarai, 1984; Metz, 1990). Similarly, fodder harvests from forests of Himalaya ranges from 2273 to 4294 Kg capita^{-1} year^{-1} (Metz, 1990); however, the reports on fodder use are fragmentary (Purohit and Samant, 1995). Protected areas in this region are also characterized by use of forest resources by human settlements in fringes (Kothari *et al.*, 1989). They are subjected to pressure from human population for grazing, cutting trees for firewood and timber, extraction of non timber forest products, hunting, etc. Therefore, attempts to protect the forest resources from the people towards wildlife management sometimes lead to conflicts (Nandkarni, 2001). Therefore,

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assessment of pressure on the protected areas from the fringe population is essential that help in identification of alternate sources of energy, predict the availability and consumption pattern and project the rate of exploitation of natural resources so that management measures are able to address micro level problems and implement corrective measures effectively.

This study deals with Askot Wildlife Sanctuary (lies between 20^0 46' 45" – 30^0 27' 45" N lat. and 80^0 01' 53" – 81^0 01' 53" E long.) situated in north of the district Pithoragarh in Uttarakhand state covering an area of approximately 600 km^2 with a wide altitudinal range (600-6905 m asl). A population of about 58,967 people spread in 109 villages live within the sanctuary (Samant *et al.*, 1999). The different communities living in the area belong to schedule caste, schedule tribes (Rajees and Bhotia), Brahmins and Rajputs. They are largely dependent upon the natural forests available in the sanctuary for fuel, fodder and other resources. Previous studies carried out in Askot Wild Life Sanctuary document biota and related aspects of resource (mainly fuel wood and fodder) use (Samant, 1995; Dhar *et al.*, 1997). This study was undertaken to look into the forest resources and their utilization pattern during 2009-10.

METHODOLOGY

Resource use sampling was conducted during March 2009 to March 2010 among Dyakot, Baikot, Saldhar and Banani villages falling between (900 and 2050 m asl) in the Askot Wildlife Sanctuary to quantify and identify the fuel, fodder and other resources. Sampling was conducted with 5 samples (bundles) randomly selected each day in each site for four days per month. Each sample was weighed with the help of a spring balance. Plant species collected were identified with the help of local people and literature surveys (Samant *et al.*, 1999). In addition, informal interviews were held with the heads of families in each of the four villages. Informal interviews involved an open ended questionnaire on quality, quantity and frequency of resource extraction, economic status, family size, cattle population and grazing activities, human and wildlife conflicts, etc. Data thus collected were analyzed as follows:

Mean collection (Kg) of the fodder/fuelwood species: (A) = T/N

Where, T = Total collection in all samples, and N =Number of species

$$\text{Mean collection sample}^{-1}\ \text{day}^{-1}\ (Cs): = \sum_{i=1}^{n=4} /TRPi$$

Where, A = Mean collection of species, and TRPi = total population for collection sample^{-1} day^{-1}

Mean collection household^{-1} day^{-1} (C_d) = 2Cs; Where Cs = mean collection sample^{-1} day^{-1}

Mean collection household^{-1} year^{-1} (Cy) = 120 C_d or Cy = 90 C_d

Where, 90/120 was the total collection days /year, and C_d = mean collection household $^{-1}$ day^{-1}

$$\text{Probability of use PU:} = \sum_{i=1}^{n=4} FiPi / \sum_{i=1}^{n=4} Pi$$

Where, Fi = frequency of collection of a species in the ith village,

and Pi = population of the ith village

Resource use index: RUI= Cy PU; Where, Cy = Mean collection household $^{-1}$ year^{-1}

RESULTS AND DISCUSSION

Fuel Wood Species and Utilization Patterns

Table 1 lists various tree species present across the four study sites. The important fuel species recorded from different sites included: *Pinus roxburghii, Macaranga postulata, Alnus nepalensis* and *Woodfordia fruticosa* at site 1 (Dyakot); *P. roxburghii, Engelhardtia spicata, A. nepalensis, Lyonia ovalifolia* and *Myrica esculenta* at site 2 (Baikot)*; P. roxburghii, E. spicata, M. postulata, Shorea robusta* and *Toona ciliata* at site 3 (Saldhar); and *Quercus lanuginosa, Q.leucotrichophora* and *Rhododendron arboreum* at site 4 (Banani).

Probability of use of fuel species was highest for *P. roxburghii* (3.10), followed by *M. postulata* (1.43), *E. spicata* (1.46) and *Q. leucotrichophora* (1.18); whereas it was found to be lowest for *S. robusta* and *T. ciliata* (0.24) (Table 2). It is quite possible that probability of use of fuel species was mainly governed by availability of fuelwood trees in the nearest access to the people. Resource use index (RUI) of the species like *P. roxburghii, E. spicata, A. nepalensis, M. postulata, Q. leucotrichophora* and *R. arboreum* show high RUI. Low RUI was computed for *Q. lanuginosa, Q. semicarpifolia, S. robusta, T. ciliata* and *E. accuminata* (Table 2).

Table 1: List of plants available across four study sites in Askot Wild Life Sanctuary

Fuel wood species		Study sites			
Species name	**Common name**	**Site 1 (Dyakot)**	**Site 2 (Baikot)**	**Site 3 (Saldhar)**	**Site 4 (Banani)**
Alnus nepalensis	Uteesh	+	-	-	+
Bauhinia variegata	Kweral	+	+	+	+
Castanopsis tribuloides	Katonj	+	-	-	-
Callicarpa arborea	Gwaila	+	-	-	-
Engelhardtia spicata	Biyasar	+	+	+	-
Eurya accuminata	Dhair	+	-	-	-
Lyonia ovalifolia	Aair	+	+	-	+
*Macaranga postulata**	Rumal	+	+	-	-
Myrica esculenta	Kaphal	+	+	-	+
*Ougeinia oojeinensis**	Sanan	+	-	-	-
*Pinus roxburghii**	Pine	+	+	+	-
Quercus lanuginosa	Riyanz	-	-	-	+
Quercus floribunda	Tilonj	-	-	-	+
Quercus leucotrichophora	Banj	+	-	+	+
*Quercus glauca**	Phaliant	+	-	+	+
Rhododendron arboreum	Burans	+	+	-	+
Syzigium cumini	Jamun	+	-	-	-
Shorea robusta	Sal	-	-	+	-
Terminalia chebula	Harar	+	+	+	-
*Toona ciliata**	Toon	+	+	+	+
Woodfordia fruticosa	Dhawl	+	-	-	-
Fodder species					
Arundinaria falcata	Ringal	-	-	+	+
Bhuhinia vahalii	Malu	+	+	+	-
Bauhinia variegata	Kweral	+	+	+	-
Castanopsis tribuloides	Katonj	+	+	-	-
Dactylis glomerata	Owns	-	+	+	-
Diploknema butyracea	Cheura	-	+	-	-
Ficus roxburghii	Timul	+	+	+	-
Ficus semichordata	Khannya	+	-	-	-
Ficus nemoralis	Kapad	-	+	-	-
Mallotus philippensis	Ruin	+	+	+	-
Maesa indica	Bakaria	+	+	+	-
Ougeinia oojeinensis	Sanan	+	-	-	-
Prunus cerasoides	Padam	+	-	+	-
Quercus glauca	Phaliant	+	-	-	+
Quercus lanuginosa	Riyanz	-	-	-	+
Quercus floribunda	Tilonj	-	-	-	+
Quercus leucotrichophora	Banj	+	-	-	+
Rhododendron arboreum	Burans	+	+	-	+
Woodfordia fructicosa	Dhwal	+	-	+	-

*Also used for timber

Table 2: Use pattern of different species for fuelwood (HH= households)

Species name	Common name	Mean collection (kg sample-^{1} day^{-1}) (Cs)	Mean collection (kg HH^{-1} day^{-1}) (Cd)	Mean collection (kg) HH^{-1} yr^{-1} (Cy)	Proba-bility of use (PU)	Resou-rce use index (RUI)
Alnus nepalensis	Uteesh	1.03	2.06	247.2	1.18	291.6
Engelhardtia spicata	Bijyasar	1.79	3.58	429.6	1.46	627.2
Eurya accuminata	Dhair	0.006	0.012	1.44	0.30	0.43
Lyonia ovalifolia	Aair	0.51	1.02	122.4	0.57	69.7
Macaranga postulata	Rumal	1.57	3.14	376.80	1.43	538.8
Myrica esculenta	Kaphal	0.19	0.38	45.6	0.27	12.3
Pinus roxburghii	Chir	7.38	14.76	1774.20	3.10	5500
Quercus lanuginosa	Riyanj	0.03	0.06	7.2	1.19	8.5
Quercus leucotrichophora	Banz	1.18	2.36	283.2	0.89	252.04
Quercus semicarpifolia	Kharsu	0.01	0.02	2.4	0.89	2.1
Rhodendron arboreum	Burans	0.65	1.3	156.0	0.59	92.04
Shorea robusta	Sal	0.009	0.018	2.16	0.24	0.51
Toona ciliata	Toon	0.011	0.02	2.4	0.24	0.57
Woodfordiya fruticosa	Dhawl	0.83	1.66	199.2	0.73	145.4

Fodder Species and Utilization Pattern

Q. leucotrichophora, *Ficus roxburghii*, *Prunus cerasoides* were the major fodder species in Baikot village. Similarly, *W. fruticosa*, *Mallotus philippensis*, *Bauhinia vareigata* were the major species in Saldhar village**,** and species like *Q. lanuginosa*, *Q. leucotrichophora*, *Q. semicarpifolia* and *R. arboreum* were common in Banani village. Among grass species, *Heteropogon contortus* was used in all study sites in major amounts. Table 3 shows use pattern of different fodder species in the study area. The fodder species which showed high probability of use were *Q. leucotricophora* (2.10), *Q. lanuginosa* (1.19), whereas lowest probability of use was shown by *R. arboreum* and *Bhuhinia vahlii*.

Utilization Pattern of Non-Timber Forest Products

Non Timber Forest Products (NTFPs) like Ringal (*Arundinaria falcata*), Salum (*Chrysopogon gryllus*), Babyo (*Eulaliopsis binata*) are few species which are being extracted by the local communities for making some of their household products. Ringal is used for manufacturing of Mat (*Mosta*), *Soopa* (used for processing of agricultural products) and Basket (*Doka*). Babyo is utilized for making ropes and broom, and also used as fodder species. Due to low occurrence in the study area it has very high market value. Salum grass is mostly used for making house roofs, which is replaced within every 6 months. The use of the plant resources was higher at higher altitude like in one of our study site in village Banani (2050 m asl), where out of 25 families living in this village 15 families were involved in manufacturing of mat, basket and soopa. The market value and other details of these products are given in Table 4.

