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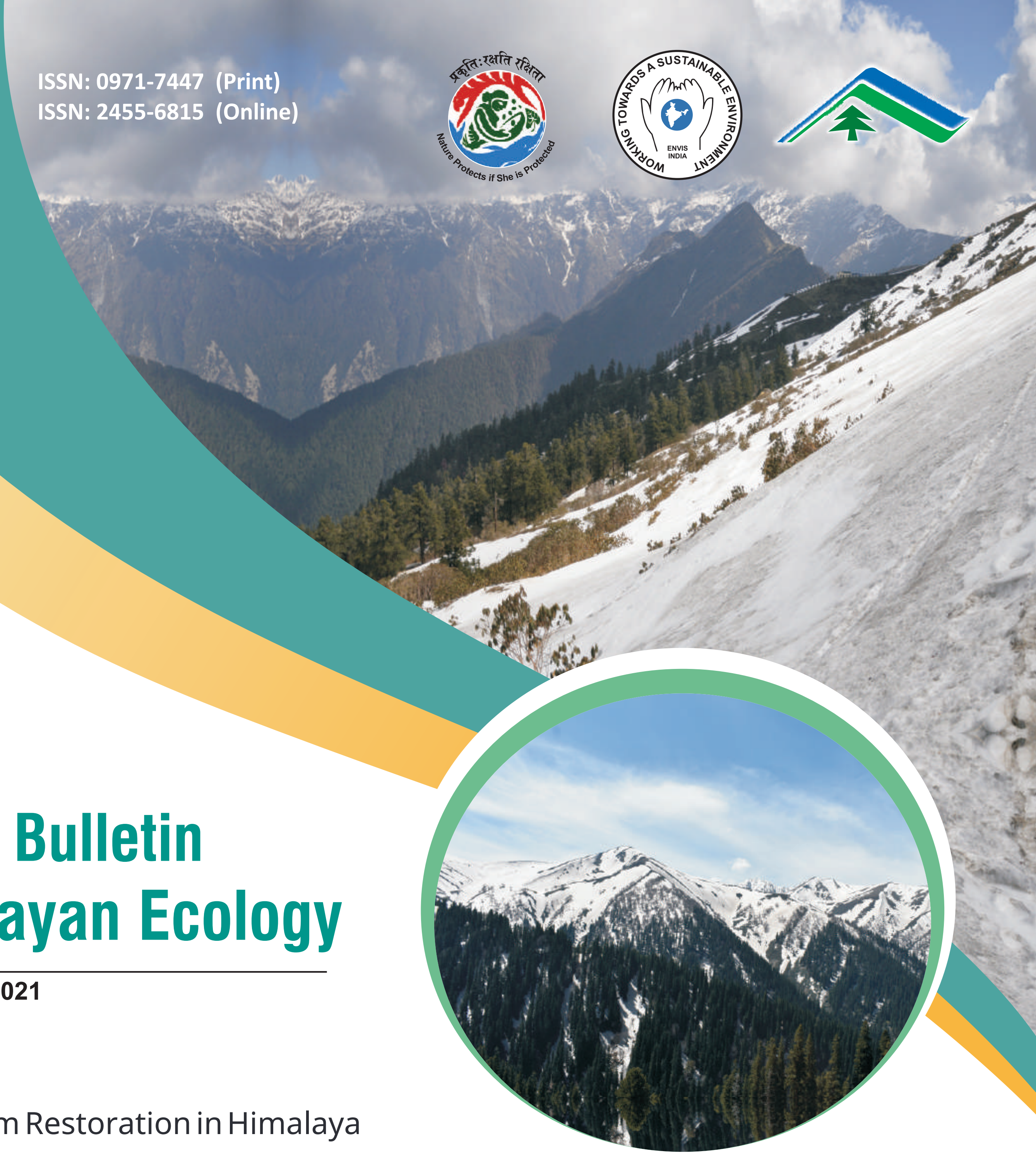

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Volume 29, 2021

• Ecosystem Restoration in Himalaya

ENVIS CENTRE ON HIMALAYAN ECOLOGY

G.B. Pant National Institute of Himalayan Environment
An Autonomous Institute of Ministry of Environment, Forest and Climate Change, Government of India)
Kosi-Katarmal, Almora-263 643, Uttarakhand, India

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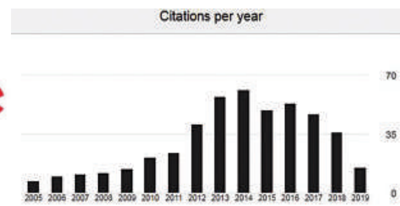

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Ecosystem Restoration in Himalaya

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G.B. Pant National Institute of Himalayan Environment
An Autonomous Institute of Ministry of Environment, Forest and Climate Change, Government of India)
Kosi-Katarmal, Almora-263 643, Uttarakhand, India

Guest Editor's Note

The planet earth supports a variety of life and ecosystems ranging from grasslands to forests, wetlands to oceans, deserts to ice caps. Ecosystems support all life on the earth. The healthier our ecosystems are, the healthier the planet and its people. Despite this realization, the ecosystems worldwide are degrading due to a range of natural and anthropogenic drivers of change and the Indian Himalayan Region (IHR) is also facing such degradation. Ecosystem degradation has led to the loss of various tangible and intangible services emanating from these ecosystems. Worldwide several attempts are ongoing to halt the degradation of ecosystems and rehabilitate and restore them so that they provide ecosystem services for human welfare. Only with healthy ecosystems can we enhance people's livelihoods, counteract climate change and stop the loss of biodiversity.

On 1 March 2019, the UN General Assembly adopted a resolution proclaiming the UN Decade on Ecosystem Restoration 2021–2030 with the objectives: (i) Showcase successful government-led and private initiatives to halt ecosystem degradation, restore those ecosystems that have already been degraded; (ii) Enhance knowledge exchange on what works and why (policy, economics and biophysical aspects), and how to implement restoration at scale; (iii) Connect initiatives working in the same landscape, region or topic, to increase efficiency and impact; (iv) Create links between ecosystem restoration opportunities and initiatives with business interested in building a robust portfolio of sustainable production and impact investment; and, (v) Bring a broader spectrum of actors on board, especially from sectors that are not traditionally involved, by demonstrating the importance of ecosystem restoration to conservation as well as generation of social and economic benefits. The UN Decade on Ecosystem Restoration runs from 2021 through 2030, which is also the deadline for the Sustainable Development Goals, and the timeline scientists have identified as the last chance to prevent impacts of climate change.

The G.B. Pant National Institute of Himalayan Environment (an autonomous Institute of Ministry of Environment, Forest and Climate Change, Govt. of India) through its Environmental Information Centre (ENVIS) publishes current advances in research on the topical issues of national and international importance with a focus on IHR. The present volume of ENVIS devoted to the UN Decade on Ecosystem Restoration contains 26 such articles related to biodiversity and natural resource restoration challenges and opportunities across the IHR spanning over soil, land, forests, water, wetlands etc. and provide solutions based on pilot R&D work. Case studies on promising plant species including medicinal plants have been recommended for ecosystem restoration. Social dimensions of restoration involving people's participation (e.g. sacred groves) have also been presented as a sustainable approach to halting land degradation.

The views in these papers in this publication are the views of the concerned authors. Therefore, they do not necessarily reflect the views of the editor, ENVIS Centre and the Institute. The comments/suggestions for further improvement of the ENVIS Bulletin are welcome.

Dr. P.P. Dhyani
Vice-Chancellor, SDSU University
& VMSB Uttarakhand Technical University
Formerly, Vice-Chancellor, SGRR University
& Director, GBPNIHE, Kosi- Katarmal, Almora

About the Bulletin

ENVIS Bulletin on Himalayan Ecology is an annual non-priced publication of the ENVIS Centreon Himalayan Ecology, which was established at the headquarters of the G.B. Pant National Institute of Himalayan Environment (GBPNIHE) in the financial year 1992-93 with the fiscal support from the Ministry of Environment, Forest & Climate Change (MoEF&CC), Government of India, New Delhi. The present volume of the ENVIS Bulletin is 29th in the series of its annual publication and contains papers on Ecosystem Restoration in Himalaya. The news and views offered in the papers in this publication are the views of the concerned authors. Therefore, they do not necessarily reflect the views of the editors, ENVIS Centre and Institute. The content of the Bulletin may be quoted or reproduced for non-commercial use provided the source is duly acknowledged.

The contributions to the next issue of the Bulletin in the form of a research paper, popular article, news item and technical report, etc., related to Himalayan Ecology, are always welcome. However, the matter supplied by the individual/organization may be edited for length and clarity. Request for institutional subscription of the Bulletin may be sent to the coordinator of the ENVIS Centre. The comments/suggestions for further improvement of the Bulletin are welcome.

Dr. G.C.S. Negi
Executive Editor - ENVIS Bulletin,
ENVIS Centre on Himalayan Ecology,
G.B. Pant National Institute of Himalayan Environment and Sustainable Development,
Kosi-Katarmal, Almora, Uttarakhand, India

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Ecosystem Restoration in Himalaya

AN OVERVIEW OF WASTELAND RESTORATION IN INDIA: THE HIMALYAN CONTEXT

GCS Negi*[1] and PP Dhyani[2]

[1]G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand, India
[2]Vice Chancellor, Sri Dev Suman Uttarakhand University, Tehri Garhwal, Uttarakhand, India

***Correspondence:** negigcs@gmail.com

ABSTRACT

The UN Decade on Ecosystem Restoration 2021-2030, "Prevent, halt and reverse the degradation of ecosystems worldwide" highlights an urgent need to restore degraded ecosystems. It emphasizes on Governments will need to align restoration efforts with national planning processes, including nationally determined contributions (INDC), and provide additional commitments and financial resources. The UN Decade on Ecosystem Restoration also aligns with the Decade of Action for the Sustainable Development Goals (SDGs). Restoring degraded ecosystems is an efficient and cost-effective way people can work with nature to address the most pressing challenges humanity is facing today, i.e. the COVID-19 global pandemic. This article provides an overview of extent, causes, impacts and preventive measures to arrest land degradation and strategies for addressing the issue with particular focus on Himalayan region. It briefly provides an overview of various methods and approaches for restoration of degraded lands and recommends a set of tree species for soil and biodiversity conservation, watershed protection, carbon sequestration and other ecological benefits for the recovery of ecosystems in the western Himalayan region.

INTRODUCTION

Restoration of ecosystems is fundamental to achieving the Sustainable Development Goals (SDGs), mainly those on climate change, poverty eradication, food security, water and biodiversity conservation. The UN Decade on Ecosystem Restoration aiming at 2012-2030 "Prevent, halt and reverse the degradation of ecosystems worldwide" is a global effort aimed at restoring the planet and ensuring One Health for People and Nature (https://www.decadeonrestoration.org). Forests, grasslands, croplands, wetlands, savannas, terrestrial, marine and coastal ecosystems and urban environments—all require protection and restoration to produce the ecological benefits. Healthy forest ecosystems act as carbon sinks, absorbing up to one-third of CO_2 emissions, harbour a wide variety of animal and plant species currently threatened, and restore these habitats and landscapes to protect and bring back some of the richest biodiversity hotspots on Earth (https://www.decadeonrestoration.org). Restoration includes measures to create green jobs, which is one of the key elements for building resilient societies post-COVID-19 global pandemic. Securing the rights of rural communities, and especially indigenous people, those have long been the custodians of ecosystems, and building on their knowledge is critical for the success of restoration and for protection of biodiversity. It has been estimated that it will take about 1 trillion US$ to restore 350mha degraded land globally that is just 0.1% of global economic output between now and 2030. Globally, land degradation affects about one-sixth of the world's population.

Land degradation is a global problem caused by a variety of factors or processes, which include soil erosion by water/wind, deterioration in physical, chemical and biological or economic properties of the soil and long-term loss of natural vegetation. It is estimated that about 2 billion ha land in the world that once was biologically productive is now under various forms of degradation (Oldeman 1991). Another estimate by (Lal and Stewart 1990) suggests that about 5-7 Mha of arable land of the world is lost annually due to land degradation. About 15% of the global land mass is degraded; the highest in Asia (37%) followed by Africa (25%), South America (14%), Europe (11%), North America (4%) and Central America (3%). Despite human dependence on this fundamental resource its degradation is rising globally.

THE INDIAN CONTEXT

In India, the estimates of land degradation by different agencies vary widely from about 53Mha to 188Mha, mainly due to different approaches adopted in defining degraded lands and/or different criteria used (Table 1). As per estimates of National Bureau of Soil and Landuse Planning (NBS&LP) an area of

187.8Mha is affected by various land degradation problems with water erosion (45.3%), followed by chemical deterioration (4.8%), wind erosion (4.1%) and physical deterioration (3.5%) (Sehgal and Abrol 1994). These estimates were revised to 146.8 Mha on 1:250,000 scale in 2005. As per the Wasteland Atlas of India (2011) developed by National Remote Sensing Agency (NRSA) there are 23 categories of wastelands covering 19.4% of the country's geographical area (Table 2). The NRSA has estimated that 80 Mha out of about 142Mha under cultivation and 11 Mha of pasture lands are substantially degraded while 40Mha out of 75Mha of forest land has a canopy of less than 40%. Thus a total of 131Mha (40% of country's total land mass) has productivity well below its actual potential. Among different regions, highest erosion rate occurs in the black soil region (23.7- 112.5t/ha/yr) followed by Shiwalik region (80 t/ha/yr), NE region with shifting cultivation (27-40t/ha/yr), snow clad cold deserts and arid regions of western Rajasthan to more than 80t/ha/yr in Shiwalik region. Sheet erosion affects red soils (4-10t/ha/yr) and black soils (11-43t/ha/yr). Gully erosion seriously affects hilly areas (>33t/ha/yr) while hill slope erosion is more than 80t/ha/yr (Dhruvanarayana and Ram Babu 1983). On experimental plot scale soil loss in the western Himalayan forests has been estimated 2.1t/ha/yr and on a watershed scale it ranges from 2-37t/ha/yr (Negi 2002). As per harmonized area statistics on land degradation a total of 96.72Mha (80.19 Mha on arable land and 16.53Mha under open forest) area is affected by water erosion either exclusively or in conjunction with salinity/acidity which is about 80% of 120.72Mha total degraded area in the country (Maji 2007).

CAUSES OF LAND DEGRADATION

Land degradation is a consequence of either natural hazards or direct anthropogenic and underlying causes. Natural hazards lead to high susceptibility of land to erosion such as high intensity rain storms on steep slopes and soils having less resistance to water erosion, high speed winds, soil fertility decline due to heavy leaching of soil nutrients in humid climates, acidity or loss of nutrients, water logging etc. The direct or anthropogenic causes are human induced, which result from unsustainable land use and inappropriate land management practices such as deforestation and over-exploitation of vegetation, overgrazing, cultivation on steep slopes and marginal/fragile lands without applying soil conservation measures, shifting cultivation, faulty crop rotations, imbalanced fertilizer use or excessive use of agro-chemicals, over-exploitation of ground water and improper management of canal water. The underlying causes are the factors indirectly responsible for land degradation such as population pressure, land shortage, tenure rights, socio-economic pressure and poverty. Land shortage and poverty together led to non-sustainable land management and consequently land degradation. Following are details of few of the major causes of land degradation:

(i) Water erosion

Water is a major agent of soil erosion. About 125Mha area in the country suffers from water erosion (@ >10t/ha/yr) either exclusively or in combination with other land degradation problems like salinity, acidity etc. According to (Dhruvanarayana and Ram Babu 1983) about 5334 MT of soil is lost annually in India, which is equivalent to 16.4t/ha/yr. About 10% of the total eroded soil gets deposited in the reservoirs thereby reducing their storage capacity by 1-2% every year and also the hydroelectric power generation. Of the remaining, 61% is displaced from one place to another, while 29% is permanently lost into the sea causing irretrievable loss of the soil resource. Recently CSWRTI, Dehradun and NBSS&LUP, Nagpur have computed the potential erosion rates for different states of the country using 10mx10m grid size data from the parameters of Universal Soil Loss Equation (USLE). Considering 10t/ha as the permissible soil loss limit (Mandal *et al*., 2009), it has been indicated that on the whole, about 39% area in India has potential erosion rate of more than the permissible limit, while 11% area falls in very severe category with erosion rate of > 40t/ha. The states of Nagaland, Meghalaya, Arunachal Pradesh, Assam, Chhatisgarh and Jharkhand have more than 60% of their total geographical area beyond the permissible erosion rate of 10t/ha. Similarly, more than 40% area in the states of Uttar Pradesh, Uttarakhand, Madhya Pradesh and Manipur is affected by erosion rate exceeding the permissible limit (Anonymous 2008; Kuniyal *et al.*, 2021).

(ii) Wind erosion

Wind erosion is prevalent in arid and semi arid regions of the country covering an area of about 28,600km^2 in the states of Rajasthan, Haryana, Gujarat and Punjab. About 68% of the wind erosion affected area is covered by sand dunes and sandy plains (Narain and Kar 2006). According to recent estimates about 75% area of Western Rajasthan is affected by wind erosion hazard of different intensities (Narain *et al*., 2000) besides 13% area under water erosion and 4% under water logging and salinity/ alkalinity. Decreasing rainfall and increasing wind strength from east to west are responsible for the spatial variability in sand reactivation pattern.

(iii) Waterlogging, salinization and acidification

In India about 4.5Mha area is affected by water logging, half of which occurs in canal commands and the remaining half in other regions (Anonymous 2004a). Canal irrigation mainly causes the problems of water logging and salinization in the irrigated command areas of arid and semi arid regions. Maximum such area lies in Uttar Pradesh followed by Gujarat, Rajasthan, Andhra Pradesh and Bihar. Similarly, salt affected soils occur in 8.55Mha, out of which 41% lies in canal command areas. Though salt affected soils occur all over the country, they are mainly concentrated in arid, semi-arid and sub-humid regions in India. The states most affected are Uttar Pradesh, Gujarat, Rajasthan, West Bengal and Andhra Pradesh (Singh 1992). Acid soils cover an area of 49Mha in India out of which 25Mha have pH below 5.5 and 25Mha between 5.5 and 6.5 (Misra 2004). The acid soils are found in Himalayan region, eastern and north eastern peninsular India and coastal plains, covering states of north eastern region West Bengal, Bihar, Orissa, Andhra Pradesh, Kerala, Madhya Pradesh, Karnataka, Maharashtra, Tamil Nadu, Himachal Pradesh, Jammu and Kashmir and Uttarakhand.

(iv) Floods and droughts

Floods, droughts and other climatological extremes cause widespread land degradation apart from heavy monetary loss to the country. It has been estimated that 8 major river valleys spread over 40Mha area of the country covering 260 million population are affected by floods. Drought occurs over an extended period of time and space making it unpredictable and the losses are difficult to quantify (Samra 2002). It is estimated that about 68% of total sown area and 23% of total area of the country spread in 16 states, *viz*; Andhra Pradesh, Bihar, Chhatisgarh, Gujarat, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttarakhand and West Bengal covering a total of 183 districts and 12% of population are accounted as drought prone (CESI 2006), Except Kerala, Punjab and north-eastern region, every state has one or more drought prone areas. Drought is said to have occurred in an area when the annual rainfall is less than 75% of the normal in 20% of the years examined.

(v) Gullies and ravines

Gullies are defined as advanced form of rill erosion and results from continuous non-judicious use of the land. They generally originate on sloping lands due to improper management and concentration of flowing water leading to severe erosion hazards. Gullies are commonly noticed in the plateau region of Eastern India, along the foothills of Himalayas and in extensive areas of Deccan plateau. Ravines, on the other hand, are a network of gullies almost parallel to each other and generally associated with some river system. The major factors responsible for formation and development of ravines include misuse and management of rainwater and faulty agricultural practices in the upper river catchments resulting in heavy siltation rates and meandering of rivers and backflow of water from adjoining porous strata into the river system leaving behind a network of gullies. In India ravines (Gullies) occur along the rivers Beas, Yamuna, Ganga, Chambal, Kaisindh, Mahi, Narmada, Sabarmati and their tributaries in the States of Punjab, Uttar Pradesh, Bihar, West Bengal, Rajasthan, Madhya Pradesh and Gujarat (Sharda 2011).

(vi) Forest degradation

India being a primarily agrarian society depends heavily on forests and other grazing land for fodder to feed livestock. The areas which are most affected by vegetation degradation include pasture lands and open forests. The states which have considerable proportion of permanent pastures and grazing lands include: HP(32%), Sikkim(10%), MP (including Chhatisgarh)(6%), Karnataka(5.1%), Rajasthan(5%), Gujarat(4.5%) and Mahararashtra(4%) (Sharda 2011). The common grazing lands around the villages which include cultivable waste, permanent pasture and marginal croplands have been highly exploited and neglected. In India, with about 500 million livestock population, more than 50% of fodder demand is met from grasslands. The average grazing intensity in India is about 42 animals per ha of land against the threshold level of 5 animals per ha (Sahay 2000). An estimated 100 million cow units graze in forest lands against a sustainable level of 31 million per annum (MoEF 1999) affecting approximately 78% of India's forests.