Table 3: Use pattern for different fodder species (HH= Household)

Species name	Common name	Mean collection (kg sample^{-1} day^{-1}) (Cs)	Mean collection (kg HH^{-1} day^{-1}) (Cd)	Mean collection (kg) HH^{-1} yr^{-1} (Cy)	Probability of use (PU)	Resource use index (RUI)
Bauhinia variegata	Qweral	0.83	1.66	199.2	0.54	107.56
Bhuhinia vahalii	Malu	0.11	0.22	26.4	0.54	14.2
Castanopsis tribuloides	Katonj	0.35	0.7	84.0	0.30	25.2
Diploknema butyracea	Cheura	0.51	1.02	122.4	1.10	134.6
Ficus roxburghii	Timul	0.56	1.12	134.4	0.61	81.98
Maesa indica	Bakaria	0.26	0.52	62.4	0.30	18.72
Mallotus philippensis	Ruin	0.93	1.86	223.2	0.77	171.8
Prunus cerasoides	Padam	0.24	0.48	57.6	0.73	42.04
Quercus glauca	Phaliant	0.66	0.43	51.6	0.90	46.44
Quercus lanuginosa	Riyanj	1.1	2.2	26.4	1.19	31.4
Quercus leucotrichophora	Banj	1.87	3.74	448.8	2.10	942.48
Quercus semicarpifolia	Kharsu	0.38	0.76	91.6	0.29	26.5
Rhododendron arboreum	Burans	0.23	0.46	55.2	0.27	14.9
Woodfordia fruticosa	Dhawl	0.93	1.86	223.2	0.48	107.1

Table 4: Weight and price in local markets of some of the products based on NTFPs

Name of the species / common name	Name of the product	Weight (Kg)/ item	Price (Rs.)/item
Arundinaria falcata (Ringal)	Basket Soopa Mat	4.5-5.75 5.75-3.4 6.0-9.5 (9x6 feet)	120-160 100-130 1800-2200
Eulaliopsis binata (Babyo)	Broom	2-3	80

CONCLUSION

Extraction of different forest products takes place in the Askot Wildlife Sanctuary year round as per the availability of resources and household need. It was noted that fuel collection in the area was mainly being done during winter months (October to March), however, occasional collection was done throughout the year. Further the collection of a particular species depends largely on the wood quality and its accessibility. Earlier workers have also reported that fuel wood is the most extracted material from the Himalayan forests and its consumption in the Garhwal Himalaya ranges between 20-25 kg per household per day (Singh *et al.*, 2010). Present survey also shows that a few species are exploited for various products out of many other species available in and around the protected area. Selective pressure on these species may eliminate their population from the study sites that will likely lead to compositional changes in forest and associated wildlife. Since the past few years have witnessed a greater loss of forest resources, and a higher conflict between the different stakeholders, which is mainly due to increasing population level and anthropogenic encroachments in the protected areas. Therefore, measures are required to modify the resource use pattern suiting to the villager's need, through introduction of alternative energy and fodder resources, implementation of schemes like eco-development of protected areas and effective implementation of legislation to maintain the ecology of Askot Wild Life Sanctuary.

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Provisioning Services of Forest Ecosystems in the Western Himalayan Mountains

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INTRODUCTION

Healthy ecosystems accomplish a diverse array of processes that provide both goods and services to mankind. Ecosystem goods and services are generated as a consequence of interaction and exchange between biotic and abiotic components of an ecosystem through the universal driving forces of matter and energy (Costanza *et al.*, 1997; Rudolf *et al.*, 2002; Singh, 2002). Ecosystem goods refer to products attached with a priority in the marketplace or the tangible services that people obtain directly from the ecosystems (e.g. timber, fuel wood, fodder, medicinal plants, NTFPs and raw materials, etc.), whereas the ecosystem services (e.g. purification of air and water, mitigation of floods and droughts, carbon sequestration, soil and water conservation, aesthetic value, etc.) are the indirect benefits provided by the forest ecosystems, but are rarely bought or sold in the conventional markets.

The concept of ecosystem services (ES) is becoming increasingly popular since the last decade of the 20th century. The release of the Millennium Ecosystem Assessment (2005) was an important milestone, highlighting the dependence of humans on ecosystems, and stressed the need to better describe, quantify and value (ecologically, culturally and economically) the ES. Although early references to the concept of ecosystem functions, services and their economic value date back to the mid-1960s; concerns have been shown that in this emerging discipline the data on ES often appears at incompatible scales of analysis and is classified differently by different authors, and in order to make comparative ecological economic analysis possible, a standardized framework for the comprehensive assessment of ecosystem functions, goods and services is needed (Rudolf *et al.*, 2002).

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In the western Himalayan mountains quantification of forest ecosystem goods derived by local inhabitants has been carried out by several workers (e.g., Pandey and Singh, 1984; Ralhan *et al.*, 1991; Singh *et al.*, 1992; Negi and Agrawal, 2006; Semwal *et al.*, 2007; Singh and Sundriyal, 2009), but forest type differences in ES are least understood (cf. Joshi and Negi, 2011). This study was carried out to quantify various provisioning services (ecosystem goods) obtained by the local inhabitants from Oak and Pine forests of Uttarakhand with an objective to understand the forest-type differences in provisioning of various ecosystem goods and services and its implication for conservation and management of forests in the Central Himalayan region.

AN OVERVIEW OF BENEFITS ASSOCIATED WITH OAK AND PINE FORESTS

In the most populated belt (1000–2000 m asl) of Uttarakhand state (a large part of the western Himalaya) Oak (*Quercus spp.*) and Pine (*Pinus roxburghii*) forests form the dominant forest vegetation (Singh and Singh, 1992). In this region, Oak and Pine forests cover about 12.3% and 16.4%, respectively of the total geographical area of the Uttarakhand state. Local people depend on these forests for a variety of goods and services for their subsistence living (Table 1). The Oak forest is valued by the people in terms of provisioning of goods such as, quality fuel wood, year-round green fodder, nutrient-rich leaf litter used as organic manure, nutrient-rich soil, and a variety of minor forest products including medicinal plants. Wild edibles such as *Myrica* fruits and *Rhododendron* flowers have medicinal properties. *Rhododendron* flowers are sweet in taste, and juice, jelly and squash is made out of its flowers and which is useful in the treatment of high blood pressure, diarrhea, and dysentery (Maikhuri *et al.*, 1994; Semwal *et al.*, 2007).

Most importantly people believe that Oak forests retain water for a longer period, resulting in a sustained water yield (Singh and Pande, 1989). Soil and water conservation (SWC) is considered among the most important services generated by the Oak forests, however, more systematic studies are required to prove this assumption experimentally (Negi, 2002). The Oak forests are also known for rich biodiversity (Dhar *et al.*, 1997). Among the important goods provided by the Pine forests are timber and resin. Blacksmiths use the bark of Pine trees. The Pine forests produce good amount of ground herbage because of their open canopy, which permits abundant sunlight to the forest floor (Semwal and Mehta, 1996). Pine wood does not make a good fuel and its litter fall restricts growth of many species (Singh and Singh, 1992). Pine being a fire-resistant and stress-tolerant species proliferates in inhospitable habitats where Oak cannot grow. The slow growing Oak requires suitable microsite conditions (e.g., deep, moist and fertile soil) for growth and survival. Pine is capable of colonizing the landslide sites (Singh and Singh, 1992). On the contrary Oak requires mature habitats to grow and regenerate. The economic benefits from Pine forests, such as resin and minor timber are important. For example, data collected from Forest Deptt., Almora Division (Uttarakhand) revealed that the revenue earned annually from the sale of various forest products was about 27 time more for the Pine forests (Rs. 169.58 lakh) than the Oak forests (Rs. 6.32 Lakhs). Therefore, there are certain advantages associated with each of the two forest types considering the need of different stakeholders.

Table 1: Some ecosystem services provided by Oak and Pine forests in the Central Himalayan region

Ecosystem goods and services	Oak forests	Pine forests
Ecosystem goods		
Fodder	Low-quality, but available yr-round	Non-palatable
Fuelwood	Good quality	Inferior quality
Seed	Supports wild life	Edible by human
Medicinal value	Some	Some
Minor forest products	Many	Few
Timber	Rarely used	Frequently used
Agricultural implements	Good	Hardly used
Resin	No	Yes
Bark of tree	No specific use	Used by blacksmiths
Use of leaf litter as manure	High	Low
Other use of leaves	None	Roofing / brooms
Biomass production	10-20 t/ha/yr	Comparable
Ground herbage yield	Low	High
Ecosystem services		
Carbon sequestration	High	High
Nutrient cycling	More extra-tree cycling	More intra-tree cycling
Biodiversity	High	Low
Fire resistance	Low	High
Regeneration	k- strategist	r-strategist
Soil conservation	Good	Poor
Water regulation	Good	Poor
Microhabitat for flora and fauna	High	Low

Source: Negi and Agrawal (2003)

METHODOLOGY

This study was carried out in twenty randomly selected villages (10 villages each in Chamoli and Champawat districts of Uttarakhand), which were surrounded by Oak and Pine forests and represented varying degree of anthropogenic pressure as they are exploited for a variety of forest goods and services (Table 1). Beside this main criteria used for the selection of the sample villages for this study were: (1) Absolute dependence of the people of sampled villages either on the Oak or Pine forests available in the immediate surroundings of these villages; (2) Wide range of human and livestock population of these villages to represent various extraction regimes of ES from the surrounding forests; and (3) Wide range of altitudinal distribution of the villages that could be considered as a proxy to represent the complexity of climatic, edaphic, and topographic factors found in the study region. In the 20 selected villages a total of 1318 households (involving over 70% women) were sampled using a structured questionnaire in Oak forest dependent villages (n= 636 households) and Pine forest dependent villages (n= 682 households). Similar methods have been followed in this region by earlier workers (e.g., Ralhan *et al.*, 1991; Saksena *et al.*, 1995; Singh and Sundriyal, 2009; Singh *et al.*, 2010). Household visits as well as field checks were also carried out involving queries with women groups (prime collector of forest products) while collecting the forest resources and also weighing head loads of fuel wood, fodder and other forest products occasionally. Utmost care was taken to record the answers from the respondents with regard to quantities of various goods derived exclusively from the forests. Help of the local youth was taken in such household surveys to better capture the various provisioning services of the forests, and almost 90% of the households in these villages were sampled. Total annual quantities of various ecosystem goods collected by individual households were pooled to compute the quantities at village level.