Impacts of land degradation

Land degradation has multifarious impacts which apart from lowering the productive potential also results in deterioration of soil health, pollution of surface and ground water resources, loss of storage capacity of reservoirs, loss of biodiversity, landlessness, poverty, food insecurity and several types of environmental hazards. Also, various forms of land degradation have different impacts. Water erosion removes soil organic matter and other plant nutrients thus causing loss of productivity, which has been estimated to vary from 5 to 50% depending upon type of soil and crop and intensity of erosion (Sehgal and Abrol 1994). It has been estimated that nearly 5.37 to 8.4 MT of plant nutrients are lost every year from Indian soils due to water erosion. The annual loss in production of major crops due to soil erosion has been estimated to vary from 7.2 MT (UNEP 1993) to 13.5 MT (Bansil 1990). Similarly, wind erosion causes decrease in land productivity at both the sites from where the finer particles are blown away and at sites where they are deposited. Deep ploughing of sand plains lost more than 3000 tonnes of soil per ha during a sand storm of 1987, while areas with 10-12% plant cover or with higher cloddy surface experience low soil loss (Samra and Narain 2006). Water logging causes reduction in oxygen supply to the root zone resulting in excess accumulation of toxic organic constituents and reduced forms of metallic ions such as iron and manganese; thus causing complete failure of crops. It is estimated that India loses 1.2 to 1.6 MT of food grain production every year due to waterlogging resulting from temporary submergence of soils by floods as well as rise in water table (Brandon *et al*., 1995). The loss in productivity due to salinity in India is estimated to vary from 6.2 MT (UNEP 1993) to 9.7 MT (Bansil 1990). It is estimated that reclamation of 8.5Mha salt affected soils in India with suitable technology can produce additional 50-55 MT of food grain annually with benefit: cost ratio of 4.6 without government subsidy on gypsum (Yadav 2007). The reclamation and management package for waterlogged, saline and alkali soils consist of land leveling and construction of bunds, adequate drainage provision for removal of excess salt and horizontal sub surface drainage to control water table assured source of good quality irrigation water application of amendments (gypsum/ pyrite) in alkali soils, leaching of excess salts, selection of suitable crops and cropping sequences and nutrient and water management (Tyagi 1998).

THE INDIAN HIMALAYAN CONTEXT

Land is a finite physical resource particularly in the undulating terrain of Himalayan mountains. In the Indian Himalayan region (IHR) wasteland account for about 34% of the total geographical area (i.e., 180533km^2), which is about two times as compared to India (i.e., 19.4%). This is mainly because about 22% land in the IHR is either under snow or barren rocky areas and does not support any biological growth (Task Force Report of Planning Commission 2010). Out of the 23 categories of wasteland (as listed under Table 2) the snow covered area(37%) and barren rocky areas (28%) comprise the largest area under wasteland (Fig. 1). A total of 18% of total wasteland in IHR is categorized under dense and/or open scrub. Other important wasteland categories are underutilized and degraded forest scrub (7% of total wasteland) and shifting cultivation area (5% of total wasteland). The lowest proportion of wasteland is recorded for land under sand (category 15-19 listed in Table 2). In the IHR, out of the 11 hilly states and 1 UTs, J&K (data for Ladakh UT yet to come) has maximum wasteland, followed by HP, AP and Uttarakhand (Fig. 2). Other states comprise relatively less area under wasteland. J&K has the maximum wasteland (74%) of its total geographical area, which is mainly because of high proportion of barren rocks and snow covered area. Sikkim, a tiny Himalayan state comprised 46% of its geographical area as wasteland, which is again due to snow covered area. HP comprised40%, Nagaland32%, Manipur25%, Uttarakhand24% and Mizoram23% wasteland of their total geographical area, respectively (Fig. 2).

The wasteland statistics of the IHR states over a period 2005-06 and 2008-09 (Table 3) reveals that there has been slight change in the area in all the states over this four years duration (Table 4). On the one hand waterlogged and marshy land-seasonal (category 6) was declined by 43% and gullied ravinous land-medium (category 1) was declined by 34%; on the other hand degraded land under plantation crops (category 14) increased by 25%. Looking at detailed account of wasteland under various categories across the IHR states it is apparent that open scrub is omnipresent across all the IHR states and the maximum share of this category of wasteland is represented by Meghalaya. Whereas, area under snow is the second important wasteland category across most of the IHR states. Darjeeling and Tripura are characterized by underutilized/degraded forest-scrub dominated wasteland.

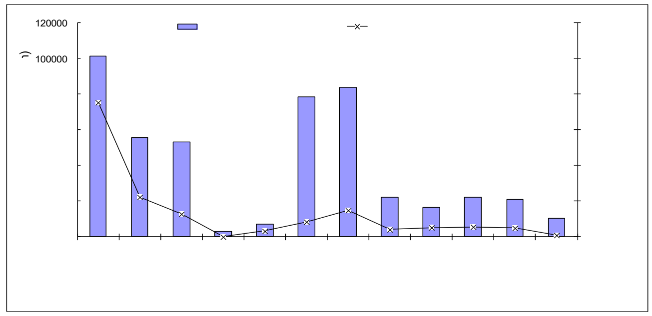

Fig. 1. Total geographical area of different Indian Himalayan states and their respective total wasteland area (for West Bengal only Darjeeling district is considered).

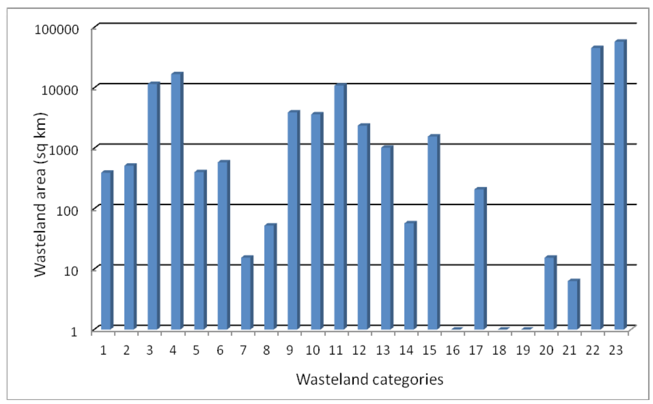

Fig. 2. Total wasteland area under different categories in Indian Himalayan region (wasteland categories are based on Dept. of Land Resources, Govt. of India) (wasteland category details: 1- Gullied ravinous land-medium, 2- Gullied and/or ravinous land-Deep/very deep ravine, 3- Land with dense scrub, 4- Land with open scrub, 5- Waterlogged and Marshy land-Permanent, 6- Waterlogged and marshy land-Seasonal, 7- Land affected by salinity/alkalinity-Moderate, 8- Land affected by salinity/alkalinity-Strong, 9- Shifting cultivation area-current Jhum, 10- Shifting cultivation area-Abandoned Jhum, 11- Under utilised/degraded forest-scrub dominated, 12- Agricultural land inside notified forest land, 13- Degraded pastures/grazing land, 14- Degraded land under plantation crops, 15- Sands-Riverine, 16- Sands-Coastal sand, 17- Sands-Desert Sand, 18- Sands- Semi- stabilized to stabilized (>40m) dune, 19- Sands- Semi- stabilized to stabilized moderately(15-40), 20- Mining Wastelands, 21- Industrial wastelands, 22- Barren rocky area, 23- Snow cover and/or glacial area).

ECO RESTORATION OF WASTE LANDS

Ecological restoration of the wastelands is essential for sustaining the diversity of life on Earth and re-establishing an ecologically healthy relationship between man and nature. Degradation of ecosystems and its negative impacts on biological diversity and community livelihoods are well understood. Conservation of natural systems is highly challenging in areas where local communities are intimately dependent on natural resources for their livelihood. There is a growing realization that it is not possible to conserve the earth's biological diversity through the protection of critical areas alone. Various governments and developmental agencies are looking forward to have proper approaches, measures and methodologies for ecological restoration of degraded land. However, the extent of degraded areas is increasing fast. The restoration of degraded landscapes pose a serious challenge to manage ecosystem health and fulfill community needs as well as improvise ecosystem services (e.g. soil formation and fertility management, watershed protection, carbon sequestration, air and water purification, climate stability, etc.), which is so essential for survival of human beings on this planet earth.

A degraded ecosystem (e.g., degraded forest areas, mines, landslides, abandoned lands) can be considered restored when it regains its structure, ecological processes and functions. A meaningful ecological restoration will restore the flow of ecological goods, services and ecological integrity (processes, structure, function and composition) of the degraded land. It will improvise productive capacity of lands with relation to biodiversity and livelihoods. It should also illustrate resilience to normal environmental stresses and disturbance, and support communities' social and economic gains to an optimum level. There have been several attempts for ecological restoration of degraded lands, however the level of success vary from case to case with relation to achieve an acceptable trade-off between biodiversity conservation and human livelihoods. Restoration programmes must consider the basic needs of the local population, which is a key for community participation. Planning process for ecological restoration of any given habitat comprises selection of site, types (vegetal and/or engineering measures) and number of interventions to be taken up, the size of the landscape to be restored and basic community needs that can be fulfilled from the target area. There is a need to improvise the existing knowledge and understanding on ecological restoration by frequent exchange of ideas among professionals and practitioners. Besides, there is still a need to encourage awareness and support ecological restoration by strengthening economic opportunities and revive traditional cultural practices on restoration (Bernbaum 1995; Dhyani 2013).

STRATEGIES FOR ARRESTING LAND DEGRADATION

In India, participatory watershed management has been accepted as a tool for all conservation and developmental activities with a focus on socio economic aspects apart from biophysical attributes following 'bottom up' participatory approaches. Common guidelines for watershed development projects have been formulated and implemented since April 1, 2008 for all the concerned ministries. Under these guidelines, 50% of the total budget is earmarked for natural resource management with special emphasis on treatment of degraded/wastelands and water resource development. It involves adoption of appropriate resource conserving technologies on arable and non-arable lands for holistic development of rainfed areas and wastelands for sustained productivity and environmental security. For efficient management of natural resources issues such as (i) Integrated land resource management policy; (ii) Methodologies for optimal land use planning at different scales using modern tools and procedures; (iii) Development of integrated farming systems in different agro ecological regions of the country to maximize productivity and profitability, input use efficiency, cropping intensity, resource conservation, employment generation, environmental security and poverty alleviation are required. It would encompass optimal combination of various enterprises, viz., agriculture, horticulture, livestock, fishery, etc. for different categories of farmers and farming situations to achieve efficient utilization of land and water resources and prevent over exploitation of land; and (iv) Location specific alternate land use systems, viz., agri-horti, horti-pastoral, agri-horti-silvi, agri-silvi-medicinal and silvi-pastoral need to be developed for scientific planning of land resources following watershed approach. Following are the two strategies employed for arresting land degradation.

(a) Land use planning

Application of ecological principles to land use planning is undoubtedly the most important input for arresting degradation of mountain areas. Successful application of a programme for rejuvenation and management of degraded lands would involve land classification for use based on natural ecological features such as soil depth, texture, slope, availability of water, production potential of biological resources, population pressure and socio-economic attributes. The Himalayan lands, based on capability, can broadly be classified into two categories; lands suited for cultivation and lands not suited for cultivation (Gupta and Tejwani 1980). These categories can further be divided into four capability classes each (Class I - VIII).

(b) Selecting tree species for plantation

Plantations are a useful tool for restoration especially in areas where degradation is advanced, for instance in conditions of severe soil compaction, invasion by grasses, and advanced land fragmentation (Montagnini 2002). Tree plantations are sometimes the only alternative in restoring forest landscapes, at least in the short term, especially on very badly degraded soils. As the area of degraded lands expands, there is a greater need for tree species that can grow in such conditions and yield useful products (timber, fuelwood, leaf manure, non-timber forest products and others) as well as environmental benefits (recovery of ecosystem biodiversity, soil conservation, watershed protection, carbon sequestration) and other ecological effects, such as nutrient recycling, or attracting birds and other wildlife to the landscape. Within a forest landscape, the preferred choice for restoration would be natural regeneration. Planting would only be a secondary option, to be used in cases where natural regeneration cannot proceed due to the obstacles mentioned above (poor soil conditions, long distances to seed sources, isolation, invasion by aggressive grasses). Within a landscape context, there should be a balance of socio-economic goals (e.g., food grain productivity) and biodiversity conservation objectives for restoration. Fast growing, native pioneer species with high productivity are recommended for the initial stages of restoration of degraded lands (Piotto *et al*., 2003a,b; Montagnini *et al*., 2002). These species can help in facilitating the environment for late successional, longer-lived species whose end products are more valuable. Preference should always be given to local species especially those that are endangered. Native trees are more appropriate than exotics, because (1) they are often better adapted to local environmental conditions, (2) seeds may be more easily available, and (3) farmers are usually familiar with them and their use. Besides, the use of indigenous trees help preserve genetic diversity and serve as habitat for the local fauna. However, certain disadvantages are also associated with native species but they outweigh the benefits accrued from them locally. For many native species, studies on the phenology of trees may be needed (i.e., timing of flowering, fruiting, seed production, and seed collection). In addition, there must be enough seed storage capacity, which in some cases may require refrigeration, desiccation, and other procedures to accommodate seeds of tree species from mature forests. Finally, growing requirements in the nursery must also be known, including need for fertilizers, inoculation with mycorrhizae, and time when they can be transplanted to the field conditions. Farmers most often prefer species whose silvicultural characteristics are well known, and species that have well-defined end use and good markets. Seed or seedling availability in local nurseries is also an important factor defining farmers' preferences.

Information on the following ecological characteristics of tree species will be useful in selecting them for plantation purposes: light requirements, growth under different soil fertility conditions, resistance to drought, tolerance to low or high pH, tolerance to high concentrations of toxic metals, resistance against pest and disease, ability to sprout and to respond to pruning and coppicing, seed production, germination characteristics, need for inoculation with mycorrhizae, need for fertilizers, wood characteristics, and other uses. Mixed species' plantations from a number of field experiments suggest that mixed designs can be more productive than monospecific systems (Wormald 1992). In addition, mixed plantations yield more diverse forest products than pure stands. Mixed stands may also favour wildlife and contribute to higher landscape diversity. Mixed plantations thus are often restricted to relatively small areas or to situations when diversifying production is a great advantage, such as for small farmers of limited resources. Also, it is well established that land uses like agroforestry and agri-horticulture increase the soil organic content (Das and Itnal 1994). Different species vary in their capacity to build up organic carbon under similar soil and climatic conditions. The SOC in the degraded soils can be improved by adopting measures such as: (i) Conservation tillage utilizing crop residues; (ii) Growing leguminous cover crops to enhance biodiversity and produce quality residue for incorporation in soils; (iii) Adding N, P, K and all deficient nutrients to accelerate the process of humification to convert organic residues to humus besides optimizing production; (iv) Adding organic manures (FYM, compost and vermi-compost) in soil; (v) Adding soil conservation measures, viz; contour cultivation, contour and graded bunding, terracing etc. to hold humified organic residues along with the soil; and (vi) Maintaining microbial biodiversity which is inherently important to the concept of soil health and transformation of soil organic matter through various soil processes.

REHABILITATION OF LANDSLIDE AFFECTED LAND

Land suffering from landslips and landslides, mismanagement of vegetation cover through unscientific removal, overgrazing, fire, unstable geology, seismic disturbance by blasting for road construction activity, unscientific mining/ quarrying with improper road alignment, toe cutting by hill torrents, and excessive water discharge from the upper catchments are some of the factors responsible for large scale landslips, landslides and soil erosion in the Himalaya. These affect the communication and transport systems in sensitive areas. Research has shown that such slides can effectively be controlled and stabilized both by mechanical and vegetative measures (Mathur 1975; cited in Sharda 2011). The practices recommended are: (i) Enclosure of the area to eliminate grazing and exploitation of trees and shrubs; (ii) Construction of a retaining wall at the toe of the slide which could be of gabion and/or stone masonry; (iii) Protection of bare slopes through contour walling to suitable intervals (5-7m); (iv) Mulching in order to stop moisture evaporation from the soil surface and preventing direct impact of raindrops on the soil; and (v) Planting of mulched area with fast growing species, such as *Ipomoea carnea, Vitex negundo, Arundo donax, Pennisetum purpreum* and *Salix tetrasperma*. Other species such as *Woodfordia fruticaosa, Lannea grandis, Erythrina suberosa, Alnus nepalensis, Wendlandia exserta, Boehemeria rugulosa, Moringa petrygosperma, Bauhinia retusa, Melia azaderach* and *Populus ciliata* are recommended depending upon the situation. Several grasses like *Eulaiopsis binata, Chrysopogon* *fulvus, Dactylus glomerata, Lolium perenne, Eragrostis curvala* and *Cenchrus* spp. are very promising. Such areas should not be disturbed by grazing, however, grass cutting after 2-3 years of establishment may be recommended. For arresting the small landslides and hill slope instabilities resulting from erosion and mass movements of soil due to varying natural and man mad factors a set of plants and other materials (bio-engineering) has been devised under a package of practice named Mountain Risk Engineering by GBPNIHE (Agrawal 1999). This refers to the use of any form of vegetation, either alone or in conjunction with other physical measures, as an engineering material.

REHABILITATION OF GULLIED LANDS

The Siwaliks and the outer hill ranges are most affected by hill torrents due to flash floods during the rainy season. Direct impact of falling raindrops results in loosening of the soil which facilitates sheet erosion. Rills are formed which change to gullies extending their tentacles in all directions invading adjoining fertile lands. An integrated approach to watershed management is perhaps the only answer for the treatment of such lands. Control of chos can be achieved through works in the upper catchment. For stream bank erosion control, mechanical measures such as construction of bunds and spurs are carried out. The denuded catchments area treated as follows: (i) enclosure form increased human and animal influences; (ii) contour field bunding; (iii) bench terracing; (iv) contour trenching; (v) construction of vegetative and masonry check dams; (vi) gully plugging; (vi) landslip control with wattling, and (vii) sowing/planting of denuded lands.

PREVENTION OF EROSION OF STREAM BANKS

Hill streams are characterized by wide spreading bed, ill defined banks, flashy flows and swift currents. These are primarily ephemeral, flowing during the rainy season. The sudden and violent flows cause movement of large detritus comprised of boulders, shingle, sand and silt depending upon the geology. This detritus raises the bed of the rivers thus reducing the flood carrying capacity, resulting in overflows, meandering of the course of flows and erosion of the banks. Such torrents render vast agricultural areas unproductive by underscouring and deposition of boulders and over them torrent training work comprises various vegetative and engineering works, such as, construction of retards, revetments, spurs and grade stabilization. Along the eroding bank of a torrent with stable gradient, retards are erected in order to retard the stream velocities and to prevent erosion of the bank or scouring of its toes. Plantation of stream banks and islands with fast growing species such as, *Lanus nitida, A. nepalensis, Betula alnoides, Ulmus wallichiana, Trewia nudiflora*, etc., not only will reduce the action of stream currents but will also provide valuable material for various purposes.

WASTELAND RESTORATION IN THE HIMALAYAN MOUNTAINS

It is being increasingly appreciated that eco-development and environmental conservation of the Himalayan ecological systems is not only crucial to support the life support systems but also to the economy in the entire downstream catchments. The technology of the rejuvenation of the Himalayan lands, therefore, demands an integrated inter disciplinary approach for land management. Of the total wasteland in IHR nearly 51500 sq km area can be considered curable that comprised degraded forest area, scrubland, shifting cultivation area, underutilized and degraded pasture area. Over the years various methods and approaches of wasteland restoration have been implemented by several R&D organizations, Govt. Line Deptts. etc. In these approaches choice of the local people on plantation of multi-purpose indigenous tree, shrub and grasses have been given priority over the non-native species. Common tree species thus found suitable for plantation for reforestation of degraded lands are listed in Table 4. Models of land restoration such as agroforestry, agri-sylviculture, sylvi-pasture, contour hedgerow farming systems technology, Sloping watershed environment engineering technology (SWEET) involving participation of local communities and stakeholders (rural people, NGOs, College students, Govt. Deptts., Army personnel), blending science and religion etc. have been also applied (Negi and Joshi 2001). These package of practices aim to contribute towards equitable, socio-economic development of the mountain people that sustains living standards that are harmonious with the mountain environment. These approaches/ methods are briefly described as follows:

(i) Sloping watershed environment engineering technology (SWEET)

(*Source:* Anonymous 1994). SWEET is a scientific framework that promotes regeneration of degraded lands blending development with environmental conservation developed by GBPIHED. This package is an integration of a number of rural technologies such as low-cost water harvesting, polypits, nursery techniques, afforestation, bio-fencing, etc. The package, in its implementation, takes into account land use history, vegetation, physical and socio-economic setting, active participation of stakeholders, social fencing and biofencing, etc. To harvest rainwater water storage tanks are constructed on the plantation site based on rainfall pattern, water availability, and geological conditions. Community need based plant species, are grown in mixed cropping depending upon the eco-physiological vigour of the transplants are preferred. Physical as well as biological treatments of degraded lands are essential for enhancing their productive potential. Bio-composting of weeds and agriculture waste can be utilized to supplement FYM. Use of polypits for bio-composting may be encouraged. This technology package aims to contribute towards equitable, socio-economic development of the mountain people that sustains ecological balance in harmony with the mountain environment.

(ii) Participatory approach involving socio-cultural and religious ethos of the stakeholders

The ancient "Badrivan" sacred forest was revived using acclimatized planting stock and participatory approach using religious (distribution of Briksha Prasada to the pilgrims as an act of devotion to the local deity) and associated sacred and cultural ethos of people. For this high altitude native tree species such as *Juniperus macropoda*, bhojpatra (*Betula utilis*), and a shrub species, badriphal (*Hippophae salicifolia*) were planted by the priests, pilgrims and local people. To protect the tender plants in the initial few years shade to avoid snow is required. This approach was recognized and acclaimed at regional, national and international levels (Bernbaum 1995; 1999). The World Conservation Union (IUCN) has also included Badrivan approach in its guidelines for planning and managing mountain protected areas (Hamilton and Mc Millan 2004). The successful reforestation of wastelands around Badrinath shrine was also replicated in other parts of the region that clearly demonstrated the value of adopting a 'cultural approach' for reforesting degraded lands and also illustrated the importance of blending science and religion for the protection of the environment and biodiversity conservation. Further the involvement of Indian army and paramilitary people, NGOs, local priests etc. was ensured to scale up this approach for land restoration in other areas of this region (Dhyani 2014).

(iii) Plantation of multi-purpose tree species in community wastelands through stakeholders participation

This approach is mostly followed across the region, particularly around the human settlements where firewood, fodder, fiber, fruits, fertilizer (the 5 Fs) are the major resources required by the communities to sustain their livelihood (Maikhuri *et al.*, 2012). In the low altitude areas studies on the eco-physiological health of major trees found a set of species, namely Utis (*Alnus nepalensis*), Banj (*Quercus leucotrichophora*), Manipuri Oak (*Q. serrata*), Phalyant (*Quercus glauca*), Bhimal (*Grewia optiva*), *Boehmeria rugulosa*, Kharik (*Celtis australis*), *Melia azedarach* and *Sapindus mukurossi* suitable for reforestation of degraded lands (Dhyani 2014). These species perform better in the abandoned and degraded wastelands in the low to mid altitudes of west Himalayan region. It may be pointed out that species such as *B. rugulosa, Populus deltoids, A. nepalensis* and *Cupressus torulosa* endure drought and survive on degraded and dry sites. Therefore, proportion of these multipurpose tree species in plantations should be increased to meet the daily demand of forest resources the people. *A. nepalensis* is an early successional species which also had high survival (61.4%) and height growth (262cm after 3 yrs) on the degraded sites emerge as the most promising species for plantation to restore degraded moist lands (Table 5; Negi *et al.*, 1992). The other added advantage of this species is that it improves soil quality, because of its nitrogen rich litter (concentration = 3.15%) which is highest among the native species of this region.

(iv) Agroforestry for rehabilitation of abandoned cropland

In this region a number of indigenous agroforestry trees and shrubs (MPTs) grow in and around the crop fields and they serve many purposes and fulfill many needs (the 5 Fs) of the rural people (Table 6). Village people protect these trees in their crop filed bunds and cultivable wasteland, but they lack know-how on propagation and nursery and plantation technology of these species. These species are also suitable for their ecosystem services such as nitrogen fixation and soil and water conservation. For example, *A. nepalnesis* a fast growing species fixes 29-117kg of nitrogen/ha/yr (Sharma and Ambasht 1984), and regenerates profusely on fresh landslide sites, but it is inferior for fodder and fuelwood. Similarly, *Grewia optiva*, with over 75% survival yields quality fodder (crude protein, 26%) during summer, good fuelwood, fibre (used for rope making) and endures heavy lopping. *Q. leucotrichophora* is another useful species although slow growing is greatly valued as it provides quality fuelwood, leaves for manure and fodder during lean months, and is also a key species for soil and water conservation (Negi *et al.*, 1998). Apart from height growth and survival, people rightly attach a number of other values to each species. For example, the timber value of *Dalbergia sissoo* is high, *Melia azederach* suits minor timber needs, flower buds of *Bauhinia variegata* are used as a vegetable, *Ougeinia dalbergioides* is best for agricultural implements, and *Prunus cerasoides* is a sacred species and used in religious rituals. All these species can also provide green fodder year-round (Table 6). Some of these species are shallow rooted, short in stature and have a sparse crown, permitting abundant sunlight to filter through the agricultural crops, hence affecting crop yield only marginally (Nautiyal and Negi 1994). In some, leaf drop coincides with germination and growth of winter crops. As the trees complete their leafing, flowering and fruiting during summer (the fallow period of the crop fields), they stagger the demand for nutrients and moisture from soil and least affect the development of rainy season crops. Some endure high lopping stress and have a deep root system, competing very little with food crops for water and nutrients (Negi 1996).

(v) Sylvi-pasture system for restoration of community wastelands

This system was found suitable for restoration of community grazing lands. This system involves a three pronged approach

- vegetative, engineering and social. Among the vegetative component suitable combination of MPTs and fodder grasses such as both native: *Apluda mutica*, *Chrysopogon fulvus, Digitaria cruciata, Setaria* spp., and non-native: *Trifolium alexandrium, Styloxanthus hamata, Cenchrus ciliaris, Prosopis juliflora, Crotolaria juncea, Cassia tora, Panicum maximum*, fodder maize etc.) and fodder trees (mainly native; given in Table 5 and 6) need to be planted keeping in view their micro-habitat requirements. Selection of species is done based on suitability of climate, soil and people's priorities and past experiences/ findings. The concept of regeneration of good variety of native fodder grasses also need to be considered for silvi-pasture development. The Physical component includes operations such as, clearing the site for weeds and bushes, fencing, employing soil and water conservation measures (e.g., trench digging along contours, gully plugging, maintenance of terrace risers and cropfield bunds etc.). Among the social considerations participation of stakeholder's community should be a strong component to exclude anthropogenic interference (e.g., grazing, cutting of fodder/ fuelwood, protection from fire, physical participation in the silvi-pasture development etc.) from the restoration sites. Following this approach, Kothyari *et al*., (2011) achieved gradual increase in soil fertility, ground grass cover and canopy of planted fodder and firewood species and rainwater runoff and soil loss from the treated wasteland was reduced by over 60% within 12 years of project duration and a gradual reduction in women's workload.

RECOMMENDATIONS

1. Strengthening of village institutions is a key for wasteland restoration as these institutions comprise crucial traditional knowledge about dynamics of various land uses. The best practices must be scaled up.

2. Strengthen participatory consultation within and among communities to share knowledge, beliefs and resources for restoration of degraded lands.

3. Emphasize upon ecological, agro-ecological, and socio-economic considerations in wasteland restoration activities.

4. Develop strong linkages among technical institutions, village institutions, practitioners and policy planners regarding wasteland restoration activities.

5. Strengthen formal and technical information network on land rehabilitation engineering, erosion control measures and productivity enhancing techniques.

6. Inclusion of religions/cultural/economic/livelihood concerns in restoration activities so that communities have due incentive to participate in such activities. Private sector can help in some cases.

7. Rural planning must consider community wasteland restoration an important component as village people depend upon the common property resources for their livelihood. Strong and due technical, extension, education and finance support must be extended to all stakeholders.

8. Develop a restoration framework for development of various types of degraded land by addressing ecological, bio-cultural and socio-economic benefits.

9. Create/encourage an environment that promotes community innovations and practices in wasteland restoration activities.

10. Develop clear indicators of success for restoration of various types of lands. Other than cultural and economic benefits, revival of ecosystem processes must be given due weightage.

11. Technical institutes must extend all possible technical know-how to village communities to develop and restore degraded and culturable wastelands.

12. Considering the small farm size of majority of farmers, the agro-ecosystem management must focus as such lands by developing cooperative mechanisms.

13. Facilitate community mobilization for shared labour and other resources for restoration works.

14. Facilitate community skill development and training on key sectors of ecological restoration of agro-ecosystem and other land use types.

Table 1. An overview of the assessment of wastelands in India

Year	Reporting Agency	Area (million ha)	% of total area
1976	National Commission on Agriculture (NCA)	175.0	53
1980	Directorate of Economics & Statistics, Dept. of Agri. & Cooperation	38.4	12
1980	Department of Environment and Forest (BB Vohra)	95.0	29
1982	Ministry of Agriculture	175.0	53
1984	Society for promotion of Wasteland Development (SPWD)	129.6	39
1985	National Wasteland Development Board (MoEF)	123.0	37
1994	National Bureau of Soil Survey & Land Use Planning (ICAR)	187.0	57

1995	National Remote Sensing Agency (NRSA)	63.9	20
1998	Department of Rural development, Govt. of India	125.0	38
2000	National Wasteland Development Board (NWDB)*	63.9	19
2005	National Wasteland Development Board (NWDB)*	55.6	17
2010	National Wasteland Development Board (NWDB)*	47.2	14
2011	Department of Land Resources, Ministry of Rural Development*	46.7	14

Table 2. Area under each category of wasteland in India

S. No.	Wasteland Category	India Wasteland area (km^2) in 2008-09	% change over 2005-06	IHR Wasteland area (km^2) in 2008-09	% change over total WL
1	Gullied ravinous land-medium	6145.96	0.19	394.63	-0.03
2	Gullied and/or ravinous land-Deep/ very deep ravine	1266.06	0.04	517.46	-0.01
3	Land with dense scrub	86979.91	2.75	11592.27	-0.20
4	Land with open scrub	93033.00	2.94	16897.11	0.04
5	Waterlogged and Marshy land-Permanent	1757.07	0.06	404.49	-0.02
6	Waterlogged and marshy land-Seasonal	6946.31	0.22	587.38	0.12
7	Land affected by salinity/ alkalinity-Moderate	5414.53	0.17	15.47	0.00
8	Land affected by salinity/ alkalinity -Strong	1391.09	0.04	52.66	-0.01
9	Shifting cultivation area-current Jhum	4814.68	0.15	3923.59	-0.03
10	Shifting cultivation area-Abandoned Jhum	4210.46	0.13	3645.11	-0.01
11	Under-utilized/ degraded forest-scrub dominated	83699.71	2.64	10941.02	-0.07
12	Agricultural land inside notified forest land	15680.26	0.50	2376.63	-0.02
13	Degraded pastures/ grazing land	6832.17	0.22	1022.78	-0.01
14	Degraded land under plantation crops	278.53	0.01	57.38	0.00
15	Sands-Riverine	2111.96	0.07	1565.26	-0.01
16	Sands-Coastal sand	654.47	0.02	0.00	0.00
17	Sands-Desert Sand	3934.80	0.12	209.51	-0.04
18	Sands-Semi- stabilized to stabilized (>40m) dune	9279.75	0.29	0.00	-0.06
19	Sands-Semi- stabilized to stabilized moderately(15-40) due	14273.03	0.45	0.00	-0.04
20	Mining Wastelands	593.65	0.02	15.45	0.00
21	Industrial wastelands	58.00	0.00	6.35	0.00
22	Barren rocky area	59482.29	1.88	45857.84	-0.31
23	Snow cover and/or glacial area	58183.44	1.84	58183.45	0.55
Total		**467021.16**	**-0.17**	**14.75**	**-0.17**

*Wasteland Atlas of India (2011)

Table 3. State wise total area under wastelands (sq km) during 2008-09 vs. 2005-06 and % wasteland to total geographical area

S. No.	IHR States	No. of Dis-tricts	Total geo-graphi-cal area (TGA)	Total wasteland		WL (2008-09) as % of TGA
				2005-06	2008-09	
1	Jammu & Kashmir	14	101387	6021.14	75435.77	74.40
2	Himachal Pradesh	12	55673	22470.05	22347.88	40.14
3	Uttara-khand	13	53453	12790.06	12859.53	24.06
4	Darjeeling dist. (WB)	1	3149	34.97	34.45	1.09
5	Sikkim	4	7096	3280.88	3273.15	46.13
6	Assam	23	78438	8778.02	8453.86	10.78
7	Arunachal Pradesh	16	83743	5743.83	14895.24	17.79
8	Meghalaya	7	22429	3865.76	4127.43	18.40
9	Nagaland	7	16579	4815.18	5266.72	31.77
10	Manipur	9	22327	7027.47	5648.53	25.30
11	Mizoram	8	21081	73754.38	4958.64	23.52
12	Tripura	4	10486	1315.17	964.64	9.20

Table 4. Change in wasteland status during 2005-06 to 2008-09 in IHR

S. No.	Category	Wasteland area (km²) in 2005-06)	Wasteland area (km²) in 2008-09	Area change	% Change relative to 2005-06
1	Gullied ravinous land-medium	593.37	394.63	-198.74	-33.49
2	Gullied and/or ravinous land-Deep/very deep ravine	557.76	517.46	-40.3	-7.23
3	Land with dense scrub	11224.42	11592.27	367.85	3.28
4	Land with open scrub	14309.26	16897.11	2587.85	18.09
5	Waterlogged and Marshy land-Permanent	570.02	404.49	-165.53	-29.04
6	Waterlogged and marshy land-Seasonal	1036.77	587.38	-449.39	-43.35
7	Land affected by salinity/alkalinity-Moderate	16.65	15.47	-1.18	-7.09
8	Land affected by salinity/alkalinity-Strong	56.68	52.66	-4.02	-7.09
9	Shifting cultivation area-current Jhum	4586.09	3923.59	-662.5	-14.45
10	Shifting cultivation area-Abandoned Jhum	4185.53	3645.11	-540.42	-12.91
11	Underutilized/degraded forest-scrub dominated	12938.62	10941.02	-1997.6	-15.44
12	Agricultural land inside notified forest land	2386.74	2376.63	-10.11	-0.42
13	Degraded pastures/grazing land	886.78	1022.78	136	15.34
14	Degraded land under plantation crops	45.99	57.38	11.39	24.77
15	Sands-Riverine	1730.73	1565.26	-165.47	-9.56
16	Sands-Coastal sand	0	0.00	0	0
17	Sands-Desert Sand	226.07	209.51	-16.56	-7.33
18	Sands- Semi- stabilized to stabilized (>40 m) dune	0	0.00	0	0.00
19	Sands- Semi- stabilized to stabilized moderately(15-40) dune	0	0.00	0	0.00
20	Mining Wastelands	14.46	15.45	0.99	6.85
21	Industrial wastelands	6.46	6.35	-0.11	-1.70

22	Barren rocky area	53829.04	45857.84	-7971.2	-14.81
23	Snow cover and/or glacial area	40694.8	58183.45	17488.65	42.98
Total wasteland		149896.2	158265.84	8369.64	83.70
Total Geographical Area		475871			

Table 5: Survival, height growth and diameter growth of the seedlings of different species (*Source*: Negi and Dhyani 2014)

Species	Seedling Survival (%)	Height growth (cm)	Diameter growth (cm)
Acacia arabica Willd.	44.7	73.7	0.8
Acer oblongum Wall.	46.8	55.4	0.6
Albizia lebbek Benth.	52.3	58.9	0.7
Alnus nepalensis Don.	61.4	233.6	3.6
Bauhinia variegata Ham.	46.0	41.4	0.5
Boehmeria rugulosa Wedd.	67.6	65.4	4.2
Cupressus torulosa Don.	51.4	122.6	2.6
Diploknema butyracea Roxb.	44.6	31.1	0.7
Fraxinus micrantha Lingelsh.	48.1	125.1	1.1
Grewia optiva Roxb.	39.4	76.7	0.8
Melia azedarach Linn.	26.4	83.2	0.8
Populus deltoides Marsh.	47.8	149.7	0.9
Prunus cerasoides Roxb.	43.4	50.0	0.5
Pinus roxburghii Sarg.	67.5	122.1	4.5
Quercus serrata Thunb.	21.2	22.7	0.4
Q. leucotrichophora A. Camus.	41.0	84.4	1.2
Sapindus mukurossi Gaertn.	36.5	62.8	0.6
Toona ciliata Royle	53.3	57.8	0.6

Table 6. Agroforestry trees and shrubs and their survival and growth on mountain wastelands

Species	Main use	Minor use	Crude protein (%)	Season of major use	Height (cm)	Survival (%)
Non-Nitrogen Fixers						
Bauhinia variegata (D)	FD, FR	AG,F	18.1	winter	143.7±7.1	62
Celtis australis (D)	FD, FR	AG	8.2	summer	75.9± 5.9	70
Grewia optiva (D)	FD, FR	F	26.1	winter	63.9±3.9	77
Melia azedarach (D)	MT, FR	FD	18.4	Rainy	66.8±5.9	65
Prunus cerasoides (D)	SC, S	FR,FD	19.2	Year-round	167.8±10.9	36
Quercus leucotrichophora (E)	FD, FR, SC	AG	18.1	Year-round	115.7±8.1	25
Nitrogen Fixers						
Albizia stipulate (D)	FR	FD	15.0	summer	93.9±5.6	51
Alnus nepalensis (D)	SC	FR, FD	12.6	Year-round	262.3±15.0	26
Dalbergia sissoo (D)	T	FD	9.1	summer	134.0±9.8	69
Ougeinia dalbergioides (D)	FD,AG	MT, M	18.2	summer	60.0±3.3	66

FD= fodder, FR= firewood, MT= minor timber, SC= soil and water conservation, S= sacred, T= timber, AG= agricultural implements, F= fibre, M = medicine

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ORGANIC FARMING IN SIKKIM: AN APPROACH TOWARDS ECOSYSTEM RESTORATION

Depesh Subba

Sikkim Institute of Higher Nyingma Studies(SIHNS) Sheda, Pangthang (Gangtok), Sikkim, India

*Correspondence: depeshsubba11@gmail.com

ABSTRACT

Agriculture is a main source of food and livelihood for global population. In recent times, the modern agriculture practices have replaced traditional one to meet the increasing demand of food. In this process, the use of fertilizers, pesticide, insecticides or chemical use has been rampant which has put the production 'centric' agriculture in big a 'question mark' considering issue of sustainability. Therefore, the need to adopt a sustainable agriculture approach is highly felt especially in developing countries like India where the primary activity is agriculture. However, amidst such issues, Sikkim- a small landlocked Indian state located in Easter Himalayan has found its own alternative practice of agriculture by becoming the first 'organic farming' state of India overcoming topographical and environment barriers. Its success story is a 'lesson to learn' for other Indian states. However, it is still in nascent stage which proffers both opportunities and challenges. Therefore, this paper tries to comprehend the present and the future prospects of Sikkim's organic farming.

Keywords: Sikkim, Organic farming, Ecosystem, Sustainable agriculture

INTRODUCTION

Our world has been facing multiple challenges in recent years. The critical issues like climate change and environmental crisis are also among them. The recently launched IPCC 2021 report also states that there is an urgent need to correct our approach towards handling these issues. To tackle theses issues, a timely intervention in our development approach would be a key. In past, various global organizations/bodies had made numerous commitments/efforts to address such crisis; unfortunately their impact/achievement was dismal at ground level. Presently, a globally committed Sustainable Development Goals are in process to address critical global issues with aim to achieve its targets in 2030.

Similarly, a concept of 'nature-based solution' also has been in limelight recently to address the environmental and climate crisis in the development process. According to IUCN "nature-based solutions are actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits. They are undermined by benefits that flow from healthy ecosystems and target major challenges like climate change, disaster risk reduction, and food and water security, health and are critical to economic development".

The UN has also emphasized these critical environmental issues in this year's World Environment Day 2021 theme: "Ecosystem Restoration". It also marked the launched of "UN Decade on Ecosystem Restoration (2021-2030)- a global mission to revive billions of hectares, from forests to farmlands, from the top of mountains to the depth of the sea. The ecosystem restoration means preventing, halting and reversing this damage- to go from exploiting nature to healing it" (UNEP; UN).

Therefore, it is an urgent time to realize the critical environmental issue and adopt a sustainable approach in every development process as an effort towards ecosystem restoration. There are many sectors in larger development framework which needs to relook their approaches. Among them, agriculture is one of critical sectors which need a sustainable approach to address the burning issues of environmental degradation, climate change, food security.

NEED OF SUSTAINABLE AGRICULTURE PRACTICE

Agriculture is the backbone of any economy. It is the major source of income and employment opportunity for rural households especially in developing countries. In recent years, the pressure has mounded over agriculture sector due to factors like high population growth, diversion of agriculture land, environmental degradation, climate change etc. In addition, the growth rate between agriculture and non-agriculture sector has been wide. Even after diversified agriculture practices, the supply-demand gap of agriculture products remains wide. This phenomenon was rightly articulated by Thomas Robert Malthus in his book 'Essay on the Principle of Population' (1798)[i] where he stated geometric

population growth and arithmetic agriculture production.
Never the less, over the years, the agriculture practices have evolved substantially replacing rudimentary agriculture practice by efficient and scientific one to meet the increasing food demands. However, in this process, the use of fertilizers, pesticide, insecticides or chemical use has been rampant which has put the 'production' centric agriculture in a big 'question mark'. The issue of food security has been another critical issue to deal in recent years. Therefore, the need to adopt the new sustainable agriculture approach is highly felt. In developing countries like India where the majority of population depends on agriculture for their livelihood, the 'sustainable agriculture' practice has important role to play considering its huge population size, public health and environment.

ORGANIC FARMING OF SIKKIM: AN APPROACH TOWARDS ECOSYSTEM RESTORATION

Amidst such issues, Sikkim- a small landlocked Indian state located in Easter Himalayan has found a sustainable agriculture practice i.e. Organic Farming. On 18 January 2016, Sikkim declared the first fully 'organic state' of India by Honorable Prime Minister Narendra Modi. It is a positive step towards the sustainable agriculture in particular and overall sustainable development in general. Organic farming means cultivation of crops with techniques like use of manure, biological pest control, compost or vermi compost and rotation of crop (Chhetri 2015). It is a holistic management system, which enhances agro-ecosystem health, utilizing both traditional & scientific knowledge and relies on ecosystem management rather than external agricultural inputs. It is an integrated and holistic agriculture practice based on the principles of conventional practices which are free from chemically induced inputs with the blend of traditional knowledge and modern technology (Sharma

Health	Ecology	Fairness	Care
Overall sustenance and enhancement of soil health, plant, animal, ecological and public health.	Promotes health and sustainable ecological system.	Fairness and accountability regarding common environment and opportunities.	Utmost precautionary care in the practice of organic farming incorporating various dimensions for the sustainable future.