RESULTS

Oak Forests

The quantities of different ecosystem goods obtained annually from the Oak and Pine forests (averaged across the studied villages) are given in Fig. 1 and Fig. 2, respectively. Across the 10 villages falling in the vicinity of Oak forests the average quantity of tree fodder collected across the villages (160788 kg/yr) varied from 67155 - 284010 kg/yr/village. Average per capita (animal unit) quantity of this green fodder computes to 169 kg/yr; (range = 123 - 231 kg/yr). Total quantity of green fodder (ground) collected from the Oak forests (85344 kg/yr) varied from 117750 - 37650 kg/yr/village and the mean value was computed 95 kg/capita (animal unit)/yr; (range= 46 - 149 kg). Average quantity of bedding leaves collected from the Oak forests annually (169436 kg/yr) varied from 60458 - 421590 kg/yr/village. On an average this value was computed 171 kg/animal unit/yr.

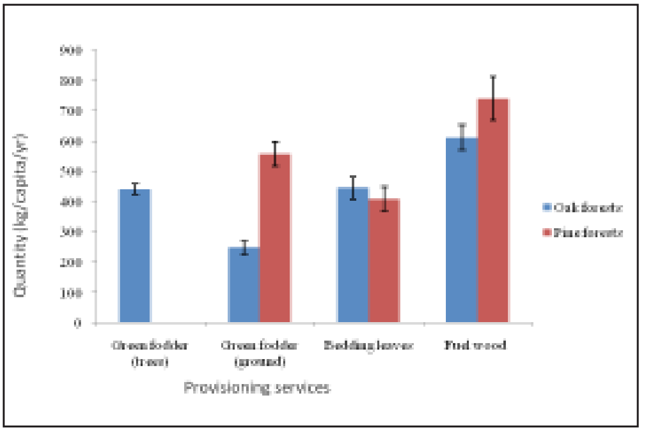

Fig. 1: Quantity of major provisioning services of Oak and Pine forests

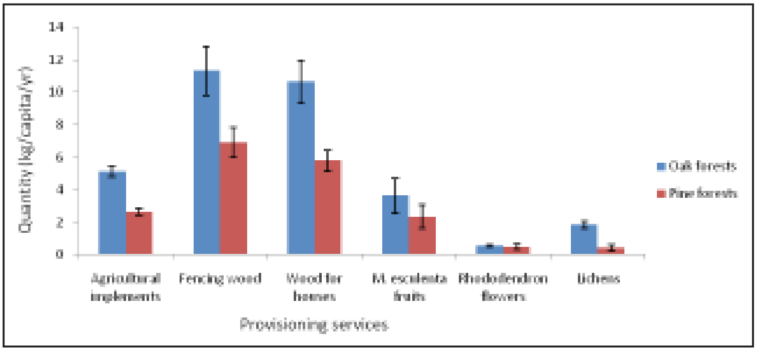

Fig. 2: Quantity of minor provisioning services (including NTFPs) of Oak and Pine forests

Fuel wood was the other major forest good collected by the local people. On an average across 10 villages the total quantity of fuel wood collected from Oak forests annually (229252 kg/yr) varied from 97090 - 458100 kg/yr/village (Fig. 1). Average per capita quantity of fuel wood collected (611 kg/capita/yr) varied from 422 - 791 kg/capita/yr. Average quantity of wood for agricultural implements collected from Oak forests annually was recorded 1877 kg (5 kg/capita) and wood collected as tree poles and branches for fencing was recorded 4397 kg/yr (range= 1095 - 10215 kg/yr/village). A small quantity of wood (average= 3970 kg/yr; 11 kg/capita/yr) was also collected for making houses and animal shed (minor timber) from Oak forests annually.

People also collect a range of wild edibles from the Oak forests. For example, fruits of *Myrica esculenta* (locally called as Kaphal) are collected and eaten raw, squeezed for juice and also sold in the nearby towns. Average quantity of *M. esculenta* fruits collected across the 10 villages was recorded 1605 kg/yr (4 kg/capita/yr). Similarly, flowers of *Rhododendron arboreum* are also collected for making squash and juice. Average quantity of *Rhododendron* flowers collected across the ten villages was recorded 220 kg/yr. (about 1 kg/ capita/yr) (Fig. 2). Lichens are other minor forest product collected by the local people to sell to local vendors for further selling to Forest Development Corporation, Govt. of Uttarakhand. Average quantity of lichens collected across the 10 villages was recorded 670 kg/yr. (2 kg/capita/yr).

Pine Forests

Total quantity of green fodder (ground) collected from the Pine forests (average across 10 villages) was recorded 205657 kg/yr. (range= 123053 - 311720 kg/yr/village). This mean value was computed 242 kg/capita (animal unit)/yr). Average quantity of bedding leaves collected from the Pine forests annually (154160 kg/yr) varied from 85810 - 347115 kg/yr/village among the villages. On an average this value was computed 181 kg/animal unit/yr.

Fuel wood is the main source of cooking energy in the study area. On an average across 10 villages the total quantity of fuel wood collected from Pine forests (275353 kg/yr) varied from 76302 - 456900 kg/yr/village among the villages (Fig. 1). Average per capita quantity of fuel wood collected was computed 741 kg/capita/yr. Average quantity of wood for agricultural implements (971 kg/yr) varied from 538 - 1749 kg/yr. across the villages. Average per capita quantity of wood for agricultural implements was computed only 3 kg/capita/yr. Similarly, average quantity of wood collected as tree poles and branches for fencing (2403 kg/yr) varied from 1575 - 3330 kg/yr/village among the villages. A small quantity of wood (average= 2208 kg/yr; 6 kg/capita/yr) was also collected for making houses and animal shed from the Pine forests annually. People also collect a range of wild edibles from the Pine forests. Average quantity of *M. esculenta* fruits collected across the 10 villages was recorded 930 kg/yr (range= 64-3540 kg/yr/village) that computes to 2 kg/capita/yr. Similarly, average quantity of *Rhododendron* flowers was recorded 167 kg/yr (range= 193 – 468 kg/yr), that computes to about 0.49 kg/capita/yr. Average quantity of lichens collected (156 kg/yr) varied from 270 - 485 kg/yr among the villages (Fig. 2).

DISCUSSION

Results of this study have clearly demonstrated that Oak forests provide a greater variety and greater quantity of ecosystem goods as compared to Pine forests to the rural people across the studied villages in the region except for fuelwood**.** Green fodder collected from Oak trees was recorded 440 kg/capita/yr. But Pine leaves (needle) are non-palatable and contain resin. *Q. leucotrichophora* had crude protein 9.5%, crude fibre 31.3%, and nitrogen free extract 48.4% (Purohit and Samant, 1995). Nutritive fodder is required for growth, maintenance and reproduction of livestock. Although collection of ground herbage from Pine forests (242 kg/animal unit/yr) was found more than the Oak forests (169 kg/animal unit/yr) in this study, it is available only during monsoon season. Yield of ground herbage in the Pine forests has been reported better as compared to Oak forests in this region (Singh and Singh, 1992). Open canopy of Pine forests permits abundant sunlight to forest floor that favours good yield of grasses. Another important ES provided by Oak forests is maintenance of crop field fertility in the form of manuring leaves used as cattle bedding and subsequently for FYM preparation. Collection of bedding leaves was more (445 kg/capita/yr) in Oak forest as compared to Pine forest (409 kg/capita/yr). The Oak leaf litter is nutrient-rich leaf litter (Oak= 1.72% and Pine= 1.02% nitrogen) as compared to Pine litter (Kandpal and Negi, 2003). Soil fertility and crop yield have also been found better in the crop fields where Oak leaf litter-based FYM is applied as compared to the crop fields where Pine leaf litter-based FYM is applied (Kumar *et al.*, 2009).

The quantity of fuel wood collected from Pine forests was found more (741 vs. 611 kg/capita/yr) as compared to Oak forests. However, this difference was insignificant. Oak fuel wood is superior than the Pine wood as the former has high calorific value (15.7 kJ/g dry weight) (Nautiyal and Negi, 1994), and Oak forests in the vicinity of villages are heavily lopped for fuelwood. The Pine fuel wood generates obnoxious smoke harmful to people (Saiyed *et al.*, 2001), particularly to the womenfolk who have to perform the task of cooking mostly in the rural areas of this region. Fuel wood collection recorded in the present study (1.68-2.03 kg/capita/day) is slightly higher as reported (1.5 kg/capita/day) for this region by Pandey and Singh (1984), Ralhan *et al.*, (1991) and Bhatt *et al.*, (1994). However, higher values have been reported by Awasthi *et al.*, (2003) in Garhwal Himalaya (3 kg/capita/day).

In this region, Pine forests are mainly promoted for the commercial value of resin and timber which is extracted by the State Government for employment and revenue generation. For example, data obtained from Forest Department indicate that in Champawat district in 2008-09 collection of lichens was 2478.23 q and collection of resin was 7983.91 q. Quantity of mosses collected in 2009-10 was 1711.90 q. Similarly, in 2010-11 in Chamoli district quantity of lichens collected was 4543.72 q, mosses 694.72 q and resin 11043.72 q. In the 20 studied villages quantity of wild edibles (e.g., *Myrica* fruits and *Rhododendron* flowers) collected from the Oak forests was as much as twice as compared to

Pine forests. Pine cones and mature wood are also used as a fire starter or crushed and molded into presto-log shapes (Thomas & Schumann, 1992). Besides, it is believed that asthma patients benefit from spending time in Pine forests (Kala, 2003). Also the resin of Pine is applied to boils, heel cracks, and on either side of the eyes to reduce swelling. Thus, the ES that are provided by these forests when viewed from ecological and social considerations are also different from one forest type to another (Singh, 2007; Negi and Semwal, 2010).

From the foregoing description it can be inferred that ecosystem services vary from one forest type to another and determined also by human dependence on different types of services offered by a given ecosystem type. Agroecosystems powered by forest ES in this region support high agro-biodiversity (Maikhuri *et al.*, 1997), and provide not only food grain, but also vegetables, pulses, crop residue and fodder. Further, the goods and services provided by the livestock component (such as, milk, dung, meat, skin, wool, traction energy, etc.) are an integral part of agroecosystem of this region and considered to be maintained by the forest ecosystem services. Similarly, water, the product of forested catchments is crucial for sustaining biological growth. Detailed investigations are required to identify the goods and ES generated by these two major forest ecosystems of this region. The superiority of one forest ecosystem over the other with regards to goods and services provided would be helpful in the regeneration / afforestation programme. Such studies would offer better choices for decision making in planning landuse and maximize the ES. Further, it is not easy to document all the ES precisely, and to make people perceive their roles. It is the perception of the users of these forests that determines the valuation of services, and individual's preferences depends upon the availability of these forests, how much they know about the environment and their significance to their lives (Singh, 2002).