2014; Charyulu and Biswas 2010).
Agriculture is the primary activity in Sikkim. The agriculture practice is always a difficult task in mountainous Sikkim where economic 'return to scale' of production is low. It is estimated that around 15.36% of total geographical area in Sikkim is under agriculture. The farm land constitute only 10.20% and rest are covered by forest, uncultivable and non-agricultural use (Sikkim Organic Mission 2014, Govt. of Sikkim). Traditionally, the practice of chemical fertilizers in agriculture was minimal in Sikkim; that too banned completely after 2016. On 18 January 2016 Sikkim achieved a watershed development in agriculture sector by becoming the first 'Organic State' of India. The brain child behind to make Sikkim an organic state is Pawan Kumar Chamling (then Chief Minister of Sikkim). Under his leadership, Sikkim's vision to become entirely organic state was started in 2003 when the state legislature passed the resolution. The Government of Sikkim (GoS) initiated the concept of organic farming with following principles[ii]:
It also incorporates 'Nutrient Management', 'Pest Management',

Table 1. Construction of compost-urine pits and vermi compost pits in Sikkim: 2010-12

Year	District	Rural compost cum urine pits (nos)	Vermi compost pits (nos)	Total
2010-11	North	284	473	757
	East	386	608	994
	South	400	675	1075
	West	430	676	1106
	Total	1500	2432	3932
2011-12	North	210	94	304
	East	1532	531	2063
	South	1597	362	1959
	West	1687	369	2056
	Total	5026	1356	6382
Grand Total		6526	3788	10314

Source: Comprehensive Progress Report 2014, Government of Sikkim.

'Disease Management' and 'Moisture Management'. Some of initiatives taken by the GoS to strengthen organic farming are: removal of subsidy on chemical fertilizers and pesticide, closing of selling points and non issue of license to fertilizers and pesticide traders, restriction on transportation of pesticides and fertilizers from outside, reduction of

Table 2. Status of organic conversion and certification

Financial Year	Target (ha)	Achievement (ha)
2010-11	18,000	18,234
2011-12	18,000	19,216
2012-13	14,000	19,188
Total	50,000	56,638

Source: Comprehensive Progress Report 2014, Government of Sikkim.

Central Government's quota on chemical fertilizers and pesticide, issue of certificates to organically produce products, construction of compost and vermi compost in rural areas at subsidized rate, establishment of Integrated Pest management (IPM) laboratory, seed proceeding units. Further, the adaptation of bio-village, the subsidized vermi composting pit construction, use of certified organic manure and bio-fertilizers are among others. Till 2009, more than 100 villages adopted the bio village profiting more than 10, 000 farmers across four districts. The construction of rural compost and vermi compost has been major infrastructural boost for organic farming. (Sikkim Organic Mission, GoS, 2014). The construction of compost-cum-urine pits and vermi compost pits has substantially increased in the year 2010-11 and 2011-12 across four districts. Following are the district-wise detail of compost-cum-urine pits and vermi compost pits construction:

There has been substantial increase in the installment of compost-cum-urine pits and vermi-compost pit within one year gap. It is observed from the table 1 that compost-cum-urine pits recorded high growth from 1500 units in 2010-11 to 5026 in 2011-12 (grand total 6526) whereas vermi compost declined from 2432 to 1356 units (grand total 3788). However, overall combination of compost-cum-urine pits and vermi-compost pit has increased manifold from 3932 to 6382 in one year making overall grand total of 10314 units From 2010 onwards, Sikkim has been achieving considerably more than its target in conversion and certification under organic land. Till 2012-13, Sikkim had total 56,638 hectare of land under organic farming certification achieving more than its target of 50000 hectare. In 2016-17, Sikkim had produced about 80,000 metric tonne of various organic vegetables over farm area of 14,000 hectares out of the certified land of 76,392 hectares after becoming a fully organic state (Khorlo Bhutia, Secretary, Horticulture and Cash Crop Development Department, GoS 2014).

FUTURE PROSPECT: OPPORTUNITIES AND CHALLENGES

The organic farming of Sikkim is still in its nascent stage

Dalley khorsani (Chilli)

Rayo saag (spinaches)

Tarul (Tubers)

Besar (Turmeric)

Lasun (garlic)

Tomato

which proffers both opportunities and challenges.

Opportunities

Over the years, the demographic composition of Sikkim has changed, constituting considerable chunk of young unemployed population. With growing young population with limited employment opportunities is bound to have socio-economic repercussion. This has been critical issue to address in Sikkim. To address the issue, the GoS has been promoting numerous initiatives in tourism, ecotourism/ village tourism to ease the pressure of demographic dividend. Like these sectors, the doors have also opened up in the field of organic farming as well. The GoS has been offering various initiatives like loans (interest free or partial free), agriculture inputs like construction of green-house, tanks, distribution of animals, biogas pits and vermi compost pit to promote organic farming. Here, youths can venture and flourish the concept of organic farming from local-to-global level. The 'organic product' has scope in both domestic and international market as demand for 'organic product' is high and it continues to be so. With changing lifestyle, environment and health concerns, the demand for organic products is further set to intensify and Sikkim can become a major player/exporter of organic products. The possibility is there to get brand or trademark recognition like Geographical Indicator (GI)[iii] tag for organic products like Sikkim's large cardamom which is in the list of GI items. Similarly, Sikkim specific agriculture products which have socio-cultural essence like tubers, 'dalley khorsani' (chilli), zinger, turmeric, garlic, 'kinema' (fermented soyabean), 'gundruk' (fermented spinach) have potential to flourish. Besides these, other products like Kiwi fruit, cardamom, ginger, turmeric have huge production potential. Organic farming not only restricts in typical 'farming' but it also encourages other allied agriculture activities like livestock, dairy sector because they are complementary to each other.

Challenges

Over the years, the area under agriculture has been decreasing in Sikkim due to factors like fragmented landholdings, urbanization and conversion of agriculture land to non-agriculture land. Diversion of cultivable land in the name of development activities can downplay the idea of 'organic farming'. For instance, Sikkim is rapidly becoming an industrial hub at the cost of agriculture land. Sikkim has already more than fifteen major Pharmaceutical companies and many developmental projects in a small geographical area. In addition, the shift in household pattern from traditional joint family system to nuclear family has further results the fragmentation of already scarce agricultural land. Therefore, it is challenging task to prevent such diversion of agricultural land.

SUGGESTIONS

To make organic farming successful there should be short, medium and long term strategies. Although, the production from 'organic farming' alone is insufficient to fulfill the demand but it will definitely eases the burden of dependence to other states. It will be satisfactory if it meets the local demand and eases high local food inflation. Therefore, self reliant in local agricultural products should be Sikkim's first priority followed by long term strategy like export. Sikkim also needs a comprehensive plan integrating agriculture and livestock production to utilize nutrient cycle in its optimum level. Further, it is suggestive to strengthen the infrastructures (transport facilities, smooth electricity supply) and cold-storage facilities along with well-knitted market mechanism for equitable and efficient distribution of organic products. The provision of soil testing, issue of soil health cards and auditing from various agencies should be done at regular interval. Importantly, insurance to farmers in case of crop failure or low production should be there along with price mechanism. In addition, public awareness and vocational training at village, school or higher level is highly felt. It is also equally important to stimulate the agriculture practices among public especially among young generation. Therefore, the collective efforts from farmers, local mass media, schools, communities or NGOs, NABARD and cooperative banks, 'panchayats', self-help groups, civil society, youths, bureaucrats and research institutions like ICAR are crucial to make the organic farming of Sikkim successful.

CONCLUSION

Organic farming of Sikkim is an area-specific resilient and sustainable agriculture practice which is evergreen source of income. It should look from the spectrum of sustainable agriculture instead of 'production' centric agriculture. It has multiple socio-economic and environmental implications which directly counter twin challenges i.e. local food security and sustainability in long run. In fact, it is a nature-based solution towards ecosystem restoration in real sense.

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END NOTES

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According to the WTO, "Geographical indications are indications which identify a good as originating in the territory of a Member, or a region or locality in that territory, where a given quality, reputation or other characteristic of the good is essentially attributable to its geographical origin."

PARTICIPATORY WATER RESOURCE DEVELOPMENT AND REHABILITATION OF DEGRADED LANDS FOR THE LIVELIHOOD IMPROVEMENT OF TRIBAL FARMERS IN MID HIMALAYAN REGION

J.M.S. Tomar*, R. Kaushal, S.K. Kar, D. M. Kadam, A.C. Rathore, Ramanjeet Singh and R. Singh

ICAR-Indian Institute of Soil and Water Conservation, Dehradun, Uttarakhand, India

***Correspondence:** jmstomar@gmail.com

ABSTRACT

Inhabitants of mid-Himalayan region have to struggle for adequate water resources, food security, and sustainable livelihoods due to various topographical and socio-economic constraints. Considering the situation of natural resource degradation and associated livelihood challenges in selected village, a four-step strategy was devised to address critical problems; 1) Participatory water resource development 2) Diversification of crops through high value vegetable farming 3) Mushroom cultivation and 4) Rehabilation of degraded community land through agroforestry in conjunction with soil and water conservation measures. Project interventions led to development of adequate water resources at farmers field. Perennial springs located at higher altitudes were tapped and water was transferred through HDPE pipes to cemented tanks located in farmers' fields. After availability of water resources, high value vegetable crops such as tomato, cucumber, onion and green pea were promoted to diversify existing traditional mono-cropping. It led to significant enhancement in farmers income, manifested in terms of more than 2.5 fold increment in net income. Similarly, adoption of mushroom cultivation led to creation of additional annual income of Rs. 34,250 per year. Our efforts pertaining to rehabilation of degraded community lands via promotion of agroforestry in conjunction with different soil and water conservation practices led to increase in fodder and fuelwood availability in project area. Besides, several intangible benefits such as prevention of soil erosion, enhancement of soil organic carbon and water recharge were realised by villagers.

Keywords: Watershed, Spring water harvesting, Crop diversification, Participatory approach, Degraded land and Water resources

INTRODUCTION

About 70% of the mountainous population of Uttarakhand state depends on agricultural activity for their sustenance and livelihood security. However, various climatic, geographical, and socio-economic constraints have led to an abysmally low level of agricultural productivity in the region. Irrigation water availability is the most critical resource for sustaining the livelihoods of people living in this region. Though mid and high hills of the state fall under annual rainfall range of 1000-2500mm, most of it flows down the steep slopes as runoff and is not available for agriculture and domestic use. Therefore, the inhabitants of these reaches in the Himalayan region have to struggle for adequate water resources, food security, and sustainable livelihoods due to various topographical and socio-economic constraints (Dadhwal *et al*., 2012; Tomar *et al*., 2013). Thus, majority of North-west Himalayan regions present an enigmatic situation of paucity amidst plenty on the water front (Singh *et al*., 2020). For several generations, the inhabitants of the Himalayan region have to depend on the natural water springs and streams to meet their daily needs for drinking water purposes and domestic uses such as irrigation, animal consumption, etc. Traditional water harvesting, such as Nahlas, Khals, and Guhls, plays an important role in the hilly region, meeting domestic, livestock, and irrigation needs. But these are inadequate to meet the present day's rising water demand. Furthermore, modern techniques such as lift irrigation through electric motors have limited applicability due to heavy investment and other geographical limitations. Alternatively, gravity based spring water harvesting through community participatory approach could be sustainable way to meet rising agriculture and domestic water demand (Singh *et al*., 2020). This technology involves transfer of water from untapped perennial springs positioned at higher elevations to the storage tank situated at lower elevations in village through low cost pipes. About 90% of the agricultural lands, spread across the mid and high hills, are rainfed and vulnerable to severe soil erosion and degradation due to erratic rainfall, cloud bursts, and long, uncertain dry spells during crop growth (Tomar and Bhatt 2005). Watershed development has been considered as an essential strategy for enhancing agriculture productivity, ecological and livelihood security of rural communities residing in vulnerable ecosystems (Rao 2000). However, the active involvement of the local community in the watershed developmental activities is of utmost importance for the successful implementation of developmental programmes (Wani *et al*., 2003). Considering the situation of natural resource degradation and associated livelihood challenges in North-west Himalayan region a holistic scientific framework for development of water resource, rehabilation of degraded land and livelihood security was developed and excuted through peoples' participation.

MATERIAL AND METHODS

Study area

The present study was conducted in Sahiya-Udpalta village, located at a latitude of 30'36'20" N, and longitude of 77'51'42" E, and an elevation of 1523m in Dehradun district of Uttarakhand state (Fig. 1).

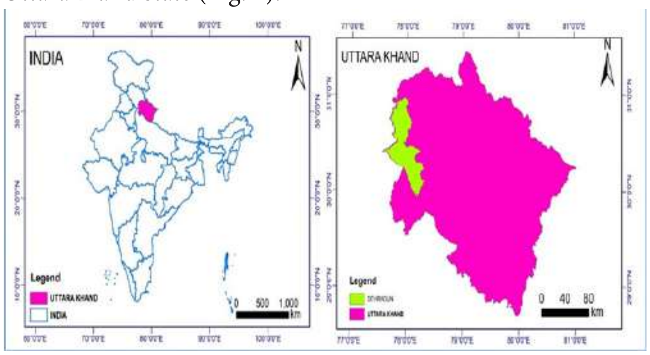

Fig. 1. Location map of the study area

There are about 70 households in the village of Udpalta, and more than half are engaged in agriculture, while the remaining half are involved in labour and other livelihood activities. The people of this village belong to the scheduled tribe (Jaunsari) and have their own unique socio-cultural traditions and value system. This tribal village is neglected in many aspects, including assured irrigation for the crop at critical growth stages, drinking water during the lean period and market/input supply. Besides, soil erosion and landslides are significant problems (Photo 1).

Photo 1. Discussion with local farmers' regarding project activity

The majority of the farming community belongs to the marginal to poor farmer category and depends on traditional farming/animal husbandry activities. The village landscape is divided into settled agriculture on terraced sloping landscape with scattered trees of *Grawia optiva* and *Celtis australis*. For meeting the fodder and fuelwood needs villagers are mainly depended on deodar and mixed forest surrounding their village. The climate of the project area is sub-temperate with a prominent winter season with average maximum and minimum temperature of 38°C and 1°C, respectively. Rainfall in the area is mainly received during monsoon season from July to September. In winter, the surrounding hills also receive snowfall.

Problem identification

Before initiation of study, rapid rural appraisal was conducted through field group discussion, series of meetings, farm visits and interactions with farmers' and stakeholders in 2016-17. Multiple factors were considered for survey such as eco-physiological and environmental situation, agriculture and socio-economic status, farmers' perceptions and problems etc. Following broad constraints affecting natural resource base, agricultural production and livelihood security of inhabitants were recorded in the study area.

1. Water scarcity: Inadequate water availability for agricultural production and domestic use was identified as principal constraint. Scarcity of water during lean season was key challenge affecting agriculture. We noted huge potential of agricultural development and diversification if water paucity problem is addressed properly.
2. Land degradation: The majority of village land has intrinsic constraints such as steep slopes, undulating topography and fragile geology, which favour intense soil erosion in the region. Therefore, increased barren or underutilised land with features like shallow soil depth with high percentage of gravels/pebbles/stones, poor soil organic carbon, low soil fertility and low water holding capacity etc.
3. Small and scattered land holdings with less crop diversification were predominant in the area. Farmers had traditionally relied on monocropping of cereals and minor millets. Hence, most of the cropping systems were far from their productive potential.

One or more of these reasons shattered the enthusiasm and interest of the farming community in agriculture, besides non-availability of sufficient job opportunities at the local level are key reasons for the migration of rural youths to urban and plain areas.

Action Framework

A scientific framework to address the vital issues of water scarcity, degraded land and monocropping in agriculture was formulated. After detailed deliberation, four stride strategy was devised under this framework; 1) Participatory water resource development through spring water harvesting. 2) Promotion of vegetable based alternate land use systems to diversify agriculture systems. 3) Introduction of mushroom cultivation, capacity building and entrepreneurship development and 4) Rehabilitate community degraded land with agroforestry and soil and water conservation measures.

RESULTS AND DISCUSSION

Participatory water resource development

A detailed field survey was conducted with the help of local people in watershed region in order to identify natural perennial springs with sufficient discharge. Different natural springs with year-round water availability were selected for water harvesting. Accordingly, one perennial spring positioned 4km away from Udpalta village in upper riches, having sufficient discharge of approximately 2 lps throughout year was selected for tapping (site 1, Fig. 3). Subsequently, inlet chamber was constructed near selected spring (site 2, Fig. 3). The HDPE pipeline (1 inch) of approximately 4km was laid in the rugged hilly terrain to harvest water from selected perennial spring. This HDPE pipeline was connected to the water tank for temporary water storage in the farmer's field at site 5 (Fig. 3). Similarly, five other perennial springs located at different sites in nearby hillhocks were tapped to provide water at farmers' fields (Details given in Table 1). The HDPE pipeline was laid out through participatory-based approach. Cleaning and rejuvenation of old tanks, as well as the construction of new tanks were carried out in the project activity. The developed water resources were utilised for agricultural purposes such as vegetable production (tomato, cucumber, onion, green pea etc.) and to meet the domestic needs of farmers' households.

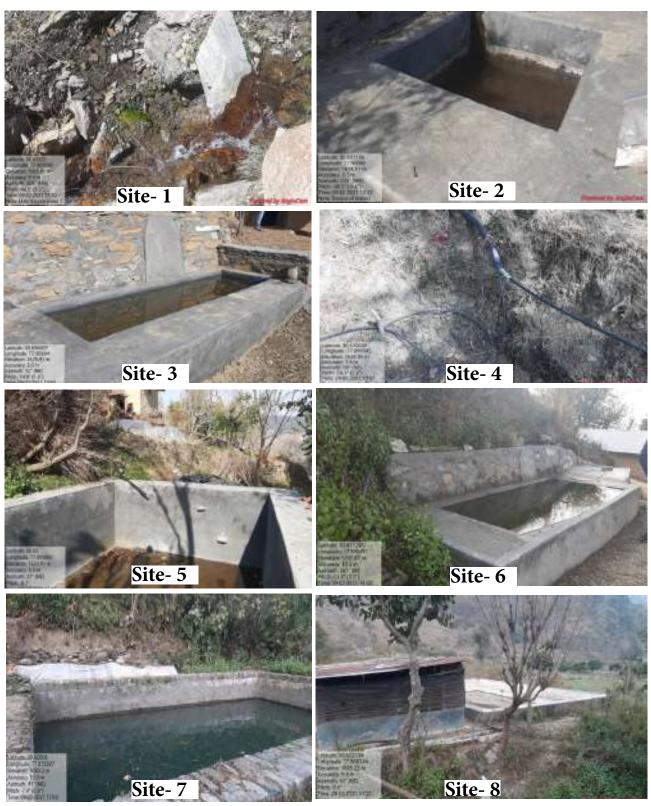

Fig. 3. Water resources developed at different sites of the village

Promotion of vegetable based alternate land use systems to diversify agriculture systems

Prior to intervention, farmers' were mainly engaged in cultivation of traditional crops such as wheat, finger millet, maize, paddy and potato. Details of baseline data for crop area, production, gross and net income before intervention (2016-17) are summarised in Table 1. Before the intervention, the farmer used to get gross income of Rs. 85626 and net annual profit of Rs. 52,435.00 from 3 acres of land (2016-17) (Table 1). After development of water resources through participatory approach i.e., spring water harvesting and water storage in tanks, farmers' exhibited interest in cultivation of high value vegetable crops. Accordingly, seeds of high yielding vegetbale varieties such as tomato Cv. Himsona, cucumber Cv. Malini, onion Cv. Agri- found light red, green pea Cv. Golden GS-10 and toria Cv. Hill-1 provided to farmers' (Fig. 4). Additionally, selected fruit species like mango and guava were also promoted on the fallow land. The details of area, production, gross and net income of vegetable crops is provided in Table 2. Farmers realised a > 2.5 fold increase in net income (Rs. 145835.0) compared to earlier traditional agriculture systems (Rs. 52,435.00) due to the availability of irrigation water and high-yielding vegetable varieties.

Table 2. Status of traditional crop area, production, gross and net income before intervention in 2016-17

Name of crop Component	Benchmark (Baseline period 2016-17)			
	Area (acre)	Production (Q)	Gross Income(Rs)	Net Income(Rs)
Wheat	0.20	1.56	2627	1620
Finger millet	0.50	3.30	9234	6200
Maize	0.75	6.90	10690	7540
Paddy	0.20	1.82	2675	1275
Potato	0.30	15.50	12400	7800
Tomato	0.60	31.0	48000	28000
Fallow land	0.45	-	-	-
Total	**3.00**	**60.08**	**85626**	**52435.00**

Table 3. Status of high yielding vegetable crop area, production, gross and net income after intervention in 2020-21

Name of crop Component	Area (acre) Number	Production (Q)	Gross Income (Rs)	Net Income (Rs)
Tomato (Cv. Himsona)	0.60	45.00	74250	57375
Cucumber (Cv.Malini)	0.30	22.65	27180	14242
Onion (Cv. Agri-found light red)	0.30	33.00	26400	18460

Green Pea (Cv.Golden GS-10)	0.50	22.64	57051	36433
Paddy	0.40	7.50	6750	3730
Toria (Cv. Hill-1)	0.50	1.12	8100	3100
Fellow land (Fruit trees)	0.40	At present in juvenile phase	-	-
Total	3.00	131.91	199731	133340.0

Fig. 4. Successful adoption and cultivation of high-value vegetable crops in Udpalta village

Mushroom production and entrepreneurship development

In order to diversify income sources and provide employment opportunities to rural youth, mushroom cultivation was encouraged in Udpalta village. Two speicies of mushroom namely button mushroom (*Agaricus bisporus*) and oyster mushroom (*Pleurotus* spp.) were promoted. Initially, five farmers were trained and guided in scientific mushroom cultivation and subsequently technological backstopping was provided for establishment of low-cost mushroom unit using locally available resources. Consequently, one low-cost mushroom unit was established in an abandoned house by Mr. Pradeep Rai, with 3-tier rack made of bamboo sticks and mud floor. Subsequently, spawn of button and oyster mushroom was provided for initiation of culture. After taking up mushroom cultivation, farmer is now getting an additional annual income of Rs. 34,250 per year.

Rehabilitation of degraded community land

Community land of around 1ha positioned adjacent to village was severely degraded due to continuous erosion and landslides caused by heavy rains and cloud bursts during monsoon season. The vegetation at the site consists of scattered scrub and annuals. In order to rehabilitate community degraded land, three tree species namely, Oak (*Quercus leucotrichophora*), Kachnar

Table 1. Details of water resources developed in project area

Site No.	Location details	Latitude	Longitude	Altitude (m)	Tank size L x W x H (m)	Volume (lit.) of water storage developed	Remarks
1	Perennial natural spring tapped	30.632158	77.902034	1665.81	Water diverted to inlet chamber at sl no. 2	Source	Key source of water for village
2	Inlet chamber	30.631155	77.90066	1674.91	1*1*1	1000	Inlet chamber constructed near main perennial spring for water harvesting
3	Cemented water pond at Guadeke kheda	30.630007	77.90204	1625.91	4.5*1*1	4500	Approx. 1Km HDPE pipe line (0.5 inch) was laid out to tap water from natural spring
4	Connected with low cost polylined tanak	30.630059	77.899945	1634.85	2*1*0.5	1000	HDPE pipe (0.5 inch) was laid out from approx. 1Km distance and located in polylined tanak for irrigation purpose.
5	Cemented water pond at Udpalta	30.62	77.893861	1623.91	6*4*1.6	38400	HDPE pipe line (1.5 inch) were laid out from approx 3km distance main water source through participatory mode.
6	Cemented water pond at Siliya kheda	30.621245	77.886491	1397.07	1.5*1*0.75	1125	HDPE pipe line (0.5 inch) were laid out from approx. 1km away natural spring through participatory mode.
7	Cemented water pond at Sahaiya kheda	30.62006	77.872297	1083.2	10.5*6*2.5	150000	HDPE pipe line (1.5 inch) were laid out from 2km distance to tap water from Shyarli khad through participatory mode
8	Cemented water pond at Amlawa gad	30.622134	77.868144	1069.22	12.5*8*1.5	150000	1 km HDPE pipe line (1.5 inch) were laid out and water colledcted in storage tank for integrated farming

(*Bauhinia variegate*) and Siris (*Albizia lebbeck*) were selected. Similarly, to meet the fodder and fuelwood demand, saplings of Bhimal (*Grewia optiva*), Mulberry (*Morus alba*) and Kharik (*Celtis australis*) were provided to the farmers for plantation on bunds. On degraded lands, one year old nursery raised seedlings were planted at distance of 3m on contour lines in staggared manner. For planting the seedlings, pit of 45cm x 45cm x 45cm was dug out. The trees were planted randomly to develop mixed plantations. The interspace of trees was planted with Chrysopogon fulvus at spacing of 50cm x 50cm. Soil and water conservation measures such as staggered contour trenches, gabion cross barriers, brushwood check dams, coir geotextiles etc., were adopted to control soil erosion and conserve moisture. Each tree was supported by staggered trenches of 2x0.3x0.3m. To check the extension of gully erosion, bush wood check dams were erected on mild slopes and gabion check dams were constructed on steep slopes. The area prone to mass erosion was protected by coir geotextile (700GSM density). The ends of coir geotextile were placed with wooden bags of Salix to support them in place. The coir geotextile area was broadcast with the help of root slips of lemongrass. All the sites were well protected with barbed wire fencing which was further supported by bio-fencing of Agave americana to restrict the entry of stray animals and minimise other disturbances .

Fig. 5. Successful Mushroom cultivation

Three years old oak plantation

After 6 year oak plantation

Contour trenching on sloping land

Fig. 5. Rehabilitation of community degraded land through agroforestry in conjunction with soil and water conservation measures in Udpalta village

In erosion-prone sites having slopes varying from 30-50%, soil and water conservation measures viz., coir geotextile (400 Sqm coir geotextile with 700GSM density) and staggered contour trenches (SCT) were implemented. A diversion drain was dug at the top of the site to drain excess runoff. We noted strong potential of soil conservation measures in improving vegetation growth, ecological features, and soil properties. We observed species richness in soil and water conservation measures (Coir geotextile, wattling, and staggered contour trench) on higher side by 41.7%, 22.9% and 20.8%, respectively, compared to control (14.5%). Altogether, plant taxa in control and conservation treatments were represented by 25 species belonging to 9 families. Asteraceae and Poaceae were noticed to be the dominant families with 8 and 5 species, respectively.

Table 5. Details of tree species alongwith adopted land use at project site

Tree species	Common Name	Land use
Albizia lebbeck	Siris	Rehabilitation of degraded lands
Celtis australis	Kharik	Plantation on farm bunds
Bauhinia variegate	Kachnar	Rehabilitation of degraded lands
Grewia optiva	Bhimal	Plantation on farm bunds
Morus alba	Mulberry	Plantation on farm bunds
Quercus leucotrichophora	Oak	Rehabilitation of degraded lands

DISCUSSION

We found remarkable impacts of different project activities on farmers' livelihoods and natural ecosystems reflected in terms of augumentation in net family income, agriculture diversification and land rehabilitation through agroforestry and soil and water conservation. We noted several tangible and intangible benfits such as increase in water availability in water scarce areas, crop diversification through an increase in cultivation of high value vegetable crops and increase in crop production and productivity on sustained basis. In hilly state of Uttarakhand, around 10 to 12% of agricultural lands are irrigated in hilly districts as the present surface and sub-surface (springs) water resources have not been tapped extensively. Consequently, agriculture in this hilly districts is mainly rainfed, subsistence or there is not enough surplus for the market. We successfully developed spring water harvesting model at project sites in participatory mode. It acts as sustainable solution to address water scarcity in hilly areas; and is an efficient tool for mitigating climate change. This low-cost water harvesting technology enhances the water for agriculture and domestic needs in farmers' fields. Earlier Singh *et al.*, (2020) highlighted the significance of spring water harvesting in hilly regions of Uttarakhand. They reported availibity of total of 670m^3 water per day to the farmers' through spring water harvesting, which has led to 3.17- fold increase in net irrigated area. Moreover, spring water harvesting in participatory mode holds potential for other hilly areas such as lesser Himalayas, Western Ghats, etc. Furthermore, it is aptly appropriate for a group of small-and marginal-farmers in hilly areas to develop a common as well as individual water resource for sustainable development.

After availability of water resources, we promoted high value vegetable crops such as tomato, cucumber, onion, green pea, toria etc. It led to significant enhancement in farmers income, manifested in terms of more than 2.5 fold increment in net income. Thus we successfully diversified the traditional agriculture systems and diverted farmers' away from traditional, non-viable monocropping of cereals.

The major driving force behind this change is the establishment of water resources for irrigation by introducing a cost effective technological intervention of spring water harvesting. Earlier, Birthal *et al.*, (2007) reported that agricultural diversification toward high-value crops has the potential to boost farm incomes of smallholder farmers. Irrigation enables farmers to diversify their crops through year-round farming. This can boost food security and profitability by enabling farmers to grow a greater range and variety of commodities and benefit from seasonal price variations in the market. Diversification, both in agricultural production and income sources, reduces the risks associated with crop failure: diseases, pests, extreme climate events, fluctuating market demand and commodity prices (Joshi *et al.*, 2004; Cunguara and Garrett 2011). In our study, promotion of low-cost mushroom cultivation led to significant enhancement in farmer's income reflected in the form of additional annual income of Rs. 34,250 per year. Mushroom cultivation is profitable for landless persons, unemployed youths, and women who can adopt it as a business. Mushroom are an indoor, short-duration crop, that utilises vertical space and converts agricultural and forestry wastes into nutritious food (mushrooms) and organic manure (Das 2014). Singh *et al.*, (2019) reported that mushroom production was found to be the most important source of income, accounting for 37.74 percent of total income.

Our efforts pertaining to rehabilation of degraded community lands via promotion of agro-forestry in conjunction with different soil and water conservation practices led to increase in fodder and fuelwood availability in project area. Additionally, several intangible benefits such as prevention of soil erosion, enhancement of soil organic carbon and water recharge were realised by villagers. Earlier, significance of soil and water conservation practices such as staggered contour trenches and geo-jute application for enhancing tree survival and to checking soil erosion was noted by Tomar *et al.*, (2012) and Chaturvedi *et al.*, (2014). Application of geo-jute in erosion prone hilly region has ability to check the detachment of soil particles and intercept splashed particles. It can also improve soil contact and enhance water storage of soil, thus increases soil moisture availability.

CONCLUSION

The development of participatory water resources through spring water harvesting, subsequent promotion of high value vegetable crops, mushroom farming, and rehabilation of degraded land through agroforestry by adopting soil and water conservation measures aided the sustainable development of tribal villagers. Inventive, scientific, and need based participatory project interventions taken up have exhibited remarkable impact with enhancement in water availability for irrigation in a sizable area and diversification of traditional agriculture through cultivation of high value vegetable crops and mushrooms, with many fold increase in annual net income. Furthermore, agroforestry promotion in conjunction with soil and water conservation practices holds potential to rehabilitate degraded land in hilly terrain.

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ECOSYSTEM RESTORATION AND BIODIVERSITY CONSERVATION PRACTICE IN ETHNIC COMMUNITIES OF ARUNACHAL HIMALAYA

K.S. Kanwal

G.B. Pant National Institute of Himalayan Environment, Himachal Regional Centre, Mohal, Kullu, Himachal Pradesh, India

Correspondence: kskanwal@gbpihed.nic.in

ABSTRACT

United Nations General Assembly declared the 2021–2030 the UN Decade on Ecosystem Restoration with main objectives to scale up the restoration of degraded ecosystems and provide solutions for mitigating climate change impacts including strengthening food, water, and biodiversity conservation opportunities globally. As per the United Nation Environment Programme (UNEP) projection, restoration of 350 million hectares of degraded land during 2021-2030 could generate USD 9 trillion in ecosystem services and additionally 13-26 gigatons of greenhouse gases (GHG) would be removed from the atmosphere. For achieving the above ambitious targets and expansion of restoration efforts from small landscape to areas of millions of hectares, engagement of diverse range of stakeholders particularly local communities would be essentially required. Eastern parts of India is home of indigenous communities, which live in close harmony with the nature. Arunachal Pradesh popularly known as the land of rising sun is the largest mountain state in North-East India. The state is uniquely situated in the transition zone between the Himalayan and Indo-Burmese regions, and recognized as one of the 25 mega biodiversity hotspots of the world, and also among the 200 globally important ecoregions. Forest is the most important resource in the state with the predominantly 26 major tribe groups and more than 110 minor ethnic/tribal communities living in close association with forests and highly dependent on numerous forest products for their livelihood. Indigenous communities of the state have developed various traditional practices after practical interventions and observations for ecosystem restoration, resource management including biodiversity conservation. The present article provides an overview of various Ecorestoration and Biodiversity Conservation practicies carried out by ethnic communities of Arunachal Pradesh and also suggest future way forward actions to scale up these efforts. Collective action and wider partnership of diverse stakeholdersareurgently required for strengthening the efforts of ecosystem restoration and conservation of biodiversity of the state.

Keywords: Ecosystem Restoration, Indigenous knowledge, Biodiversity conservation, Sustainable development, Arunachal Himalaya

INTRODUCTION

As per UNEP, ecosystem restoration is defined as a process of reversing the degradation of ecosystems, such as landscapes, lakes and oceans to regain their ecological functionality. It can also be defined as to improve the productivity and capacity of ecosystems to meet the needs of society. This can be done through promoting natural regeneration of overexploited ecosystems. United Nation general assembly declared the 2021-2030 the UN Decade on Ecosystem Restoration with main objectives program to massively scale up the restoration of degraded and destroyed ecosystems and provide solutions for climate change global impacts including strengthening food, water, and biodiversity conservation opportunities globally. Globally, about 20% of the world's vegetation cover is showing declining trends in productivity linked with erosion, depletion and pollution. Climate change and ecosystem degradation could reduce crop yields by 10% globally and up to 50% in several parts of the world by 2050. Ecosystem restoration is key to achieving the Sustainable Development Goals, primarly linked with climate change, poverty eradication, food security, water and biodiversity conservation Ecosystem restorationis also a main pillar of international environmental conventions viz. Ramsar Convention on wetlands and the Rio Conventions on biodiversity, desertification and climate change. Eastern Himalayan region of India is home of around 200 indigenous communities, which lives in close harmony with the nature. Arunachal Pradesh also popularly known as the "land of the dawn-lit mountains" is the largest mountain state in North-East India. It covers a geographical area of 83,743km^2, which constitutes 2.54% of the total area of the country, 15.76% of the Indian Himalayan Region and 43.62% of the Himalayan Biodiversity Hot Spot (Samal *et al.*, 2013). The state is uniquely situated in the transition zone between the Himalayan and Indo-Burmese regions, being recognized as one of the 25 mega biodiversity hotspots of the world and also among the 200 globally important ecoregions. Arunachal Pradesh is also prevalently known as "cradle of all flowering plants" and "paradise of the botanists". The state is endowed with vast natural resources viz. water, forest, non timber forest products (NTFP), minerals, agriculture and biological resources. Culturally, the state is also quite rich being home to 26 major and more than 110 minor tribal communities. The major tribes are Adi, Aka, Apatani, Bangni, Hill Miri, Idu, Khawa, Khamba, Khamti, Memba, Miji, Mishimi, Monpa, Nah, Nocte, Nyishi, Sherdukpen, Singpho, Sulung, Tagin, Tangsa and Wancho. The indigenous community of the Arunachal Pradesh mainly depends on agriculture and forest resources for their sustenance and livelihood requirement. As per the Wasteland Atlas of India 2019, the wasteland/degraded has been increased by 167.47km^2 between 2008-2016 in Arunachal Pradesh. Shifting cultivation (abandoned Jhum land) has increased by 256.72km^2 in the state. Deforestation and loss of vegetation cover are the main factors for land degradation and desertification in the region (Fig 1).

Indigenous communities of the state have developed various traditional practices after practical interventions and observations for ecosystem restoration, resource management including biodiversity conservation. Traditional ecosystem resources management practices have sustained the tribal communities and also played key role in conservation of biological resources of this Himalayan state. Traditional practices in resources management are basically people's innovations to environmental stress and transformation developed and refined through trial and error. Keeping in view of above, the present article provides an overview of various Ecorestoration and Biodiversity Conservation efforts carried out by ethnic communities of Arunachal Pradesh and also suggest future actions to scale up these efforts.

Fig. 1. Deforestation and loss of vegetation cover main factors for land degradation and biodiversity loss in the Arunachal Himalaya

METHODOLOGY

The information on status of natural resources, forest, ecosystem restoration, biodiversity and traditional indigenous knowledge system of community of Arunachal Pradesh were collected from review of existing literature viz. research papers, books, reports, thesis, monographs etc. The information was also collected from online resources particularly information available in government websites. Five field survey and consultation with local communities was also carried out in Ziro valley, Yazali of Lower Subansiri district, Lumla, Jung and Seru villages of Tawang district, West Kameng, Papumpare and West Siang districts to get the firsthand information on natural resource management, ecorestoration and biodiversity conservation in Arunachal Himalaya.

RESULTS AND DISCUSSION

Biodiversity of Arunachal Pradesh

Arunachal Pradesh contains nearly 50% of the total flowering plant species (about 5000 sp. of angiosperm) in India (Takhtajan 1969). The flora of state comprises about 29 species of Gymnosperm, 452 species of Pteridophytes and large number of other lower plants species (Sinha 2008). The state is recognized as 'Orchid Paradise' because of having the highest concentration of orchid species. Out of about 1350 species of orchids known so far from India, about 558 species (about 40% of the country) of orchids belonging to 144 genera are reported from Arunachal Pradesh (Rao 2010). The state also harbours about 61 species of Rhododendron (out of 72 species known from India) out of which 9 species and 1 subspecies are endemic. Besides this, there are about 18 species of *Hedychium*, 16 species of *Quercus*, and a large number of ferns and lichens occur in the state (Sinha 2008). The endemic and threatened species may face severe endangerment under the anthropogenic disturbance such as land degradation and impact of climate change because of their narrow biogeographical range of distribution. Tribal communities of state use numerous plants species for ethnobotanical and ethnomedicinal purpose; so far more than 500 species of medicinal plants are catalogued from the state (Haridassan *et al*., 1995). As per IUCN Conservation Assessment and Management Prioritization criteria (CAMP 2003), 44 medicinal plant species of state have been categorized under red list category. Presently, biodiversity of the state is facing several threats and challenges mainly due to land degradation, shortening of fallow period in shifting cultivation (jhum), habitat destruction, hunting, uncontrolled grazing, forest fires, encroachment, developmental interventions, illegal and over extraction of forest products and arising threat of climate change (Samal *et al*., 2015). Comprehensive documentation of land degradation and biodiversity status, education and awareness of community, enhancement of livelihood opportunities, skill development, strengthening of traditional indigenous knowledge, formulation land rehabilitation and conservation oriented developmental plans/programmes/policies will help in ecosystem restoration and conservationof biological diversity of the state.

Forest resources of Arunachal Pradesh

Tribal communities live in close association with forests and highly dependent on numerous forest products for their livelihood. Indigenous communities have developed various indigenous traditional knowledge systems for sustainable utilization and management of forest resource through a long series of practical interventions and observations transmitted from generation to generation. The total recorded forest area in the state is 51,541km^2 which constitutes about 61.55% of state's geographical area. The State has considerable area (around 11.82% of geographical area of the state) under protected area network (PAN), whereas national average is below 5% (Kumar and Chaudhry 2015).The forest of the state provides various direct resources such as timber, fuel wood, NTFPs, bamboo, cane, medicinal plants, wild edible plants, aromatic plants, dye and resin, fiber, ornamental plants etc. In addition to this, forest provides key ecosystem services viz. Provisioning ,Regulating, Supporting, Cultural to theecosystem.It is estimated that around Rs. 1,518 billion per year value ecosystem services have produced from the forests of the state (Kumar and Chaudhry 2015).

Efforts of ethnic communities of Arunachal Himalaya for Ecosystem Restoration and Biodiversity Conservation

Indigenous peoples have depended on variety of natural and biological resources for their survival and livelihoods since time immemorial. They are fully aware that biological diversity is a crucial factor in generating the ecological services and natural resources on which they depend (Gadgil 1993). The indigenous communities of the state are practicing varioustraditional knowledge system viz. community conserved areas, scared groves, ethnobotanical and ethnomedicine uses of plants, water and soil conservation, sustainable utilization of forest resources, environmental protection, land preparation and utilization, jhum cultivation, mithun rearing, piscesculture, traditionalagro-forestry system, food preservation etc (Fig. 2).

Fig. 2. Monpa Scared groves and community conserved areas at Tawang district support in ecosystem restoration and biodiversity conservation

since time immemorial. However, these rich indigenous knowledge systems of communities are depleting very rapidly due to diverse factors. Following indigenous knowledge systems for ecosystem restoration and biodiversity conservation are being practiced by indigenous communities of the Arunachal Pradesh (Table 1).

CONCLUSION

Arunachal Pradesh has abundance of natural, land, forest and biological resources. The vast natural resource of the state is largely untapped due diverse reasons. Forest, NTFPs, agriculture, horticulture, and water resources sectors can provide livelihood and development opportunities to tribal communities of the state.The rich biodiversity, diverse landscape and scenic beauty offer huge potential for ecotourism in the state. There is urgent need to strengthen the infrastructure development in the state for sustainable utilization of various natural resources for socio-economic development of the state. However, at the same time natural and biological resources of the state are also facing tremendous pressure and threat from various anthropogenic and climatic reasons.Therefore, there is need for sustainable land management, ecosystem restoration, resource utilization of resources for development and maintenance of environmental sustainability of the state.In recent time due to modernization and change in socio-cultural dynamic the rich traditional indigenous knowledge arebeing either diluted or in the process of dilution. Community participation in ecosystem and biodiversity conservation programs and documentation and popularization of indigenous knowledge system among younger generation is essentially required for sustainability of the region. Strengthening and promotion of IKS, organization of mass awareness and educational programmes onecosystem restoration, sustainable resource utilization and biodiversity conservation, community participation inresource planning and development will facilitate restoration of degraded areas, management of natural resources and conservation of biodiversity in this Himalayan state. In addition to this, collective action and wider partnership of diverse stakeholders viz. policy makers, local community, researchers, academicians, NGO, CBO etc. are urgently required for achieving the targets of UN Decade on Ecosystem Restoration for overall sustainability of land and people of the Arunachal Himalaya.