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Oaks of Central Himalaya : A Source of Tasar Silk

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INTRODUCTION

Very early in history man recognized the significance of oaks and included this tree in his religious, language, numbering, and chronology systems (Graves, 1966). Native Americans also included the oak in their mythology (Buhner, 1996), and in medicine as astringents, tonics, haemostatic, and antiseptics (Hutchens, 1991). The angiosperm genus *Quercus* (Oak) is the most widely distributed member of the family Fagaceae and among the most important hardwoods of the Northern hemisphere. This genus is anemophilous (wind pollinated) with trees or shrubs, either deciduous or evergreen includes about 450 species (Chalupa, 1995). Nearly 400 species of Oak are distributed throughout the temperate regions of the world (Johnson *et al.*, 2002). In the Himalayan region 23 species of Oak are found, most of them are evergreen. Out of these, 5 evergreen species namely *Q. leucotrichophora* (banj oak), *Q. semecarpifolia* (kharsu; brown oak), *Q. glauca* (phaniyat oak), *Q. lanuginosa* (rianj oak), *Q. floribunda* (tilonj oak) and one planted deciduous species *Q. serrata* (manipuri oak) have been found growing in the Central Himalaya between 1000 – 3600 m asl (Champion and Seth, 1968) and represent the climax vegetation of the region (Singh and Singh, 1992). Oaks are source of firewood, charcoal, fodder, agricultural implements and are used in tasar (silk) sericulture (Singh *et al.*, 1997). Additionally, they play an important role in water conservation and in the prevention of soil erosion. Modern man has used the oak for a variety of purposes but their use as feeding material for tasar silk worm (*Anthereaeproyei jolly*) is important one.

India is the only country producing all the four types of commercially important wild silks (Vanya silks) namely tropical tasar, temperate tasar, Eri and Muga. Tasar culture and other associated activities have been extensively practiced in Jharkhand, Madhya Pradesh, Chhattisgarh, Orissa, Uttar Pradesh,

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Uttarakhand, North Eastern and sub-Himalayan belts of India since many decades. Due to ethnic, aesthetic and eco friendly values, wild silk has a strong demand in the national and international market. Wild silk moth farming in the forest or wasteland is one such activity where perennial income is assured without much investment and use of any machinery or power (Remadevi and Rajany, 2005). In spite of the availability of a vast wealth of tasar food plants in 111.68 lakh ha area in the tropical belt of India, tasar production is only 1.5% of the total silk production, which is 16.5% of the non–mulberry silk production of the country (Katwal, 2003).

Oak tasar silk production uses oak leaves as food for the silkworms during rearing stages. Oak tasar cocoon and silk production generates good income from oak leaves, providing a tangible incentive for sustainable management of the oak forest ecosystem. In India work on oak tasar commenced on *Q. semicarpifolia* in 1995, on an experimental basis by Appropriate Technology (AT) India, at Ukhimath (Rudraprayag district of Uttarakhand). In its initial years, it had to face up to the challenge of sensitizing hill communities on the potential of what were perceived as alien processes of cocoon rearing and silk weaving. In 2003, and 2004, AT India's silk enterprise was the single largest producer of oak cocoons in the country with a record harvest of 30 lakh and 40 lakh cocoons, respectively with a net annual return of approximately Rs. 27.6 lakhs (http://www.atindia.org/sericulture.htm). In order to keep harvesting from oak forests within sustainable limits and simultaneously augment its silk production output, AT India in 2005 initiated production of other non-mulberry silks- Eri and Muga. Eri also known as Endi or Errandi is a multi-voltine silk that has traditionally been produced across the tribal belt of India; while Muga is a unique golden yellow variety of silk which has thus far been confined to Assam. Over the years, the program has evolved to all stages of oak and Eri silk production from cocoon rearing, yarn processing, spinning and reeling up to weaving and marketing of the end products.

In Uttarakhand oaks are major forest forming species and these could be a new resource of state's economy. In this region, along with *Q. serrata,* five other evergreen species are growing naturally. *Q. semecarpifolia* is also used in silk worm rearing but it grows naturally in higher altitudes (around 2400 m asl) and does not grow well in lower altitude (Singh and Singh, 1992). *Q. serrata* is the main species which is used for silkworm rearing and sometime *Q. leucotrichophora* is also used for this purpose. *Q. serrata* is the most suitable variety for silk worm rearing, which is a medium-sized or large, handsome, deciduous tree (Troup, 1921). This tree occurs in the Himalaya from Nepal to

Arunanchal Pradesh between 900-2,400 m asl, and in the hills of Meghalaya, Manipur, Mizoram, Nagaland between 760 and 1,700 m asl. It also occurs in Myanamar (900-1,800 m asl), S.W. China, Indo-China, Taiwan, Korea and Japan. This oak is often found in subtropical wet or moist habitats. It favours damp low ground and occurs in pure stands in such locations (Negi and Nithani, 1995). In Kumaun region, Bhimtal and Pithoragarh are the two main centers of tasar silk production where *Q. serrata* is planted. However, *Q. serrata* is also being planted now in many other parts of Kumaun hills. Many strategies regarding regeneration and propagation of the oak species are developed like *in vitro* propagation for *Q. leucotrichophora, Q. glauca, Q. floribunda* and *Q. semecarpifolia* (Purohit *et al.*, 2002; Tamta *et al.*, 2008), and air layering in *Q. serrata* (Shrivastva *et al.*, 2000). These propagation strategies will not only helpful in reviving the oak forests but would also become a good source for tasar silk production and income generation in Central Himalayan region.

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19

Sacred Groves: The Ancestral Wisdom of Forest Conservation

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INTRODUCTION

Man has always cared, conserved and worshipped lakes, rivers and forests owing to his dependence on the natural resources. The religion and traditional conservation practices have been integrated with each other in such a manner that it shows a symbiotic relationship between man and nature. The traditional and cultural attitudes have made a considerable contribution towards conserving many plant species. The practice of conserving forests as sacred groves is followed all over the world by many communities. Setting aside patches of forest land on the ground of religious belief by the traditional communities has been the practice for centuries in India (Khan *et al.,* 2008). Sacred groves are community based monuments of biological and cultural diversity. Sacred groves are recognized as a system that informally forces traditional communities to protect natural resources in sustainable manner (Purthi and Burch, 2009). Sacred groves are also defined as an area of natural vegetation preserved through local taboos and sanction and are a sign of spiritual and ecological values (Godbole and Sarnaik, 2004).

The sacred groves are segments of landscape, containing vegetation and other forms of life and geographical features that are delimited and protected by human societies under the belief that keeps them in a relatively undisturbed state. The sacred groves are also confined by local communities, through customary taboos, religious beliefs and ecological implications. In the context of natural resource management, the social institutions defining the sacred groves are often linked to religious myths and a socio-cultural belief system**.** The sacred groves can be considered as a part of forest left untouched by the local inhabitants, and protected by the village folk deities. Sacred groves play a major role in environmental protection. They control air pollution, cool the atmosphere, increase soil fertility, harbour various organisms and are also an integral part of social, religious, ecological and environmental traditions (Amirthalingam, 2004).

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In India, 13,720 sacred groves have been identified from 19 states and named differently in various parts as *Ki Law Lyngdhoh* in Meghalaya, *Kovil Kadu* in Kanyakumari, *Dev Bhumi* and *Dev Vans* in Uttarakhand, etc. (Singh *et al.*, 2010). In other parts of India the sacred groves are also known as *Pavithravana* (Arunachal Pradesh), *Sarana* (Jharkhand), *Jahera* (Orissa), *Devgudi* (Maharashtra), *Kavus* (Kerala) and *Dev Van* (Himachal Pradesh). It is mainly in the mountainous areas of India like the Himalayas, the western Ghats and central India that ancient practices of sacred grove survive, sometimes in their pristine form (Chandran and Gadgil, 1998). Researchers have traced the historical links of sacred groves that date back to several thousand of years when human societies were in primitive stage (Anthwal *et al.*, 2006).

Himachal Pradesh also harbours pockets of sacred groves. These sacred groves are owned by the deities and are called *Dev Van* or *Devta ka Jungle*. The sacred groves find revenue either in the name of the temple committee or the forest department but these are managed by temple committee irrespective of the ownership. The temple committee comprises of *Kardar, Pujari, Bhadari* and *Gur*. The *Kardar* manages affairs, *Pujari* performs puja (worship) and other rituals, *Gur* is the spokesman of the deity and *Bhadari* looks after the store. In some places the conservation works are also performed by the committees. The temples are located inside the sacred groves and are surrounded by thick forests. In few cases the temple is either in the village or outside the sacred groves. However, the control of sacred grove lies with the temple committees. Local community also voluntarily facilitates conservation activities. Most of the sacred groves have natural water sources in the form of streams, tanks, ponds and wells. The water sources are also of great importance as they meet the demand of local people. In some places, there are certain restrictions and taboo associated with these water sources. Water sources in some sacred groves are specifically used for the worship purpose and other rituals.

A sacred grove has religious importance in Himachal Pradesh and the local myths and legends associated with the groves go a long way in preserving the forests. Legends are associated with the establishment of the deity but no records are available as to when the sacred groves have been established. However, it seems that the deity when established in a particular place the area adjoining the deity was declared sacred. Diverse local arts and ethnicity are allied with the deities of the groves. No one is allowed to cut trees or even extract dry leaves from the areas. There are many groves in which human entry is also restricted. In some cases people are allowed to enter bare foot and the leather goods are prohibited. Orders given by the *Gur* are strictly followed by the local community. It is a belief that the deity punishes if the vegetation is extracted from the sacred grove and the area suffers natural calamities. People from nearby villages are also associated with the temple and they strictly follow the rituals and practices. They visit the temple to perform religious ceremonies and offer their agriculture produce as well as money. The revenue generated is used for the maintenance of the temple and sacred grove. The wood of sacred grove is also used for the maintenance of the temple and as fuel for cooking community feast.