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Table 1. Efforts of ethnic communities of Arunachal Himalaya for Ecosystem Restoration and Biodiversity Conservation

S.N.	Indigenous practice	Communities	Location	Description	References
1	Indigenous land use management	Apatani, Nyishi, Monpa, Brokpa	Aptani plateau, Ziro, Lower Subansiri, Papumpare, Tawang districts	Tribal communities of the state are managing the natural systems such as forests, agriculture lands, grass lands, range lands and rain-fed zone resources for their subsistence and livelihoods through various indigenous knowledge system. In-situ (germplasm) conservation ofsocio-culturally valuable, economically potential andecologically significance species are being done in these well managed ecosystems.	Singh & Sureja 2006; Dollo *et al*., 2009; Pangging *et al*., 2011
2	Community conserved areas (CCA)	Mompa, Apatani	Tawang, West Kameng, Lower subansiri	Community Conserved Area (CCA) is known as a natural or modified ecosystem with significant biodiversity, ecological and related cultural values, voluntarily conserved by local communities through customary laws further strengthened by rules evolved by the village community. Restrictions are made on agricultural activities, felling of trees and hunting within the CCAs. However, selective harvesting of fuel wood and timber is permitted to bonafide villagers with the permission of biodiversity management committee (BMC) of respective village. Further, in order to enhance species diversity and restrict extinction of threatened species, plant species like *Taxus wallichiana, Michelia champaca, Illicium grifithii, Exbucklendia populenia, Myrica esculenta* and *Castanopsis* sp. are also planted in the CCA by the villagers.	Samal *et al*., 2013 Dollo *et al*., 2009
3	Forest conservation and management	Apatani, Nyishi	Lower Subansiri district	Community pay key role in forest conservation for sustainable utilization of fuel wood, timber, food, medicine, handicraft, housing and ritualistic materials and maintaining of other valuable ecosystem services. Protection of plants species viz. *Phyllostachys bambusoides, P. bambusoides, Pinus wallichina, Alnus nepalensis, Castanopsis indica, C. hystrix*, etc.	Dollo *et al*., 2009; Pangging *et al*., 2011
4	Traditional agriculture system	Apatani, Nyishi	Lower Subansiri & Papumpare districts	The valley rice cultivation and Apatani paddy-cum-fish culture systems are one of the most efficient crop production systems, which have further encouraged the Apatani farmers to continue their traditional practices. Jhum cultivation, Agro-silviculture, Agro-silvi-horticulture and aqua forestry have also been practiced by tribal communities of the state.	Dollo *et al*., 2009; Chaudahary *et al*., 2011; Pangging *et al*., 2011
5	Conservation of flora and fauna in scared groves	Mompa, Apatani, Nyishi	Tawang, West Kameng, Lower subansiri, Papumpare	Sacred groves act as an ideal centre for biodiversity conservation. They conserve the rare, endangered, threatened (RET) and endemic floral and faunal species, valuable non timber forest products (NTFP) including medicinal plants of the region. The sacredness, religious beliefs and taboos play a significant role in promoting sustainable utilization and conservation of flora and fauna of the region. Khan *et al*., (2007) have reported a total of 101 sacred groves in Arunachal Pradesh. Most of the sacred groves are located at high altitudes areas in the state. Many of these sacred groves are attached to the 'Gompa' i.e., Buddhist monasteries and they are under the control of monasteries and conserved due to religious considerations.	Khan *et al*., 2008; Murtem and Chaudhry 2014; Pangging *et al*., 2011
6	Customary law in ecosystem management & natural resource conservation	Adi, Apatani, Nyishi, Galo	Lower Subansiri, Papumpare, East and West Siang districts	The tribal communities of the Arunachal Pradesh have developed different customary law, taboos and mechanisms for biodiversity conservation and natural resource management. Apatani tribe of Lower Subansiri district, protect an orange bellied Himalayan squirrel Dremomys lokriah and other flora/fauna with socio-cultural and ritualistic values by a mechanism called Dapo. Under this system, illegal hunting of wild animals, over extraction of forest resources is subject to penalties. Through these customary system and beliefs most of the biological resources are conserved in the region.	Borang, 2001; Chaudahary *et al*., 2011

7	Medicinal Plants Conservation	Apatani, Mompa	Tawang, West Kameng, Lower subansiri	The tribal communities of the region conserve these valuable ethnobotanical and medicinal plants species in their home garden, kitchen garden and farm land for primary health care and sustainable utilization. They have also declared certain pockets as medicinal plants conservation areas (MPCA) for exclusively conservation of medicinal plants diversity of the region.	Mao *et al.*, 2009
8	Ecological pest and diseases control	Galo	West Siang District	The tribal communities are preserving the ecological pest anddiseases control measure knowledge over the generations. *Citrus grandis* (Pummelo) leaves used as insecticidal and repellent for the control of the rice pest *Leptocorisa oratorius*. House hold ash is used as a repellentto control pests and diseases of the cultivated crops. A numberof traditional traps are used for control of rats in the rice fields.	Bora *et al.*, 2013
9	Traditional rearing of Mithun (*Bos frontalis*)	Galo	West Siang District	Mithun (*Bos frontalis*), the semi domesticated bovine species, is an important component of the livestock production system of North-Eastern hilly region of India. Galo tribe has developeda community sponsored, community-based, welfare oriented arrangement devised to rear Mithun in a systematic and easier way. This practice is called 'Lura' means'inside the fencing.	Chaudhry *et al.*, 2011
10	Folk belief and taboos	Adi, Nyishi, Apatani, Monpa, Wancho, Mishmi, Aka	All Arunachal Pradesh	Most of the tribes believe that the forest is the abode oftheir numerous gods and spirits. They consider certain plants and animals species, water resources (ponds/lakes), areas very scared and religious therefore, tribal community has devised various folk beliefs/taboos for conservation of these resources	Chaudhuri 2008

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CONSERVATION THROUGH BELIEF: A REVIEW OF SACRED GROVES IN KARBI ANGLONG AND DIMA HASAO- ONLY DISTRICTS IN ASSAM UNDER EASTERN HIMALAYAN REGION

Kunal Chanda

Ph.D. Research Scholar, Department of Zoology, Gauhati University, India

Correspondence: kchanda9@gmail.com

ABSTRACT

Sacred groves are the remnants of forest patches that are invariably linked with religious and cultural aspects of the indigenous communities. They are considered to be repositories of rare and endemic plants that are left untouched owing to the belief that deitiesreside within them. Sacred groves occur in many parts of India such as Western Ghats, Central India, North-east India etc. where indigenous communities reside. They are known by different namesby the indigenous communities that revere them. The traditions, religious beliefs and taboos that are linked with the sacred groves have also played a crucial role inconservation of biodiversity of the region. But with the course of time, the religious beliefs, taboos and people's perception that have sustained them for generations are slowly eroding threatening the existence of the sacred groves. This paper reviews the studies on sacred groves in Karbi Anglong and Dima Hasao districts in Assam that fall under Eastern Himalayan Region. Based on available literatures on the sacred groves of the hill districts, it focuses on the floristic diversity of the sacred groves and also underlines the importance of the sacred groves in socio-cultural traditions and ethnomedicinal use of the sacred plants by the indigenous tribes in the hill districts. It also discusses the threats of the sacred groves in the hill districts under increasing pressure due to urbanization, invasion of alien species and erosion of traditional beliefs.

Keywords: Sacred groves, Eastern Himalaya, Socio-cultural belief, Indigenous communities, Biodiversity conservation, Karbi Anglong, Dima Hasao

INTRODUCTION

The tradition of nature worship can be seen to be practiced by a number of communities in different parts of the world including India. One such tradition of nature worship is designating a patch of forest or vegetation as sacred groves. The sacred groves are dedicated to the ancestral spirits and deities by the indigenous peoplewhich offer protection to them by their taboos and sanctions with cultural and ecological implications (Malhotra *et al*., 2001). Sacred groves are considered as repositories of rare and endemic species and can be attributed as remnants of primary forests that are left untouched by the local inhabitants due to their belief that deities reside within them (Khumbongmayum *et al*., 2005). Thus, it can be said that the association of traditional beliefs with the sacred groves have sustained them for generations. Sacred groves provide a wide range of ecosystem services such as carbon sequestration, conservation of traditional knowledge, water conservation etc. But in recent times, due to unplanned developmental activities, invasion of alien species, soil erosion, loss of belief, change in religious belief and population growth threatens the existence of sacred groves (Ray and Ramachandra 2010).

Sacred groves, in India are known byvarious names such Sarna or Dev in Madhya Pradesh, Devrai or Deovani in Maharashtra, Sarnas in Bihar, Orans in Rajasthan, Devaravana in Karnataka, Sarpakavu and Kavu in Tamil Nadu and Kerala, Dev van in Himachal Pradesh, Law Lyngdoh or Law Kyntang in Meghalaya, Sarana or Jaherthan in Jharkhand and Lai umang in Manipur (Bhakat 1990).

Sacred grove in India

According to Malhotra *et al*., (2001), there is an estimated 13,720 sacred groves in India. Western Ghats in India has a very high number of sacred forests (Kushalappa *et al*., 2001). Kushalappa *et al*., (2001) reported a total of 1214 sacred groves in Kodagu district of Karnataka. It has the highest density of sacred groves with one sacred grove for every 300 hectares of land. Gadgil and Vartak (1980) reported 233 sacred groves in Maharashtra that occupies an area of 3,570 hectares. Balasubramanyan and Induchoodan (1996) reported 761sacred groves in Kerala with a floristic diversity of 722 species belonging to 217 families and 474 genera. Amairthalingam (2012) reported 1275 sacred groves from 31 districts in Tamil Nadu.

Sacred groves in North-East India

In the context of North East India, there have been several literatures on sacred groves. Malhotra *et al*., (2001) reported 58 Gompa Forest Areas or sacred groves that are managed by Lamas and Mompa tribe of Kameng and West Siang districts of Arunachal Pradesh. In a recent work, Murtem and Chaudhary (2014) gave a vivid description of 79 sacred groves from four districts of Arunachal Pradesh namely Lower Subansiri, Upper Subansiri, Papum Pare and West Siang. In Manipur, Khumbongmayum *et al*., (2005) inventoried 166 sacred groves from four districts namely, Imphal east, Imphal west, Thoubal and Bishnupur districts of Manipur valley. They also reported 173 ethnomedicinal plant species belonging to 70 families and 70 genera from a detailed study of four selected sacred groves. In Meghalaya, Tiwari *et al*., (1998) reported the presence of 79 sacred groves of which Mawphlang isan important sacred grove, but later Singh *et al*., (2007) reported the presence of additional sacred groves and the count increased to 111. In Assam, sacred groves are locally known as than by Bodo and Rabha tribes. Karbi Anglong has about 40 sacred groves. Sacred groves are called as madaico by the Dimasa tribe which is generally not more than an acre. Sacred groves are also found in the Brahmaputra plains in Assam (Malhotra *et al*., 2001).

x. Apart from Karbi Anglong and Dima Hasao districts of Assam; documentation and studies pertaining to the tradition of sacred groves being maintained in other districts have not been found. It is in this context that a review of sacred groves in Karbi Anglong and Dima Hasao district of Assam has been carried. Based on review of available literatures, the following points will be addressed:

1. The socio-cultural aspects of the sacred groves.

2. Ethnomedicinal plants used by the indigenoustribes of the sacred groves.

3. Diversity of floristic speciesof the sacred groves.

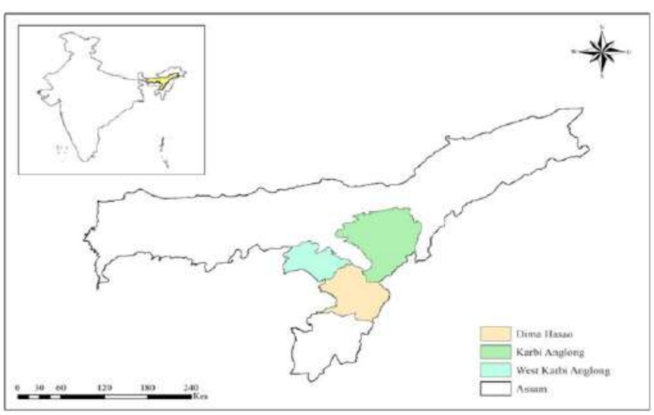

Fig. 1. Map of the study area

STUDY AREA

Karbi Anglong (unidivided) and Dima Hasao districts in Assam are the only hill districts in Assam that fall under Eastern HimalayanRegion. A map of the study area is shown in Fig. 1.

Karbi Anglong

Karbi Anglong lies between 25° 32'N to 26° 36'N latitudes and 92° 10'E to 93° 50'E longitude. In 2016, the district was split into two namely Karbi Anglong and West Karbi Anglong with Diphu as the capital of Karbi Anglong and Hamren as the capital of West Karbi Anglong.Many tribes such as Karbi, Dimasas, Bodos, Hmar, Tiwas, Garos, Khasi Chakmas and Rengma Nagas inhabit this region. It has a total geographical area of 10,434km^2 (undivided), which accounts for 13.3% of Assam (Census 2011). The area mostly consists of undulating and hilly terrain with numerous rivers and streams. The total forest cover in Karbi Anglong is 7,889.18km^2 (FSI Report 2019).

Dima Hasao

Dima Hasao lies between 24°57'N to 25°43'N latitude and 92°32'E to 93°28'E longitude with its headquarters at Haflong. It occupies a total geographic area of 4,888 km^2. Topographically, the district forms a rugged hilly country constituting the eastern flanks of the Jaintia Hill of Meghalaya and the northern flanks of the Borail range (Census 2011). The total forest cover of the district is 4,206.93km^2 (FSI Report 2019). It is a tribal-majority district with tribals such as Dimasa, Kuki, Zeme, Hmar and Garos constituting about 71% of the total population.

METHODOLOGY

For the purpose of the study, qualitative and empirical

Table 1. List of published literatures on sacred groves in Karbi Anglong and Dima Hasao district

District	Article topic	Reference
Dima Hasao	Sacred plants and sacred groves of Dimasa tribe	(Medhi and Borthakur 2013)
Karbi Anglong	Anthropological studies of sacred groves	(Bhattacharjee 2010)
Dima Hasao	Floristic and socio-cultural aspect of sacred groves of Dimasa tribe	(Langthasa *et al*., 2018)
West Karbi Anglong	Assessment of land useland cover with floristic composition of sacred grove	(Baidya *et al*., 2020)
West Karbi Anglong	Ethnomedical practice of sacred grove by Karbi Tribe	(Baidya *et al*., 2020)

Table 2. Sacred groves in Karbi Anglong and Dima Hasao districts in Assam

District		Area (In hectare)	Reference
Dima Hasao	Aludikho	1.91	(Medhi and Borthakur 2013)
	Longmailaidikho	1.10	
	Longmailumdikho	0.87	
	Manjadikho	1.14	
	Damadidikho/ Riaodikho	1.48	
	Hamridikho	0.75	
	Misimdikho	0.69	
	Baiglaidikho/Bai-giadikho	1.14	
	Waibradaikho	1.07	
	Mongrangdikho/ Semkhordikho	1.17	
	Mongrangdikho	0.72	
	Ronchandidikho	1.25	
Karbi Anglong (Undi-vided)	Bichikri	16	(Baidya *et al*., 2020)
	Harlong	1.4	
	Ronghanh Rong-bong	-	(Bhattacharjee 2010)
	Rit-asor	-	
	Arlongpuru Ham-ren	-	
	Mahamaya	-	
	Rek Anglong	-	
	Inglong kiri	-	
	Socheng	24	Karbi Anglong Community Resource Management Society
	Chinthong	5	
	Langsomepi	65	
	Linchika	21	
	Rongcheck	11	
	Amri	8	
	Tirkim	32	
	Ronghidi	8	
	Tikka	8	
	Borgaon	25	
	Jirkinding	-	
	Rongpongbong	-	
	Umsowai	-	
	Rongjangphomg	-	
	Kungripi	-	
	Rumphum	-	

'-' indicates no data reported

data pertaining to sacred groves of Karbi Anglong and Dima Hasao Districts in Assam was conducted through anextensive literature review. Papers related to sacred groves were downloaded from Google Scholar and a comprehensive list of the sacred groves of Karbi Anglong and Dima Hasao districthas been prepared (Table 1). The literature review showed that the studies are conducted on the socio-cultural norms,floristic species diversity and ethnomedicinal practicesby the indigenous tribesthat rely on the sacred groves. Furthermore, data onnumber and size of the sacred groves was also collected by a thorough literature review, shown here in (Table 2).

RESULTS

Socio-cultural aspects of sacred groves

Local indigenous people have long been dependent in the natural environment and its resources for their religious and cultural beliefs. Bhattacharjee (2010) studied the socio-cultural aspects of the sacred grovesin Karbi Anglong and reported that they are significant to the Karbi tribe. The use of certain plants from the sacred groves for their religious ceremonies and rituals has certain cultural norms and taboos associated with them. In his study 7 sacred groves were documented (Table 2) that are associated with their cultural beliefs. Rit-asor, a sacred grove is believed to the dwelling place of the deity of Jhum cultivation for which it is worshipped for better production ofcrops. Another sacred grove Bichikri is regarded as the most important sacred grove of the Karbi tribe. It is highly revered and worshipped along with the community festival Bichikri-Rongker. Their worship of the sacred groves is done to appease the deities for the protection and well-being of the tribe.

Medhi and Borthakur (2013) studied the sacred groves and the sacred plants of Dimasa tribe of Dima Hasao district. In his study, he rediscovered 12 sacred groves (Table 2) found in district; locally known as Dikhos and documented 34 species that are considered sacred by the Dimasas of which 13 species are used in religious ceremonies and 21 species are used in naming of villages and the remaining 8 species are used in naming of clans of Dimasa tribe. These finding suggests that being revered as sacred and being used in naming of clans and villages accord conservation and protection to the plant species as they arelinked with their beliefs and social customs.This connection of the Dimasas with the sacred groveshighlights their importance in their social customs and beliefs and their use of naming of villages and clans.

Ethnomedicinal plants used by the indigenous tribe of the sacred grove

Baidya *et al*., (2020) studied the ethnomedicinal plants of two sacred groves Bichikiri and Harlong in Karbi Anglong and documented 38 plant species belonging to 36 genera and 27 families that are used by the Karbi tribe for medicinal purpose. The study recorded a total of 24 species in Bichikri sacred grove and 32 species in Harlong sacred grove. The most dominant families for ethnomedicinal plants were found to be Lamiaceae and Compositae in Bichikri and Leguminosae in Harlong. The documented 38 plant species with their parts in the form of apical part, bark, bulb, fruits, flowers, leaves, roots, seeds, shoots, stems, tuber, whole plant and rhizome are used by the traditional healers to treat 30 human ailments. The ethnomedicinal plants are used for the treatment of allergy, dermatological wounds, gastrointestinal disorder, respiratory infections, reproductive and birth disorder etc.

Diversity of floristic species of the sacred groves

The demarcation of an area as a sacred grove due to cultural norms has played a remarkable role in conservation and protection of native flora that are undisturbed and thus has helped in the conservation of biodiversity of the region. Langthasa *et al*., (2018) reported a total of 44 species belonging to 42 genera and 27 families from three sacred groves or dikhos (Damadi, Misim and Longma) from Dima Hasao district out of which 29 species were herbs, 10 species were shrubs and 6 species were climbers and ferns. Highest species diversity of herbs, climbers and ferns was recorded in Damadi whereas highest shrub density was recorded in Longma.

In astudy carried out by Baidya *et al*., (2020) to assess the changes in land use land cover and floristic composition of two sacred groves Bichikri and Harlong from West Karbi Anglong, they reported a total of 116 belonging to 84 genera under 44 families out of which 46 species were trees, 27 species were shrubs and 43 species were herbs. Bichikri sacred grove recorded the highest species diversity of 68 plant species out of a total 116 plant species found in both the sacred groves. Tree species from Moraceae family was found to be most dominant whereas Acanthaceae and Malvaceae was the dominant family from shrubs, and in case of herbs Compositae was the dominant family. The most dominant tree species recorded in both the sacred groves was *Bauhinia purpurea, Clerodendrum infortunatum* and *Musa flaviflora* were the dominant shrub species followed by *Chrysopogon zizanioides* and *Thysanolaena latifolia* as the dominant herb species.

DISCUSSION

The presence of the remnant patches of sacred groves preserved by the tribes of Karbi Anglong and Dima Hasao highlights their importance in the socio-cultural, traditional beliefs and taboos that govern their lives. The relationship of the Karbi tribe is not only limited to the socio-cultural norms and taboos but also has become a crucial part in their health security as their use in treating human ailments showcases its therapeutic and pharmaceutical potential (Baidya *et al*., 2020). The traditional cultural beliefs and the taboos associated with the sacred groves play a vital role in the preservation of the groves but now with the passage of time these beliefs and taboos are now disappearing which is cause for grave concern. Langthasa *et al*., (2018) also arrived at the same conclusion that the beliefs and taboos that are linked with the sacred groves are now eroded which has led to the loss of sacred trees and degradation of the sacred groves.