Sacred groves in Himachal Pradesh lie between 720 m to 3674 m asl and the size varies from 0.02 ha to 46.4 ha. These landscapes are repository of many endangered and rare species of flora and fauna (Table 1). These sacred groves are also natural habitat for leopard, barking deer, ghoral, sambhar, Himalayan tahr, black bear, brown bear, hare, wolf, porcupine, etc. Monal, red jungle fowl, white crested khaleej, cheer pheasants, red vented bulbul, Himalayan bulbul, yellow billed blue magpie, tree pie, Himalayan thrush, koel, wood pecker, babbler, warbler, swift, swallow, lapwing, etc. are also found in sacred groves of Himachal Pradesh. The sacred groves are the abode of diverse, rare, endemic and endangered species of flora and fauna. They harbor plants of ethnobotanical importance and serve as gene banks. They help in replenishing soil as well as water sources and provide habitat for fauna. Most of them show high endemism and represent climax vegetation. The thick forest cover, as well as dead and decayed leaves of sacred groves increase soil porosity, improve soil stability and prevent soil erosion. The *in situ* conservation as well as undisturbed biotic and abiotic factors stabilizes these natural ecosystems. The sacred groves are conserved and protected by the efforts of local community and are the best example of community participation in biodiversity conservation.

The temples associated with sacred groves in Himachal Pradesh are almost 500 years old and are of vital importance for the sustenance of present and future generation, but no step has been taken to include more land under sacred groves. Infrastructure development, increasing demand, unscientific and over exploitation of natural resources are major threats and have adverse impact on the health of sacred groves. Some of the sacred groves have been converted into apple orchards and agriculture land. Encroachment and human activities like excessive fuel wood collection, overgrazing have also adversely affected the existence of sacred groves. Certain religious practices also have negative impact on sacred groves as trees form these groves are cut for many religious purposes and for construction of temples. Forest fire and landslides are other threat to sacred groves. The sacred groves can be conserved and managed by providing legal status to them. The religious sentiments attached to the sacred groves have helped to conserve natural forests in critical areas and there is a need to declare these areas as heritage sites and this practice should be encouraged by policy makers for preserving forest areas and biodiversity for future generations.

Table 1: List of plants found in sacred groves of Himachal Pradesh

Trees	Shrubs	Herbs
High Altitude	**High Altitude**	**High Altitude**
Cedrus deodara, Betula alnoides, Pinus wallichiana, Quercus semicarpifolia, Quercus leucotrichophora, Aesculus indica, Rhododendron arboreum, Abies pindrow, Picea smithiana, Acer caesium	*Astragalus chlorostachys, Berberis aristata, Berberis asiatica, Berberis lyceum, Clematis connata, Cotoneaster affinis, Cotoneaster bacillaris, Daphne papyracea, Debregeasia salicifolia, Desmodium elegans, Jasminum humile, Prinsepia utilis, Rhododendron anthopogon, Rhododendron campanulatum, Rhododendron lepidotum, Rosa webbiana, Rubus ellipticus, Rubus niveus, Viburnum cotinifolium*	*Aconitum heterophyllum, Acorus calamus, Allium humile, Anaphalis contorta, Anemone obtusiloba, Anemone rivularis, Angelica glauca, Aquilegia nivalis, Arnebia benthamii, Artemisia indica, Aster thomsonii, Atropa acuminata, Bergenia stracheyi, Caltha palustris, Corydalis govaniana, Dactylorhiza hatagirea, Datisca cannabina, Delphinium brunonianum, Duchesnea indica, Epilobium latifolium, Ferula jaeschkeana, Fritillaria roylei,Gentiana kurroo, Geranium nepalense, Geum elatum, Inula cappa, Meconopsis aculeata, Onsoma hispidum, Phlomis bracteosa, Picrorhiza kurrooa, Podophyllum hexandrum, Polygonatum verticillatum, Rheum webbianum, Primula denticulata, Saussurea costus, Swertia chirayita, Taraxacum officinale, Thalictrum foliolosum, Valeriana jatamansi, Viola biflora*
Low Altitude	**Low Altitude**	**Low Altitude**
Pinus roxburghii, Ficus religiosa, Ficus benghalensis, Shorea robusta, Populus ciliata, Acacia catechu, Cassia fistula, Tectona grandis, etc.	*Asparagus racemosus, Hypericum perforatum, Jasminum humile, Lonicera asperifolia, Rhamnus triquetra, Rosa moschata, Smilax aspera, Zanthoxylum armatum*	*Achyranthes bidentata, Adhatoda vasica, Bergenia ciliata, Cleome viscosa, Euphorbia hirta, Ranunculus diffusus, Salvia lanata, Solanum nigrum*
Associated tree species		
Alnus nepalensis, Alnus nitida, Bauhinia purpurea, Bauhinia variegata, Butea monosperma, Celtis australis, Cupressus torulosa, Dalbergia sisso, Ficus palmata, Fraxinus micrantha, Grewia optiva, Juglans regia, Morus serrata, Pinus gerardiana, Prunus cerasoides, Prunus cornuta, Pyrus Pashia, Quercus dilatata, Rhus wallichii, Robinia pseudoacacia, Taxus wallichiana, Toona ciliata		

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Invasive Vegetation in the Forests of Garhwal Himalaya: Distribution and Effect on Bird Diversity

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INTRODUCTION

Garhwal Himalaya, due to its unique geographical position, physiography and varied climate has diverse ecological conditions, vegetation, habitats, and animal communities. Great altitudinal variation divides the area in three zones viz., submontane or sub tropical, montane or temperate and alpine zone. Each zone has its own ecology, vegetation composition and faunal diversity. The submontane zone comprises the tarai-babhar area of adjacent Gangetic plains and outer sub Himalayan Siwalik hills elevated up to 1200 m asl. The warm humid climate, broad leaf forests and presence of large size animals like *Elephas maximus*, *Panthera tigris*, *Selenarctos thibetanus*, *Axis axis*, *Presbytis entellus*, *Pavo cristatus*, *Gallus gallus*, etc. are characteristics of this zone. The sal (*Shorea robusta*) and sal mixed forests with different assemblages of trees like *Dalbergia*, *Acacia*, *Dendrocalamus spp.* are common in this zone (Champion and Seth, 1968). The montane zone ranges from 1200 to 3000 m asl. and experiences cold climate. The characteristic features of this zone are presence of gentle slopes, deeply dissected valleys, evergreen broad leaf and coniferous forests. The chir pine forests, oak forests, oak mixed forests and coniferous forests are some representative habitats of this zone. Some of the common animals of montane habitats are *Panthera pardus*, *Canis aureus*, *Nemorhardus goral*, *Muntiacus muntjak*, *Lophura leucomelanos hamiltoni*, *Catreus wallichii*, *Pucrasia macrolopha*, *Lophophorus impejanus*, etc. This area experiences maximum anthropogenic pressure because more than 50% hill population resides within this zone and depends on the forests for their daily needs of fuel, fodder, etc. As a result, the forests of montane zone have either become fragmented or transformed into secondary scrubs. The area is also under urbanization, construction of road net work, hydro-electric projects, etc. Area above 3000 m asl. represents the alpine zone and characterized by severe cold, heavy snow fall in winter, stunted growth of vegetation and meadows.

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All ecological zones and forests mentioned above differ in their avifauna. For example, the submontane zone has red jungle fowl, peafowl, black partridge, common quail, crow pheasant, grey hornbill and parrots as dominant species. The temperate forests of montane zone are rich in bird diversity (Fig. 1), and some representative forms are white backed vulture, kalij pheasant, cheer pheasant, koklas pheasant, Himalayan monal, hill partridge, chukar partridge, doves, barbets, tree pie, cuckoos, bulbuls, jays, thrushes, wagtails, flycatchers, bush chats, etc. The upper zone as well as alpine habitats has comparatively low number of bird species. Some representative birds of this area are golden eagle, raven, monal, snow partridge, snow pigeon and finches.

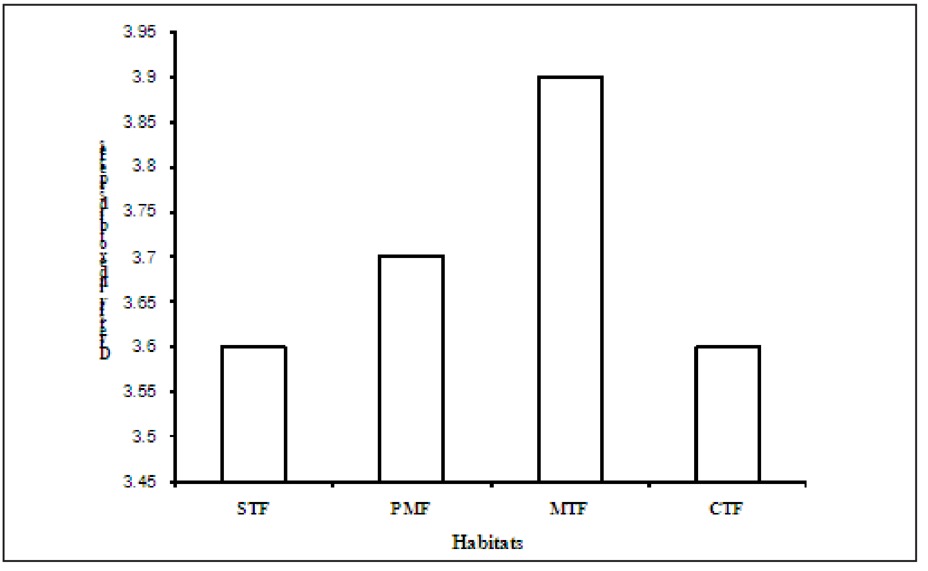


Fig. 1: Birds species richness in different forests type of Garhwal Himalaya (STF-subtropical forest, PMF- pine mixed forest, MTF- mixed temperate forest and CTF- coniferous temperate forest)

INVASIVE VEGETATION IN THE FORESTS OF GARHWAL HIMALAYA

Non-native, exotic vegetation which has been accidentally or intentionally introduced into a new habitat is called alien species. While non-native organisms which on introduction to new habitats grow and colonize rapidly, and deplete the native local flora and fauna, is called invasive species. The invasion of alien weed species has become a worldwide problem in the recent past due to its harmful effect on environment, economy and health (Mooney *et al.*, 2004). The Garhwal Himalaya is under the threat of a large number of such non-native alien plant species. Some recent studies conducted at few selected area of Garhwal division (Gaur, 1999; Negi and Hajra, 2007; Bisht *et al.*, 2010) suggest occurrence of more than hundred alien plants including certain invasive species. Three most common invasive plants observed in the district Chamoli and Pauri (Garhwal) are *Lantana*, *Eupatorium* and *Parthenium* spp., which are considered harmful to the environment because of their distribution in all

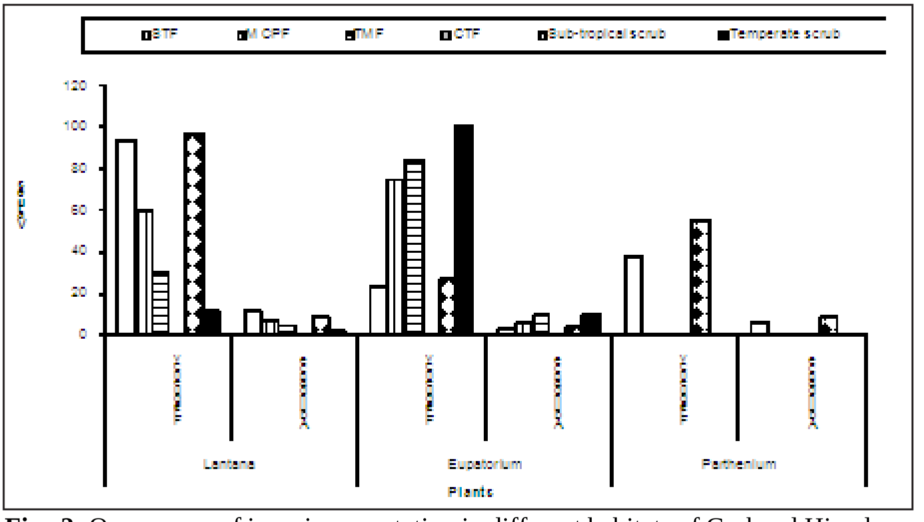


Fig. 2: Occurrence of invasive vegetation in different habitats of Garhwal Himalaya, (STF-sub-tropical forest, MCPF-mixed chir-pine forest, TMF-temperate mixed forest & CTF- coniferous temperate forest)

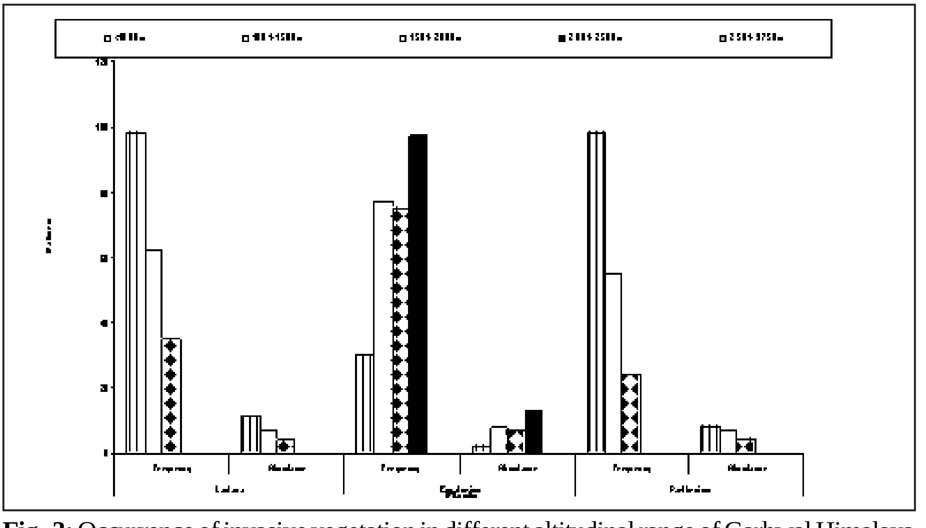
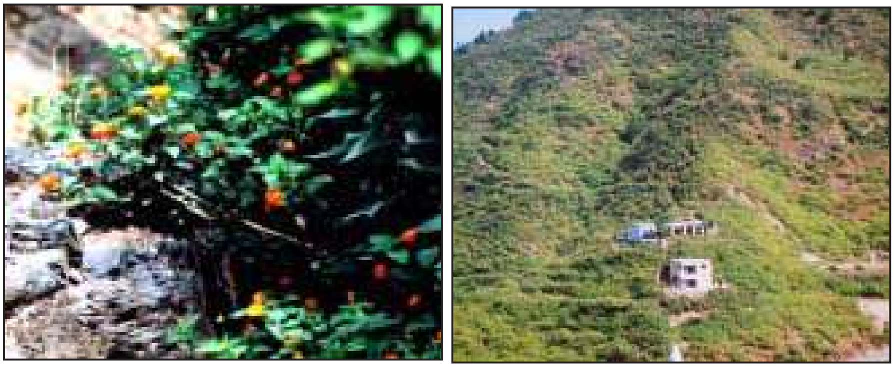


Fig. 3: Occurrence of invasive vegetation in different altitudinal range of Garhwal Himalaya

ranges and habitats. *Lantana*, a woody perennial shrub is a native of tropical America (Holm *et al.*, 1977) and initially brought to India in 1807 as an ornamental plant at the National Botanical Garden (Thakur *et al.*, 1992). But later this plant has spread out across all open areas along road sides, railway tracks, edges of crop fields and open forests all over the country. In the Garhwal Himalaya also, two species viz., *Lantana camara* and *L. indica* have been established in all habitats of submontane and montane zone up to 2000 m altitude. Its maximum infestation was found along the road sides, open wasteland, abandoned crop fields, near water bodies, in communal forests and in the reserve forests also (Bisht, 2011). Invasion of this woody shrub was found more at low altitudes especially up to 1000 m asl. range where frequency of occurrence was more than 90% (Fig. 2). In the middle range between 1000-1500 m altitudes especially on the south facing aspects, frequency of occurrence was recorded about >60%. Subtropical forests and scrubs adjacent to the motor roads were observed most infested by this exotic vegetation where weed plant was recorded with more than 90% occurrence (Fig. 3). *Eupatorium adenophorum* is another common perennial invasive vegetation of Garhwal Himalaya. It has Mexican origin and later introduced to many parts of the world as an ornamental plant during 19th century (Parsons, 1992). In Garhwal Himalaya, *Eupatorium* invasion was found highest at middle ranges of altitude between 1000-2500 m asl. where the frequency of occurrence was recorded more than 80% (Fig. 2). The temperate scrubs, temperate forests and mixed chir-pine forests were found completely infested with this weed (Fig. 3). The open habitats especially on the northern aspects were found completely homogenized (Fig. 4 A-C). *Parthenium hysterophorus* which flourishes only during summer and monsoon months (May to October) recorded maximum invasion (48-100% occurrence) at low altitudes up to range of 1500 m asl. on road sides, open areas and abandoned crop fields of subtropical zone (Fig. 4 A-C).

EFFECT OF INVASIVE VEGETATION ON BIRD FAUNA

Out of the total 1200 species of birds reported so far in the Indian subcontinent, 600 species including water birds and migratory forms are found in the hills of Garhwal Himalaya (Ali and Ripley, 1993). These feathered animals include some important groups because of their food, environmental and ecological values. The Red jungle fowl, an inhabitant of the subtropical forests, is the progenitor of all domestic forms of chicken on which a multibillion poultry industry is based (Singh and Singh, 1995). Some other birds like pheasants, partridges, quails, pigeons, doves, etc. are still illegally killed in many parts of Uttarakhand for their delicious meat. Raptors which include the vultures, kites, and owl are natural scavengers as they feed upon dead carcasses and injurious animals and keep our ecosystem clean and healthy. Many birds like parrots, parakeets, barbets, bulbuls help in dispersal of seeds and fruits of the valuable plants and some others (fly catchers, sun birds, honey eaters, etc.) contribute as pollinators.



A

B

C

Fig. 4: Complete homogenization of the invasive vegetation. (A) *Lantana* in subtropical habitats especially on south facing aspects, (B) *Eupatorium* at middle range of altitude on north facing slopes, and (C) Invasion of *Eupatorium* in feeding ground of Kaleej pheasant and Chukar partridge in Garhwal Himalaya

The colorful bird fauna of Garhwal region has been dwindled considerably in the recent past. Hunting, egg picking by the villagers for food, forest fires and habitat destruction are some significant reasons of their decline. In spite the ban imposed on hunting under Wildlife Protection Act (1972), illegal practices are still continued in many parts of the area (Bisht *et al.*, 2007). For example, the mountain quail known to found only in the *'Sher ka Danda'* area of Nainital and Jhairipani of the Mussorrie has become extinct (Shafiq *et al.,* 2000), and many other species has already been listed in the category of 'threatened birds' in Schedule-I of the Wildlife Protection Act (1972) and IUCN Red list (Hilton and Taylor, 2000). Recently it was thought prudent to correlate decline of birds with distribution and abundance of invasive species in the Garhwal region (Bisht, 2011). Therefore, long-term studies were conducted on bird fauna of three habitats established with *Lantana* infested vegetation at Patisain and *Eupatorium* infested vegetation in Lansdowne and Gadoli areas in Pauri-Garhwal. Out of these three sites, the later two sites had almost same climate and vegetation structure (*Quercus, Rhododendron, Myrica, Lyonia, Pyrus* spp. etc). A significant difference was observed in bird's richness and composition across these sites (Table 1).

Table 1: Effect of invasive vegetation on the bird fauna of Garhwal Himalaya

Status of birds	**Habitat studied and level of invasion**		
	Patisain (infested with *Lantana)*	Lansdowne (infested with < 50% *Eupatorium)*	Gadoli (infested with > 75% *Eupatorium)*
No. of orders	11	10	7
No. of families	31	32	26
No. of species	119	150	110
No. of total individuals	5805	13186	9562
Diversity index (H')	4.07	3.87	3.66
Evenness index	0.85	0.77	0.77

In the *Lantana* infested habitat, both number of species and total individuals of birds were comparatively lower than the habitat (Lansdowne) which has less infestation of *Eupatorium*. Birds richness was significantly low in the habitat completely homogenized (Gadoli) with *Eupatorium*. The decline was very specific in the populations of birds which feed on the ground (e.g., pheasants, partridges, doves, tree pie, thrushes, pipits, etc.), on insects (drongos, bush chats, tits, flycatchers, bee eaters), and on nectar, like sun birds. It can be pointed out that the invasive species does not allow growth of suitable food material to the ground feeding birds (e.g., White crested kalij pheasant and Chukar partridge), which had a very common appearance around Pauri in 2000-2001 (Bisht and

Dobriyal, 2002) when there was least infestation of *Eupatorium*. But today the entire forest is under invasion of this weed and Kalij pheasant has lost its population significantly. Though the role of hunting and other anthropogenic factors cannot be ignored, but this is a fact that all open-feeding grounds of birds have been well encroached by *Eupatorium.* Similarly, arrival of many migratory species of birds like hoopoes, wagtails, flycatchers, finches, etc. has declined during the last few years. An establishment of weeds replaces local plants; phototoxic substances released by the roots damage the soil organisms and repel the insect fauna which constitute the diet of many bird species. Invasion of weeds also causes shortage of grass eating animals like ungulates, rodents, etc. Thus it appears that the invasive vegetation (*Lantana* and *Eupatorium)* are harmful to the avifaunal diversity. Therefore, strategies for eradication of these harmful weeds are required to save the important bird fauna and ecology of the Garhwal Himalaya.