The advent of urbanization and industrialization also has an adverse consequence on the status of the sacred groves. Conversion of forest cover to rubber plantation and broom grass due to their high-income value has changed the land cover of the West Karbi Anglong district and also resulted in low species diversity of the sacred forests (Baidya *et al*., 2020). Also, the sacred groves that do not lie within the realm of the protected areas face aneven larger threat as they are not offered any protection with any laws in India.

Invasion of alien species is a major threat to the native plants of the sacred groves. Langthasa *et al*., (2018) and Baidya *et al*., (2000) also tie in with the same that the presence of invasive species such as *Ageratum conyzoides, Cynodon dactylon, Cyperus rotundus, Mimosa pudica, Mikania micrantha, Chromolaena odorata* threatens the diversity of the native plants in the sacred groves.

The conservation of the sacred groves is essential for maintaining the local biodiversity as they are invariably linked with the cultural, social, ecological and economical role of the indigenous tribes (Baidya *et al*., 2020; Langthasa *et al*., 2018). Medhi and Borthakur (2013) stated that the Dimasa tribe maintains the sacred groves adjacent to water sources as it provides immense ecosystem roles such as conservation of soil, protection of water sources and catchment water and maintenance of down stream water quality.

With common cases such as encroachment due to expansion of population growth and clearing of hectares of forest area for development activities have also intensified the degradation of the sacred groves in the hill districts. In case of the hill districts, it is seen that the protection and preservation of the sacred groves are traditionally managed by the indigenous tribes but now with the beliefs being slowly eroding it calls for an ardent need of government and policy makers to pave the way for conservation of the sacred groves.

The high presence of sacred groves in the two districts highlights the underlying importance of the sacred groves and their preservation by the indigenous tribes for generations. Many more sacred groves might still be unreported which warrants for documentation and inventory of the sacred groves of Karbi Anglong and Dima Hasao district with particular focus on the traditional knowledge related to their socio-cultural beliefs as well as resource utilization by the indigenous tribes in healthcare system. Studying these aspects will help in safeguarding these pristine sacred groves and further add to biodiversity conservation of the region.

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ECOLOGICAL DEGRADATION AND ECO-RESTORATION STRATEGIES FOR SATTAL WETLAND AREA OF THE BHAGIRATHI-ECO SENSITIVE ZONE

Priyanka Maiti[1], Jagdish Chandra Kuniyal[1]*, K Chandra Sekar[1], S.C. Arya[1], Nisha Bisht[1], Anand Kumar[1], Mahesha Nand[1] and R.C. Sundriyal[2]

[1]G. B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand, India,
[2]Department of Forestry and Natural Resources, Chauras Campus, HNB Garhwal University, Srinagar (Garhwal), Uttarakhand, India
***Correspondence:** jckuniyal@gmail.com

ABSTRACT
The Himalayan wetlands are highly sensitive and dynamic habitats, which work as water reservoirs in downstream areas, adjust local climate and promote sustainable ecosystems. The present work is focused on the assessment of the Sattal wetland area in the River Bhagirathi basin in Uttarakhand. The area is facing threats due to anthropogenic activities and other natural process, such as, shrinkage in an area, fragility and decrease in biodiversity, etc. Decreasing trend of Normalized Difference Water Index (NDWI) and increasing trend of Normalized Difference Vegetation Index (NDVI) during last five years (2016-2020), and encroachment activities in the down-hill area were assessed as degradation indicators of the area. Eco-restoration activities, viz., excavating the lower surface of the wetland, removal of *Pinus wallichiana* saplings, plantation, bio-fencing, monitoring of encroachment area, proposed plan for restoration and establishment of Sattal wetland area as eco–trail for promotion of eco-tourism are suggested toward achieving some of the important Sustainable Development Goals (SDGs) including SDG 13 (climate action), and SDG 15 (life on land).

INTRODUCTION
At present, the world is celebrating the time frame of 2021–2030 as the UN Decade on Ecosystem Restoration (UN -DER), and the resolution was formally adopted in the 73th session of the UN Assembly for restoration of degraded ecosystems. Restoration of degraded ecosystems in a sustainable way will improve the multi-functionality of an ecosystem and directly or indirectly influence the 'UN Sustainable Development Goals (UN-SDGs)' (Abhilash 2021). Currently, ~2,400 Ramsar Sites around the world are considered for their protection and among them 39 wetlands were designated under the list of wetlands of International Importance from India. Diverse schemes and programs, namely, National Plan for Conservation of Aquatic Ecosystems (NPCA), 'Wetlands Rejuvenation' programme, etc. are implemented within the country by the Ministry of Environment, Forest and Climate Change, Government of India (MoEFCC 2021). In view of eco-restoration initiatives, the present work was carried out to investigate the natural and anthropogenic drivers behind shrinkage of degraded Sattal (31°1'31.88"N, 78°46'9.51"E, 3045m) wetland area falling in Bhagirathi eco-sensitive zone of the Western Himalaya. There are seven small wetlands in the area, namely, Sankhghata Tal (3039m), Ghandoliya Tal (3025m), Rikh Tal (3016m), Bamniya Tal (2995m), Dawariya Tal (2972m), Chadgiya Tal (2969m) and Mirdunga Tal (2842m). These seven wetlands collectively is named as 'Sattal', meaning seven Tals/ wetlands. These wetlands are situated in different altitudes and downward movement of water in almost a series continues from one wetland to other. Water from the lowest wetland Mridunga Tal works as a source of irrigation water to the downstream Dharali village (2635m) and nearby apple orchard areas (Manjrekar and Singh 2012). However, the area is now under biotic pressure and is under degradation, viz., anthropogenic activities (i.e. encroachment, fuel wood collection, etc.) and other natural process, such as, shrinkage in area, flow of uphill debris, and siltation that collectively have reduced these lakes into small ponds. Currently, water is available only in three wetlands and rest is in dried/semi-dried conditions. The present work therefore integrates geospatial and field investigation of the area for the assessment of ecological degradation of the area followed by a strategy of sustainable eco-restoration planning.

STUDY AREA
The western sub-basin of the River Ganga is renowned as the Bhagirathi eco-sensitive zone. It spreads around 135km stretch of an area from Gaumukh (4034m) to Uttarkashi (1090m). It was declared as an eco-sensitive zone in 1986 under the environmental protection act. The area is very fragile and prone to landslides, flash floods, earthquakes, land subsidence and others. The tributaries of the River Bhagirathi in this zone include Kedar Ganga at Gangotri, Jadh Ganga at Bhaironghati, Kakora Gad, Jalandhari Gad at Harsil, Siyan Gad near Jhala and Asi Ganga near Uttarkashi (Bhagirathi Eco Zone- ZMP Comments 2017). The present

study was carried out in the Sattal region situated opposite to the Harshil village (2470m) and uphill of the Dharali village (2628m) close to Mandakini waterfall. The area comes under Garhwal Lesser Himalaya and consists of 7 small and shallow wetlands, namely, Sankhghata Tal (3039m), Ghandoliya Tal (3025m), Rikh Tal (3016m), Bamniya Tal (2995m), Dawariya Tal (2972m), Chadgiya Tal (2969m) and Mirdunga Tal (2842m) (Fig. 1). All the lakes are surrounded by tree species

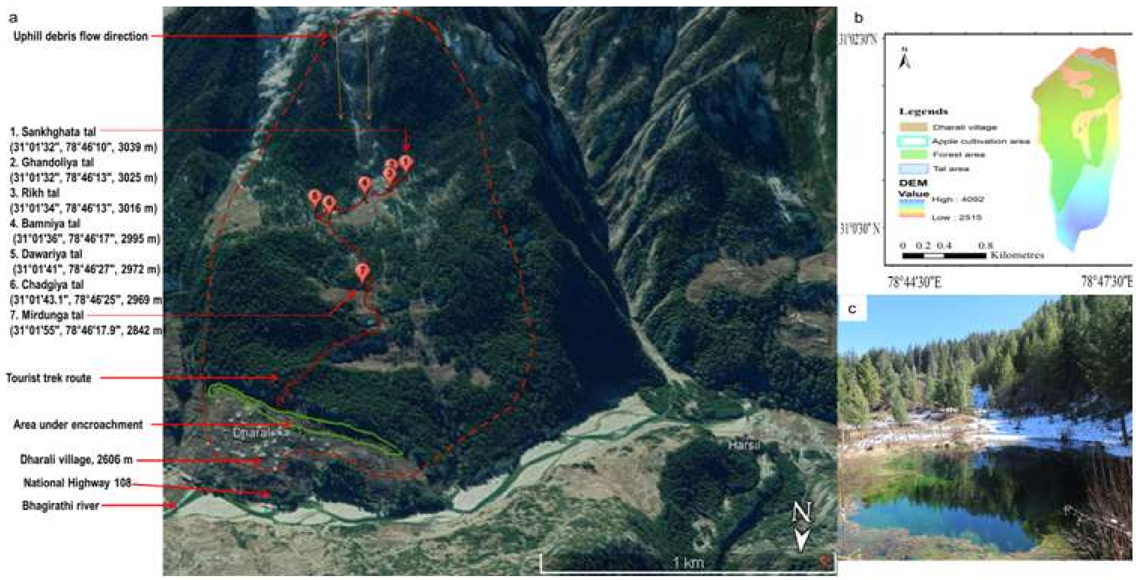

Fig. 1. (a) Study area description geographical extent, (b) Sattal wetland area, and (c) View of Mirdunga Tal (2842m) during November, 2020.

of *Acer acuminatum, Aesculus indica, Cedrus deodara, Pinus wallichiana*, etc. Faunal diversity of the area consists of the Himalayan wildlife like Brown bear (*Ursus arctos*), Himalayan goral (*Naemorhedus goral*), Monal pheasant (*Lophophorus impejanus*), etc.

Assessment of hydrological condition of the wetlands

Ecological indices like water, and vegetation are the critical

$$NDWI = \frac{\rho 3 - \rho 8}{\rho 3 + \rho 8}$$

$$NDVI = \frac{\rho 8 - \rho 4}{\rho 8 + \rho 4}$$

elements of wetland's health and their analysis in the associated areas. In the present work, Sentinel-2 satellite imageries (10m) of 2015 and 2021 during October month were used for a change detection analysis of the area using ArcGIS software. The water element was investigated by the NDWI (Du *et al*., 2016), followed by vegetation analysis by the NDVI (Cai *et al*., 2020) using the following equations:

Where, ρ3 is the Top of the Atmosphere (TOA) reflectance of the Band 3 (the green band), ρ8 is the TOA reflectance of the Band 8 (the NIR band) and ρ4 is the TOA reflectance of the Band 4 (the Red band) of Sentinel-2.

Further, five-year imagery of Sentinel 2A and 2B for the time series analysis of the area were analysed using the Google Earth Engine (Gorelick *et al*., 2017). A total of 544 cloud masked images were analysed from January, 2016 to December, 2020. These images were processed for NDVI and NDWI analysis for each pixel which fell within the area of interest. Along with the entire study area, the clipped geometry of individual lake was also considered. Afterwards, the seasonal values in the study area were computed for each study period considering four seasons, namely, pre-monsoon, monsoon, post-monsoon and winter (Singh and Mal 2014).

Vegetation analysis

The vegetation analysis has been conducted from Mirdunga Tal (2842m) to Sankhghata Tal (3039m). Further, the plant diversity analysis was also conducted from Dharali village to Mirdunga Tal to identify the illicit felling of forest trees and expansion of horticulture area. In view of illicit felling of forest tree analysis, three random plots of 100m² (50x20m) were considered along the path of forest–apple orchard transition area following horizontal belt transact method (Pradhan *et al*., 2015). Further, the vegetation analysis, 50x50m plots were laid at three different elevations, i.e., lower (2737m), middle (2972m) and higher (3071m). Thirty randomly placed quadrats of 1x1m size were taken into account in every 50x50m plot in view of sampling of herbs (Misra 1968). Similarly, for shrubs five numbers of 25m (5x5m) quadrats were considered and two hundred metre (10x10m) quadrats were studied for analysing the diversity of trees.

Village survey

A structured questionnaire was designed for village survey in Dharali village. The field team conducted the surveys through Field Group Discussion (FGDs) among the local villagers. Information about the past and present condition of the area, wetland dependency of villages, possible causes behind degradation of the Tals, fuel-wood consumption, etc. were collected. The informants were randomly chosen across three different age groups, viz., 20-40, 40-60 and >60 years (Joshi *et al.*, 2019).

RESULTS AND DISCUSSION

The alpine and sub-alpine ecosystems in the IHR are continuously degrading and therefore it is a matter of great concern (Kuniyal *et al.*, 2021). In this context, recently the Sat Tal sub -alpine wetland area of Bagirathi river valley is facing serious environmental and anthropogenic threats.

Hydrological condition of the wetlands

The spatio-temporal water change dynamics of the area was evaluated for the period from 2016 to 2020 with the applicability of different satellite-derived indices like NDVI and NDWI. The NDVI denotes a non-dimensional index which defines the density of greenery of the lakes whereas NDWI is related to variations hydrological conditions (Ashok *et al.*, 2021). The NDVI values range between -0.004-0.68 in the area. Negative values of NDVI correspond to water, whereas values close to zero (-0.1 to 0.1), correspond to barren areas of rock, sand or snow, low, positive values and represent shrub and grassland (0.2 to 0.5), while high values (0.6-0.9) indicate temperate and tropical rainforests (Yassine *et al.*, 2021). In NDWI, all positive NDWI values were classified as water and negative values indicate as non-water (Sarp and Ozcelik 2017). The highest NDVI values in monsoon season and lowest in winter season were observed. Increasing trend of NDVI and decreasing trend of NDWI values were observed in Mirdungatal area which indicate the decreasing water content. During field study, it was observed that the vegetation growth has started in the wetland floor which is lowering the water content of the area. Lowest NDWI values were obtained for Chadkiatal (red colour) and NDVI trend was found to be increased in the area. Decreasing trend of NDVI is also observed in the entire study area. The reason behind this may be the destruction of old Deodar (*Cedrus deodara*) plants from the forest area because of horticultural

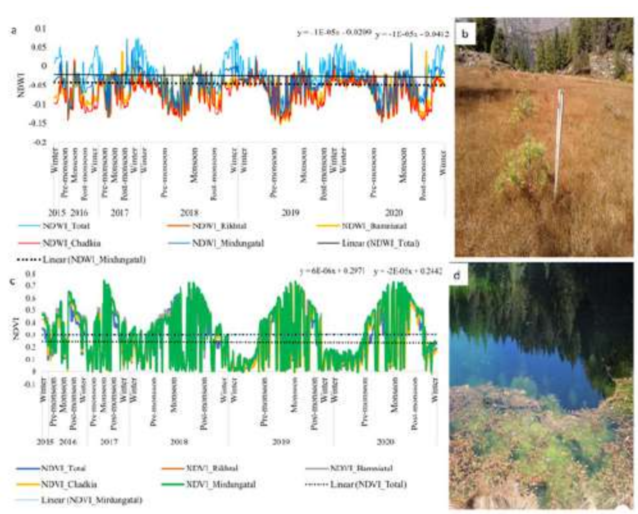

Fig. 2. (a and c) NDVI and NDWI trend analysis of the study area, (b) Pinus seedling growth in Chadkia Tal and (d)Vegetation growth in lower surface of Mirdungatal.

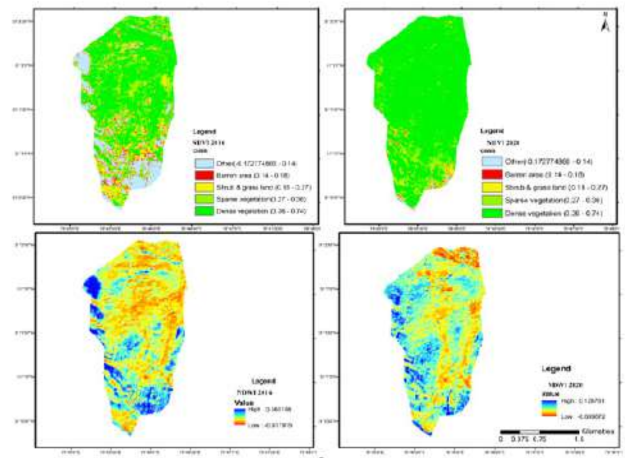

Fig. 3 NDVI and NDWI change analysis of the Sattal area

Table 1. NDVI and NDWI based land cover change detection of the area

Index	Scale range	Class	Area in 2016 in hectare (%)	Area in 2020 in hectare (%)	% change
NDVI	-1- 0.14	Other	85.3 (14.8)	86.4 (15.2)	1.29
	0.14-0.18	Barren area	23.34 (4)	23.96 (4.2)	2.66
	0.18-0.27	Shrub & grass land	71.63 (12.4)	72.87 (12.8)	1.73
	0.27-0.36	Sparse vegetation	95.24 (16.5)	95.98 (16.9)	0.78
	0.36-0.75	Dense vegetation	292.28 (50.7)	288.58 (50.8)	-1.27
NDWI	Positive	Water	14.72 (2.6)	12.34 (2.2)	-16.17
	Negative	Non-water	553.07 (95.9)	555.45 (97.8)	0.43

land expansion. Nearly 90% of the area was found to be covered by surface vegetation and growth of *Pinus wallichiana* seedlings were also found to start in the main wetland area (Fig. 2). According to the villagers, the area was a wetland of the Chadkia Tal during 10 years before but recently its 90% area is covered by a layer of vegetation.

In the entire study area, the barren area was found to be increasing at the rate of 0.53% per year which is a matter of concern. According to the villagers, the downhill flow of debris from the upper catchment in the lakes is a major reason behind the reduction of the lake area and filling of the lake

Fig. 4. (a and b) Girdling of phloem cells outside *Cedrus deodara* plant, (c) Freshly observed cut standing pole, and (d) Fuelwood usage by the villagers

Table 2. Extension of agricultural land by deforestation from Dharali village, Gangotri landscape

Encroachment	Plot - 1	Plot - 2	Plot - 3
Cut standing pole	5	1	2
Live standing pole	6	7	4
Cut & Burnt	11	39	3
Introduced apple plants	23	62	10

floors. Water content of the entire study area was also found to be decreased at a rate of 3.2% per year. It may be governed by water scarcity to the downstream at Dharali village (2635m) and nearby apple orchard areas (Fig. 3 and Table 1).

Anthropogenic pressures and vegetation profile

Further, the transition area between the forest and the apple orchard was studied. Activities included like girdling (ring-barking), the complete removal of the bark (consisting of cork cambium or phloem). In few trees, it was observed up to the Xylum of *Cedrus deodara* from around the entire circumference that ultimately makes the entire tree to be dead and the land was occupied for horticulture (apple plantation) purposes (Fig. 4). Highest number of such activity was found in the middle plot, where thirty nine *Cedrus deodara* trees were found to be gridling. These trees were almost in dead condition in 9750m^2 area. Further, around sixty-two apple plantation in the same places was introduced (Table 2).

While analysing the vegetation along the wetland area, herbs like *Anaphalis triplinervis, Epilobium laxum* and *Poa nemoralis* were found to be dominating in the upper areas of Sankhaghanta Tal followed by *Trifolium repens, Pedicularis punctata* in Chadkia Tal area and *Origanum vulgare, Potentilla argyrophylla* near Mirdunga Tal area. In shrub diversity, *Berberis asiatica, Eupatorium adenophorum*, etc. were found in the area. The tree diversity was dominated by *Pinus wallichiana* in all the three sites followed by the trees like *Abies pindrow, Cedrus deodara, Rhododendron arboretum,* etc. (Table 3).

During village survey, it was observed that highest percentage of fuelwood was obtained from *Pinus wallichiana* (82%) with a consumption of 280kg/sample/year followed by *Cedrus deodara, Rosa macrophylla*, etc. Species like *Taxus wallichiana* (Thuner), and *Artemisia* spp. are used by the villagers in the form of local dhup. *Morchella esculenta* (Gucchi mushroom) are collected by few of the villagers with a monthly income ranging from Rs.12000 to 15000. Apple orchards are the main source of income in the village initiated during 1990. There are five small water reservoirs,

Table 4. Suggested eco-restoration strategies for the Sattal Wetland area

Major trust areas	Intervention	Activities required
Natural	Plantation	Plantation activity for controlling the soil erosion and changing climate is required by the involvement of villagers. Plantation of *Abies pindrow, Abies spectabilis*, and *Quercus floribunda* near the areas of Chadkia Tal and Snghanta Tal is required in restoring the area. Planting *Cedrus deodara, Rhododendron arboreum*, and *Taxus wallichiana* near the areas started from the village boundary upto Mirdunga Tal.
	Cleaning and maintenance	Need for excavating—dredging and removing soil and vegetation from lower surface (urgently required). Removal of *Pinus wallichiana* saplings from Chadkia Tal (urgently required). Trenches and bio-engineering through plantation of native species to increase water recharge, especially *Quercus* spp. Bio-fencing and stone walls around Mirdunga Tal and ChadkiaTal.
Anthropogenic	Alternative livelihood	Establishing Sattal trek as eco-trail for the promotion of eco-tourism in the Dharali village.
	Strict monitoring	Establishment of forest check post at Sattal area for monitoring fuelwood extraction live stem cutting and tourists flow.
	Awareness campaigns	Incorporating actions that promote awareness for the altered water conditions in the Sattal area under climate change.

where upstream water from Sattal area comes down and is used as drinking water in the village and irrigation water in the apple orchards. All the seven lakes have a great spiritual value in the existing villages. A ritual named Matri-puja (worship) is performed normally on every Friday. According to the villagers, amount of snowfall in the last 10 years was found to be decreased. Expansion of horticulture and agricultural activities are responsible behind the degradation of the Sattal wetlands. Tourism and film shooting activities were also noticed during field study. Annually, few tourists visit the trek. Natural beauty, trekking, view of Bandarpunch peak, and mountain wetlands together make the entire area dazzling. This indicates increase in the tourism and its activities in the area.