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Forest Fire in Uttarakhand Himalaya : An Overview

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INTRODUCTION

Studies on fossil charcoal indicate that history of wildfires can be traced back in the Silurian era (> 400 million years ago) immediately after the arrival of plants on the face of earth (Bowman *et al.*, 2009). Fire's occurrence throughout the history of terrestrial vegetation support the hypothesis that fire must had pronounced evolutionary effects on plants and animals across the globe. Ecologists now regard fire as a natural disturbance and an integral part of ecosystem dynamics plying a vital role in ecosystem process called "creative destruction", which is always followed by the process of 'renewal' (Berkes and Folke, 1998). African fynbos, Mediterranean scrub land**,** North American chaparrals, Australian malee, tropical savannas, and pine forests of the world are considered among some of the major fire adapted ecosystems of the world because their continued existence depends on periodic occurrence of fire (Pyne *et al*., 1996). For species growing in such ecosystems, fire is an opportunity rather than a danger to capitalize upon post fire benefits of greater space, light, and lottery of soil nutrients unlocked from biomass pool instantly after burn (William and Midgley, 1995)**.** Species growing in these ecosystems not only develop various special traits, namely, thick fire resistant bark, germinating bud embedded in fire resistant foliage or under soil surface, higher rate of flower and seed production, winged seed, serotinous fruiting bodies and lignotubers to survive the recurring fire but also fire enhancing characteristics such as fine branching**,** loose flaky bark, canopies with high proportion of dead wood, and high volatile oil contents (Zedler, 1995). The high flammability of fire adapted plants was not by chance but it was the result of natural selection favouring them to evolve characteristics that make them fire impervious (William and Midgley, 1995). In any terrestrial ecosystem fire can be of natural origin or

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intentionally or accidentally caused by man. Depending upon the weather, topography and fuel type- the fire triangle- forest fires of both natural origin and man caused may reveal themselves as light or surface fire, ground fire, and crown fire/severe fire. Obviously effects on vegetation depend primarily on the type and also along a complex path defined by frequency, extent, season, phenology, mode of spread in mountainous topography and combined effects with other disturbances such as storms and diseases (Agee, 1993).

The concept of ‘fire is always bad’ has now been modified to that ‘fire may be benign as well as detrimental’ depending on its management in a given ecosystem type. Prescribed burning of vegetation is now a well established practice in grassland and forest ecosystems in many parts of the world to obtain desirable results such as to minimize fire hazards, maintain desirable habitats, and stimulate forest and pasture regeneration (Agee, 1993; Pyne *et al.*, 1996). Despite human use of fire to achieve socio-economic and ecological benefits, fire still remains an untrustworthy tool, often capable of dodging control, particularly under extreme dry weather condition and high fuel loading in grassland and forest ecosystems. This inadequate command over using fire as a management tool, even in present times, raises the unresolved question of determining fire patterns (Bowman *et al.*, 2009).

STUDY AREA

In Uttarakhand Himalaya man caused accidental and intentional wildfires in the pine forests and associated grazing lands is a common phenomenon during dry summer months every year (Fig. 1). Off late occasional events of fire can also be noticed during winter months in the pine forests of this region. Therefore it would be difficult to find a pine forest stand in the region which does not have prior fire history. Chir pine (*Pinus roxburghii*) forests cover approx. 16.4 per cent of the total forest area of 24,413.20 km^2 under the control of state forest department roughly between 900 and 1700 m asl. in the region. The area under pine forests would further increase if forest areas managed under other regimes such as Van Panchayats are also taken into account (Uttarakhand Forest Statistics, 2005-06 prepared by State Forest Department). Despite fire being such an important factor influencing vast forest areas in Uttarakhand Himalaya, scientific studies are scanty and vastly inadequate to discern out precise impacts of fire on ecosystems; leave alone prescribing it as a tool for sustainable management of forests in the region. Forest fires are becoming one of the sources of GHGs leakages particularly large fires that the region experienced in 1995, 1999 and 2009 may transform forests of the region from acting as sink to net source of GHGs. In the above backdrop, the present article describes the impacts of recurring forest fires on some of the forest and grazingland ecosystems of the region based on limited yet pioneering studies carried out by the authors in Uttarakhand. Preliminary studies carried out in this region have come out with the following facts: (i) All fires in the chir pine forests of Uttarakhand Himalaya are man-made intentional or accidental. Of the total incidences of forest fires in Uttarakhand Himalaya, 63% were intentional and remaining 37% were accidental (Tiwari *et al.*, 1986, 1987), (ii) Generally fires both intentional as well as accidental are set by individuals and not a collective decision of entire village community, (iii) Ground vegetation diversity and productivity increases after moderate intensity fires under pine associated grazing lands and hence sometimes intentional fires are set by local people to augment their fodder resources, (iv) Due to stronger vigilance by local people, generally VP forests are less affected by fire than the forests managed under other regimes, and (v) Scientifically very little is known on the impacts of forest fires on the structure and functioning of forest and grazing land ecosystems in the region.

Fig. 1: Devastating forest fire in Pine forest of Garhwal Himalaya (Photo: B.S. Bhandari)

Phytogeographically, Uttarakhand Himalaya has been placed in Western Himalaya by almost all scholars. The staggering vegetation diversity of this biotic province can be conveniently attributed to three vital factors namely altitude, latitude and longitude. Great variation in altitude is the predominant factor in this regard which is well evident from the vertical transition patterns in region's vegetation which extends from tropical to subtropical conditions at lower altitudes (ca 350 m asl) to alpine and Aeolian condition in the higher reaches (ca 5500 m asl). Broadly the vegetation pattern in the region follows the four major horizontal zones, i.e. tropical, sub-tropical, temperate and alpine. Owing to varied topography and altitude, tropical and alpine communities may occur within a short distance of only approximately 350 km. Thus, the natural distribution of Himalayan forests from the outer hills to the inner higher zones is determined primarily by altitude though geology, soils, orientation of valleys, and other biotic and abiotic factors also exert influences to a great extent (Champion and Seth, 1968). The elevation range of 300 to 2200 m asl in the Uttarakhand Himalaya reflects three vegetation regimes *viz.*, *Shorea robusta* (Sal) in the sub-tropical zone (up to 800-1000 m), *Quercus leucotrichophora* (>1500 m) in the low temperate to mid temperate zone and *Pinus roxburghii* (Chir pine) between the first two regimes. Vegetation between 2200 and 2800 m asl exhibits dense forests of *Q. floribunda* (Moru, Tilonj Oak) in the north facing moist slopes and occupies an intermediate range between *Q. leucotrichophora (Banj Oak)* and *Q. semecarpifolia* (Kharsu Oak). Above 2800 m *Q. semecarpifolia* is generally associated with *Abies pindrow, Rhododendron barbatum*, *Taxus wallichiana*, *Picea smithiana*, *Juglans regia*, *Acer ceasium*, *Buxus wallichiana*, *Toona serrata* and many other tree species. In the inner region between 2000 and 3000 m asl pure forest stands of *Cedurs deodara* are also common in the region. The outer ranges, however, exhibit pure or mixed forests dominated by *Abies spectabilis*, *Betula utilis*, *Cupressus torulosa*, etc. at the timber line *Betula* is associated with *Rhododendron campanulatum* and *Sorbus* spp. The broad leaved forests of montane/temperate zone where the oaks are major components along with high altitude conifers constitute the significant part of forest biodiversity of montane ecosystems. Along the entire altitudinal range of Uttarakhand Himalaya, the overlaps of more than one forest types are often found partly due to natural reasons and largely due to increasing anthropogenic stress such as over exploitation of forest resources and recurrent forest fires.

IMPACT OF FIRE ON SOIL, HERBACEOUS DIVERSITY AND BIOMASS PRODUCTIVITY

When the chemical properties of a pine *(P. roxburghii)* forest associated grazing land analyzed under burnt and unburnt situations, the soils under burned forests showed higher pH than unburnt ones (Bhandari, 1995; Bhandari *et al.*, 2000). High intensity fires can result in nearly complete destruction in organic matter and change the physico-chemical and biological properties of soil and therefore organic carbon and nitrogen were found higher on the unburnt soils than burnt soils. However, organic carbon and nitrogen contents increased gradually with the passage of time after burn indicating that burning alters soil physico-chemical properties in the short-term (Bhandari *et al*., 2000). Post fire herbaceous vegetation also show marked variation due to changed soil properties along with the removal of dead plant parts from the ground and provided ample opportunities for a greater number of species to grow and flourish. We observed that though there was no marked difference in the diversity parameters between burnt and unburnt pine forest stands and grazing lands, species richness was always higher on burnt sites across seasons (Table 1). Burning increased species richness by opening up of the forest canopies (mostly composed of shrubs) facilitating more insulation and resulted in relatively higher species richness of ground vegetation (Bhandari *et al*. 1997). The diversity values of burnt as well as unburnt pine forest associated grazing lands are significantly higher as compared to the diversity of herbaceous vegetation under other forest types in Uttarakhand Himalaya (Rawat, 1990; Semwal, 1990; Semwal and Mehta, 1996; Bhandari *et al*., 1999).

Our studies reveal that fire also brings in marked changes in the biomass and productivity potential of the grazing lands. Above ground net primary productivity (ANP) values of herbaceous vegetation of pine forests where the frequency of occurrence of fire was 2-5 years, in most of the cases, exceeded over ANP of herbaceous vegetation of broad leaved forests (Table 2). However, the situation changes drastically when a forest stand was swept by high intensity crown fires and heavy precipitation follows immediately after burn. Under such condition biomass and productivity values have been recorded significantly lower under burned condition than unburned one (Semwal, 1990). Light fires helped open the locked up nutrients in the biomass pool quickly, breaking the dormancy of seeds and buds of many species and promoting the growth of herbaceous vegetation (Semwal and Mehta, 1996) and thus enhanced the seasonal carrying capacity of pine associated burnt grazing lands (Table 3).

Table 1: Seasonal variation in species richness, diversity ($\overline{H}$) and beta diversity (**β**) of burnt and unburnt pine forest associated grazing lands (Source: Bhandari, 1995)

Site	**Season**	**Richness**	$\overline{H}$	**β**
Unburnt	Rainy	56	5.19	4.45
	Winter	30	3.98	3.56
	Summer	37	4.78	4.81
Burnt	Rainy	72	5.17	4.98
	Winter	33	4.38	3.23
	Summer	43	5.18	5.18

Table 2: Aboveground net primary production of ground vegetation of different forests of Uttarakhand Himalaya

Forest type	ANP (Kg ha^{-1})	Reference
Chir Pine forest in Central Himalaya	1500.0	Rana *et al*., (1988)
Chir Pine mixed broadleaf forest of Kumaun Himalaya	2000.0	Rana *et al*., (1989)
Oak burnt forest of Garhwal Himalaya	2902.0	Rawat (1990)
Oak unburnt forest of Garhwal Himalaya	1295.0	Rawat (1990)
Pine burnt forest of Garhwal Himalaya	4710.0	Mehta (1990)
Pine unburnt forest of Garhwal Himalaya	1890.0	Mehta (1990)
Pine burnt forest of Garhwal Himalaya	1596.10	Semwal (1990)
Pine unburnt forest of Garhwal Himalaya	3225.6	Semwal (1990)
Pine associated burnt *Heteropogon* grazing lands of Garhwal Himalaya	2598.0-3622.0	Bhandari (1995)
Pine associated unburnt *Heteropogon* grazing lands of Garhwal Himalaya	1212.0-1699.0	Bhandari (1995)

Table 3: Seasonal carrying capacity* of burnt and unburnt pine forest associated grazing lands

Site	Season	Cow	Heifer	Bullock	Buffalo
Burnt	Rainy	4.28	13.27	3.74	3.21
	Winter	2.31	6.62	1.87	1.60
	Summer	3.11	9.65	2.72	2.34
Unburnt	Rainy	2.75	8.27	2.91	2.19
	Winter	1.64	4.95	1.74	1.31
	Summer	2.28	6.86	2.41	1.82

Source: Bhandari *et al*., (1997); *Standardized against cow units/ha

In the western Himalayan region, broadleaf forests between 1400 and 1800 m asl. mainly dominated by oaks and associated species are gradually turning into chir pine *(P. roxburghii)* forests due to heavy human pressure such as lopping, grazing and leaf litter collection on these forests including forest fires (Singh *et al.*, 1984; Semwal, 1990; Bhandari *et al.*, 2000). The above altitudinal zone of this region is densely populated and hence identified as a problem zone from socio-economic and ecological considerations (Singh and Singh, 1992). Local inhabitants depend heavily on these forests and associated grazing lands to cater their demands of fodder, fuel, timber, etc. Recurring forest fires promote the expansion of fire promoting and adapted pine forests at the cost of ecologically crucial and socially valued oak (*Q. leucotrichophora*) forests (Singh *et al.,* 1984).

Fire assisted invasion by pine, in the oak forests completely changes the microclimatic conditions making them more suitable for invasion of *P. roxburghii* to expand its territory year after year. Such a change in the ecological status of oak forests is a cause for alarm to the forest dependent local communities, managers and policy makers who need to seek solutions to achieve a balanced environment in conserving the natural vegetation wealth of the Himalaya (Bhandari *et al*., 2000). Fortunately, recently reverse has also started taking place where oak has been observed reestablishing in chir pine forests due to various favourable factors such as greater environmental awakening, institutional and policy support, and increasing use of cleaner fuels for cooking and heating minimizing the pressure on oak forests. The phenomena of oak regeneration can be observed in the region particularly in the close proximity of several villages located above 1500 m asl. where people can keep out disturbances like fire and grazing from pine invaded oak forests for over considerable period of time (> 10 -15 years) (Semwal *et al.,* 2003). These preliminary findings reported in this article call for carrying out long-term studies on the ecology of forest fires to suggest better conservation and management practices for forest and grazing land resources of the Uttarakhand Himalaya. However, based on our experiences following recommendations can be made to reduce fire hazards in the forests of Uttarakhand: (i) Impart environmental education and training on the local inhabitants, foresters and school children with particular emphasis on the detrimental effects of uncontrolled forest fires; (ii) Reduce the fuel loading in the forests through regular controlled burning, especially from those areas that are under public influence such as road sides, trekking paths, crop fields adjoining forests, etc.; (iii) Encourage the use of flammable biomass around human settlements for other purposes, e.g., organic manuring, fuel bricks from pine needles, etc. One such initiative made by the Forest Department, Govt. of Uttarakhand is illustrated in Box-6 (Chapter 3); (iv) Raising height of rills created on the basal portion of the tree bole for resin tapping to minimize fire injuries to individual trees; and (v) In the plantation programmes instead of planting the commercially important coniferous species that are not valued by local people, plantation of multipurpose and locally valued tree species for fodder, fuel wood, and minor timber (e.g., *Bauhinia spp., Boehmeria rugulosa, Celtis australis, Dalbergia sissoo, Ficus roxburghii, Grewia optiva, Melia azedarach, Ougeinia dalbergioides, Quercus spp*., etc.) should be given priority over pine which apart from catering to local needs do not add flammability to the forests.

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Benefits of Trees Outside the Forested Area

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INTRODUCTION

Forest productivity world over is under great threat today. There are several key factors that affect productivity *per se*, however, climate change at global as well as at regional levels will greatly and adversely influence forest health in general, and productivity, in particular. During the past few decades the forests have come under an enormous pressure due to large scale deforestation for fodder, fuel wood and timber for construction purposes. Additional threats include, intensive grazing by livestock and agricultural expansion. Water is another major and critical component, which at every phenological phase of trees is potentially capable of drastically reducing overall forest productivity. The consequences of substantial reduction in productivity on account of fast changing climate can well be visualized. Exponential increase in human and livestock population over the years and economic changes are threatening the ecology of the Himalayas. Deforestation for obvious reasons without adequate afforestation is a matter of great concern in the entire Himalayas, where increased demand for firewood, tree lopping in order to feed livestock, and construction of roads have increased the destruction rate of forests. The gap between demand and supply of forest products is increasing rapidly, and if something concrete is not done immediately to decrease the pressure on the forest ecosystem the present generation will directly be held responsible for endangering the survival of future generations.

MULTIPURPOSE TREES OUTSIDE THE FOREST

This is true that the existing traditional land use systems with separate allocation to agriculture and forests are inadequate to meet the demands for diversified products like food, fuel, fodder, timber, paper, pulp, fruits, etc. The exponential growth in human and livestock population over the years coupled with the declining biomass production, soil erosion and declining cultivable land

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has increased gaps between supply and demand for timber, fuel and fodder. The scenario on fuel, fodder and timber production is not satisfactory. There is a chronic deficiency of timber, fuel wood and fodder in the country (Table 1).

Table 1: Fuel wood, timber and fodder production and consumption status in India

Forest product	Consumption	Production	Deficit (%)
Fuel wood	235 million m^3	90 million m^3	62
Timber	28 million m^3	12 million m^3	57
Fodder	900 million tonnes (dry)	441 million tonnes	51
Fodder	1100 million tonnes (green)	250 million tonnes	77

One solution to reduce the dependence on the forest ecosystem to bridge the gap between demand and supply for forest products can be to substantially increase area under plantation outside the forested territories. Therefore, agroforestry and short rotation forestry seem to be panacea for overcoming most of the problems related to deforestation and ecological imbalance. There are good number of success stories where tree based cropping systems have yielded good results. However, integration of traditional knowledge with scientific research is required for the development of improved technologies. Further, agroforestry research in context of the present global scenario is bound to have changed vision and strategies in order to make this alternate land use more viable and profitable venture. We further need to refine the technology package based on the past experiences and failures to make agroforestry and short rotation forestry more beneficial, viable, environmentally sound and widely acceptable. Diversification and sustainability in production are the two main goals to be achieved through short and long term strategies. There is immediate need to explore the possibilities of growing multipurpose tree species with high value cash crops on the farmland to attain multiple products and ecological benefits. Agroforestry as well as short rotation forestry hold potential for increased availability of on-farm wood products, energy sources, improved carbon sequestration and carbon credits. Agroforestry is being promoted and popularized by the Government and wood based industries in India in order to address the crisis of food, timber, fuel wood and fodder. There can be several options to integrate multipurpose tree species in combination with food as well as medicinal and aromatic crops outside the forested area. Some of the viable options under agroforestry are: Agri-silviculture, Agri-horticulture, Agri-silvi-horticulture, Agri-horti-silviculture, Silvi-pastoral, Horti-pastoral, Horti-silvi-pastoral, Home gardens, Energy plantations (fuel-fodder banks), and Commercial plantations. The number, size, texture and nature of tree species to be planted under these different models will depend on the need and requirement of rural population. The fuel, fodder, timber and fruit tree species dominate in the hilly regions, whereas commercial species like *Populus, Dalbergia, Eucalyptus, Cedrella* spp. etc., constitute the major component of agroforestry systems in the foot hills. Trees can be included in the pastures, wasteland, as bio fencers, windbreaks, boundary plantations, road side plantations, arboretum, fuel-fodder blocks, plantation in the watersheds, etc. Among the expected benefits of planting trees outside the forested area are reduced pressure on the natural forests, income and employment generation through integrating medicinal and aromatic plants in agroforestry models fast growing energy plantations and short rotation forestry (e.g., *Populus* spp.) that will stock high quantity of C in biomass pool, and will provide additional sink for atmospheric CO_2. So, this additional tree cover over and above the forest cover will greatly help in mitigation of green house gases through carbon sequestration and will pave the way for significant reduction in CO_2 emissions.

Implications of global warming and climate change on flora and fauna have been the hot topic of discussion and debate at national and international level during the last decade. Alarmed by the possible adverse impacts of global and regional climate change on forest ecosystems, there has been serious concern world over in understanding vulnerability of forests and finding out short and long term strategies to reverse the negative effects. The Intergovernmental Panel on Climate Change (IPCC, 2007) in its Fourth Assessment Report (AR_4) has already indicated warming trend and its repercussions on biodiversity and existing flora and fauna. The climate change in the form of elevated CO_2, drought and extreme temperature will not only result in drastic decline in production ability of plants, but may also cause elimination of some of the important germ plasm. Tree plantation outside the forest will be highly useful to conserve and / or develop genetically superior clones of multipurpose tree species, which are drought tolerant, have higher photosynthetic efficiency at elevated CO_2, have higher carbon sequestration potential and better productivity. In addition, the systematic plantation can earn carbon credits. Thus increasing green cover outside the forested area will not only reduce dependence on natural forests but will also provide many direct and indirect short and long-term benefits to human beings.