Eco-restoration strategies

Ecological Ecological degradation of Sattal wetland area is mainly governed by both natural and anthropogenic factors. Natural factors like decreased snowfall, flow of uphill debris, and vegetation growth in the Tal areas were observed in the area followed by forest downhill encroachment activities. Now-a-days, water is avail-

Table 3. Vegetation diversity analysis of the Sattal area

Near Sankhaghanta Tal (3071 m)			Near Chadkia Tal (2968 m)			Near Mirdunga Tal (2875 m)		
Species	Habit	Density (ind./ m^2)*	Species	Habit	Density (ind./ m2)*	Species	Habit	Density (ind./ m2)*
Anaphalis triplinervis	Herb	2.5	*Anaphalis triplinervis*	Herb	2.5	*Origanum vulgare*	Herb	2
Anemone obtusiloba	Herb	1	*Anemone obtusiloba*	Herb	1	*Polygonum polystachyum*	Herb	1
Cyathula tomentosa	Herb	1	*Trifolium repens*	Herb	3	*Rumex nepalensis*	Herb	1.5
Epilobium laxum	Herb	2	*Ranunculus hirtellus*	Herb	1	*Artemisia gmelinii*	Herb	1
Poa nemoralis	Herb	1.5	*Poa nemoralis*	Herb	2	*Morina longifolia*	Herb	1
Impatiens glandulifera	Herb	1	*Pedicularis punctata*	Herb	2	*Anaphalis triplinervis*	Herb	2
Origanum vulgare	Herb	2	*Potentilla nepalensis*	Herb	1.5	*Pedicularis punctata*	Herb	2
Pedicularis punctata	Herb		*Prunella vulgaris*	Herb	2	*Potentilla argyrophylla*	Herb	2
Trifolium repens	Herb	3	*Taraxacum officinale*	Herb	3	*Caltha palustris*	Herb	2
Potentilla nepalensis	Herb	1	*Berberis chitria*	Shrub	1.5	*Poa annua*	Herb	1
Prunella vulgaris	Herb	1	*Rubus paniculatus*	Shrub	1	*Viola biflora*	Herb	1
Berberis asiatica	Shrub	1.5	*Desmodium gangeticum*	Shrub	2	*Berberis chitria*	Shrub	1.5
Plectranthus japonicus	Shrub	1	*Asparagus racemosus*	Shrub	1	*Rubus paniculatus*	Shrub	1
Eupatorium adenophorum	Shrub	4	*Pinus wallichiana*	Tree	3.3	*Viburnum cotinifolium*	Shrub	2
Rubus ellipticus	Shrub	1	*Rhododendron arboreum*	Tree	2	*Rosa macrophylla*	Shrub	1
Pinus wallichiana	Tree	2.3	*Abies pindrow*	Tree	2.5	*Pinus wallichiana*	Tree	5.67
Aesculus indica	Tree	1	*Lyonia ovalifolia*	Tree	1.3	*Quercus semecarpifolia*	Tree	1
Acer acuminatum	Tree	1.5	*Persea duthiei*	Tree	2	*Abies pindrow*	Tree	2

Cedrus deodara	Tree	1	*Quercus floribunda*	Tree	2	*Persea duthiei*	Tree	2
Rhododendron arboreum	Tree	2	*Taxus wallichiana*	Tree	1	*Rhododendron arboreum*	Tree	2
Sorbus cuspidata	Tree	1	*Neolitsea pallens*	Tree	1	*Sorbus cuspidata*	Tree	1
Lyonia ovalifolia	Tree	1	*Abies spectabilis*	Tree	2	*Lyonia ovalifolia*	Tree	1.5
Pyrus pashia	Tree	1	-	-	-	*Cedrus deodara*	Tree	2

able only in three areas while remaining became dry (Maiti *et al.*, 2022). Water containing areas are very eutrophic, with dense algal growth and submerged vegetation. Some restoration efforts like stone wall fencing, and cleaning the water were carried out in the area by the Uttarakhand Forest Department in 2021. Based on this study, plantation and maintenance of the wetlands are suggested for controlling natural factors like soil erosion and siltation of debris. Further, for controlling the anthropogenic pressures activities for alternative livelihood, surveillance monitoring and awareness programmes are recommended (Table 4).

CONCLUSION

In the modern decade of UN's eco-restoration, operational integration of ecosystem services into landscape management, policy development and decision-making are globally conceded for promoting sustainable use of natural resources. In view of this, the assessment of ecological degradation of the Sattal wetland area on the fragile Bhagirathi eco-sensitive zone was made. This indicates the risk of water scarcity in the downstream of Dharali village and may pose a threat to apple orchard areas in near future. Along with the ecological conditions, the other environmental conditions will also adversely affect the horticulture and socioeconomics of the area. Therefore, micro-level eco-restoration management plan is important and relevant for implementation in view of considering each degradation threat specifically.

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IDENTIFICATION OF POTENTIAL FOREST PLANTATION SITES FOR SUSTAINABLE PLANNING IN PASOL GAD WATERSHED USING GEOSPATIAL BASED ANALYTICAL HIERARCHICAL PROCESS

Mirana Laishram Devi*[1], Suresh Kumar Bandooni[2] and Vishwambhar Prasad Sati[3]

[1,2]Department of Geography, Shaheed Bhagat Singh (Eve) College, University of Delhi, Delhi, India
[3]Department of Geography and Resource Management, School of Earth Sciences, Mizoram University, India

Correspondence: mirana.devi@gmail.com

ABSTRACT

This research paper aims to develop a model that select an adequate area for potential forest plantation for sustainable planning in the Himalaya belt of Pasol Gad watershed, Pauri Garhwal District in the state of Uttarakhand, India. The model includes the combination of Analytical Hierarchy Process with the integration of Geographical information system based on the multi-criteria evaluation techniques to analyse the potential site for future forest plantations. Different criterions were selected based on DEM, drainage, landslide, soil erosion and land use and land cover. Erdas imagine and ArcGIS software was used for the detail analysis. This framework focuses on the sustainable planning for solving the problems of forest loss, its management, forest-based activities and its importance for cultivation layout for future restructuring. Results demonstrate that about 10.3 percent area is classified into very high suitable level, 20.39 percent in highly suitable level, 23 percent in the moderate suitable level and 14.13 percent in low suitable level and around 32.36 percent fall under very low suitable level for forest plantation. After identification of the potential site for forest plantation, a demonstrative sustainable forest plan has been made based on locally available natural resources. The result of the study can be helpful and effectiveness to assess the suitable sites for forest plantation in the mountain regions.

Keywords: Forest, Plantation, Analytical Hierarchy Process, Geographical information system, Sustainable

INTRODUCTION

The process of deforestation and forest degradation in mountainous region is the result of human encroachment, demand and extreme climatic event, which have significant impacts on forest-based livelihood systems. The negative impact due to depletion of forests can be seen in many parts of the country such as extinction of biotic communities, loss in income to the local communities, soil erosion, global warming etc (Lung and Schaab 2010). However, changes in the forest cover are the result of both natural and anthropogenic factors acting at different time scales (FAO 2001). The high dependency on forests-based resources might cause to persistent loss of forest cover to an alarming rate. In the era of economic pressure, the sustainability of forest resources is very difficult. So, it is necessary to find a way to develop a diverse strategy to manage the forests for reverting forest degradation.

Forest Survey of India (FSI) 2019, indicates that India's forests cover is about 21.67 per cent of the total geographical area. In Uttarakhand, 61.43 per cent of the total geographical area is covered by forests (Sati 2019). This forest area comes under the forest department, van panchayat etc and out of these, many areas are devoid of forest, sparse trees, barren land and snow cover. Therefore, there is a large scope to increase the area under forest in Uttarakhand.

Pasolgad watershed in Pauri Garhwal district of Uttarakhand Himalaya is a home to many natural species and it is very rich in flora and fauna. The villages in and around the study area have mostly built their primary relationship with the forest for maintaining their economic structure and also for the construction of the social organization since time immemorial. But since around last 40 years, the relationship between forest and man is disturbing very rapidly.

Overgrazing and large extraction of forest resources without sustainable use has led to deforestation and forest degradation (Michael CW and Janet LO 2003). In the Garhwal Himalaya, it began during British rule in India. Forest was used as a revenue extraction rather than natural resources. Apart from this, a large forest land was converted into agricultural land. As population is growing fast, the demand for agricultural land is increasing. This process has led to a high rate of deforestation, which is continued till todate (Mitra *et al.*, 2013; Gurarni *et al.*, 2010). Further, this has led to decrease in ground water level, crop production and productivity, fuel, and fodder. Recently, the existing cropland has become abandoned because of several causes and further the land use pattern has been changed. Land use change was seen in the area where topsoil soil was degraded. The transfer of land use was mainly from natural vegetation to agriculture and from agriculture to other uses like fallow, waste, scrub and grass lands etc (Mirana *et al.*, 2014). Therefore, to check the damage of the forest resources due to the soil loss and continuous interference of human activities, an alternative solution is required to help reverting forest back. So, it is necessary to find a way and methods for proper forest plantation. This will create strategies for sustainable development and also decrease the pressure on forest resources. Hence, it will help to convert lands under fallow, waste, scrub, barren and pasture back to the forest.

Pasol gad watershed is selected for the detail study because maximum land is being converted into open forest, degraded forest, fallow, culturable waste, and pasture lands. Therefore, it is important to find out the suitable sites for forest plantation and also necessary to balance the utilization of the forest resources for the economic development and also such type of study has not been conducted so far in the region. The present study is unique, which will manifest further study on the same theme in the Himalayan region. The study is also important as it will look for identifying potentially suitable sites for forest plantation and also for sustainable planning. It will also be helpful to the local administration, stakeholders and non-governmental organizations (NGOs) in assessing potential site for a suitable and sustainable forest plantation in different part of watershed. The main objective of this study was to develop a model for suitable plantation sites. It also aimed to analyse land use and land cover change in Pasod Gad watershed. This study also suggests for sustainable use and forest resources though framing and implementation of suitable planning.

Few literatures have studied related to present study. According to Romero (1989) to finds out the potential site for the forest plantation, some criterion must be undertaken considering the sustainability. Criterions were taken keeping environmental, economic and socio-cultural structures as a key component (Joerin *et al.*, 2001) for solving complex landuse problems with manifold alternatives (Wang *et al.*, 1990; Jankowski 1995; Yu *et al.*, 2011). Numerous studies were also conducted by many scholars taking an ideal metacriterion decision making (MCDM) for land suitability analysis (LSA) based on the integration of Geospatial overlay analysis and Analytic Hierarchy Process (Mokarram and Aminzadeh 2010; Mendas and Delali 2012); Bandyopadhyay *et al.*, 2009. This technique explained the complex problems of land management with best auxiliary in various studies for the prospective land use decision-making process (Cengiz and Akbulak 2009; Malczewski and Mendas 2006). As far as various methods for identification of potential site are concerned, analytic hierarchy process (AHP) is widely used for multicriterion decision making for land suitability in various field. It determines the weight, considering the different parameters specify based on their relative momentous (Miller *et al.*, 1998).

METHODOLOGY

In the present study, Geographical Information System (GIS) based on AHP model was developed to locate the most suitable area for the forest plantation and for this both primary and secondary data are used. The important secondary sources are NATMO, IRS and SOI. The soil types, landslide zone and rainfall data were used from National Atlas & Thematic Mapping Organisation (NATMO. IRS Resource SAT, LISS III Imagery for the year 2017 was also used to collect the information of elevation, slope and land use and land cover (LULC). Shuttle Radar Topography Mission (SRTM) data of 90 m resolution is used for generating Digital elevation Model (DEM) and slope. Survey of India (SOI) toposheet No.53 O/I of the year 1967 on Scale 1: 50,000 is used to delineate the watershed boundary and also for the preparation of base map and information for the drainage network. These have been used to run the model. After this, annual available amount of landuse is calculated and a distribution map is prepared. It involves series of image enhancement techniques such as geometric correction, radiometric correction and supervised classification. Erdas 2015 and ArcGIS 10.5 software are used for the detail analysis. The weight for each criterion was given using analytical hierarchy process and then weighted overlay analysis was adopted using GIS to create the suitable site for forest plantation.

The primary survey was done using trimble hand-held GPS for ground truthing of area under LULC. Apart from it, schedule methods have been used to collect few more information like forest resource uses, hardship face by the villagers due to the decreasing area under forest and potential agencies for forest management. For these 83 respondents were selected from different villages of study area.

The formula for the land suitability score given by Cengiz and Akbulak (2009) is

$$LS = \sum_{i=1}^{n} W_i X_i$$

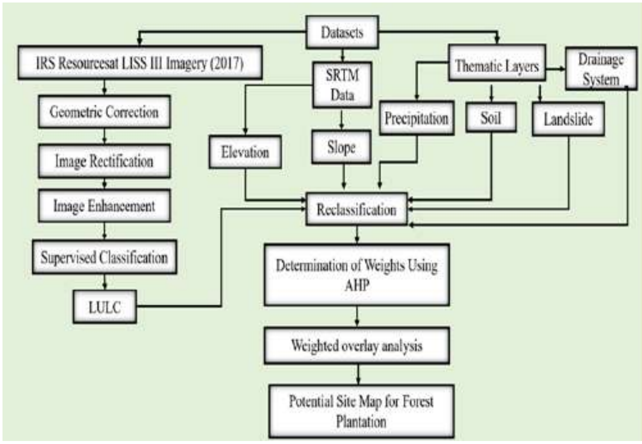

Fig.1. Methodology Framework; Source: Compiled by the author

- LS indicates the total land suitability score,
- i land suitability criteria, and n denotes the total number of land capability criteria,
- Wi denotes the weight of the selected land suitability criteria,
- Xi indicates the assigned sub-criteria score.

The model consists of GIS integrated Analytic hierarchy process (AHP) for the analysis. This process assigns numerical values to individual value decisions which make it possible to measure the degree of each criterion of the hierarchy contributing to the value of the next level depending on their maximum limitation that influence the forest area (Noel *et al.,* 2012). And this in turn, help in finding the best possible alternative between a set of feasible alternatives result (Hadipur *et al*., 2016). It is one of the most widely used technique (Lee *et al*., 2008), especially in the field of forest management, landuse/landcover planning, agriculture sectors, conservation of the forest etc due to the flexibility and efficiency result in decision-making problems (Schmoldt *et al*., 2001; Vacik and Lexer 2001; Dhar *et al*., 2008). Therefore, Analytic hierarchy process is use to determines the significance criterions in the hierarchy of the selected inputs to weighted overlay analysis (Parimala and Lopez 2012). The selection of multi criterions is considered depending on their significance. This selection depends on their maximum limitation that influence the forest which include landuse/landcover (Fig. 3), elevation (Fig. 4), slope (Fig. 5), landslide zone (Fig. 6), soil types (Fig. 7), estimated soil erosion (Fig.8), average rainfall (Fig.9). After the re-classify of each thematic layer with the new cell values of the selected multi criterions, weighted overlay analysis techniques are adopted using ArcGIS. According to (Mojid *et al*., 2009; Zolekar and Bhagat 2014, the cell values of each raster layer are multiplied by their weight.

STUDY AREA

The Pasol gad watershed lies in the eastern part of Pauri District, Uttarakhand Himalaya. It is a tributary of the Eastern Nayar. The longitudinal and latitudinal extension of the watershed is between 29° 53’ 12” to 29° 57’ 51” N and 79° 2’ 11” to 79° 7’ 34” E encompassing an area of 4886 hectares (Fig. 2). It flows in Bronchial block of Thalisain (now Syunsi) tehsil with an altitude ranging between 1100 and 2300m from mean sea level. The landscape is hilly and mountainous. The forests in the Pasol gad watershed play a vital role to the life of the locals because of the essential services like fodder, firewood, medicinal plants, pasture for livestock grazing, timber and also other non-timber forest products like fruits and conservation of natural resources. In consonance with (LEAD India, 2007), the forest ecosystems of Uttarakhand play a key role for sustaining life in the form of regulating services like climate restraint, hydrological regulation, seed dispersal, and pollination, ancillary services such as nutrient cycling as well as cultural and recreational services. Out of the total villages in the study area, the average altitude zone of seven villages is 1100 to 1700m. 16 villages are located between 1400 and 2000m and 6 villages are situated between 1600 and 2300m above the mean sea level.

RESULTS AND DISCUSSION

Land Use and Land Cover

Table.1 describes the current landuse patterns and it indicates that maximum area is under agriculture which occupies around 43.51 percent. Agriculture is the main occupation of the people, engaging around 90 per cent of the total workers of the villages. Unfortunately, the agriculture is still in primitive stage and there are possibilities for modernization. Second main land cover is forest which occupies an area of about 42.68 percent of the total study area. But the majority of the forest area is marked with open forests, scrubs, degraded forests and sparse trees. They are followed by pasture land, waterbodies, barren land and settlements.

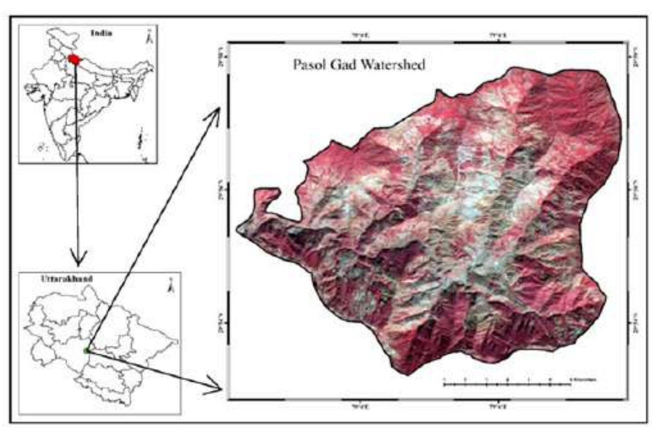

Fig.2. The location map of Pasol Gad watershed

Like other parts of Garhwal Himalaya in Uttarakhand, Pasol gad watersheds also support a wide variety of biodiversity including forests in different altitudes. Forest resources also appraise the status of the forest health and also the proliferate of the forest (Coppin and Bauer 1996; Iverson 1988; Ramachandran and Reddy 2017; Viedma *et al*., 2006).

This watershed presents a unique set of ecological characteristics over a complex variety of systems that incorporate forests, grasslands, and rivers, as well as wildlife, geology, and several other geographically distinctive peculiarities. But the conversion of forest land to agriculture and agriculture to other land use has led to the abrupt change in the ecological systems. And this change is a continues and common phenomenon depending to the development of the area. Hence, have already altered the forest resources in globally. But in the mountain regions like Pasol gad watershed where the development is very slow or no development is at all taking place. It is also observed, based on field studies that during the last many years large area under agriculture have mostly converted into fallow, waste, and grass lands mainly due to youth out migration. Out migration is mainly due to the hardship face by the villages because of less available facilities. Agriculture is mostly depended on monsoon rain which is irregular in nature and rate of runoff is very high.

Table1. Landuse/Landcover -2017, Pasol gad watershed

S.No.	Land use /Land cover	Area in Hectare	Area in Per cent
1	Settlement	79	1.63
2	Agricultural Land	2117	43.51
3	Forest	2077	42.68
4	Pasture Land	379	7.79
5	Barren Land	80	1.64
6	Water bodies	134	2.75
7	Total	4866	100

Source: L. Mirana and S.K. Bandooni 2018. *The Horizon*,4

On the other hand, wild animals also destroy the crops. Hence, large outmigration among the youth is the common phenomenon in the study area. According to the locals, the area under forests and agriculture land has decreased during last 30 years while area under pasture, fallow, waste, open forests and barren land has increased.

Types and Distribution of Forests

The forests in the study area can be classified into three categories namely Warm-Temperate (Lower altitudes temperate), Cool-Temperate (Mid altitudes temperate) and Cold-Temperate (Upper altitudes temperate) (Table 2). Few patches of subtropical forest can also be seen at very low height mainly along the river's banks.

It is observed that no regular plans are prepared to manage civil and soyam forest area except very few ones, these forests

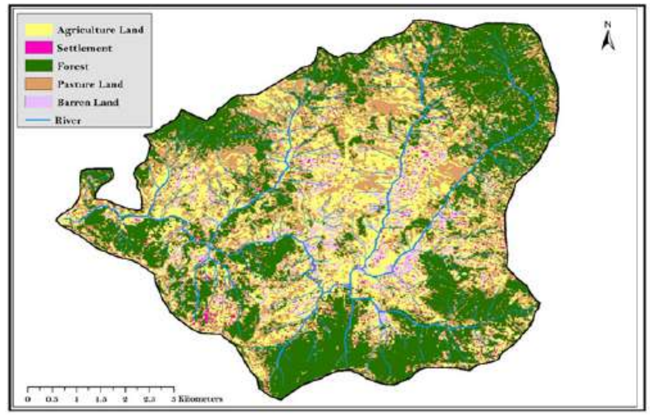

Fig. 3. Landuse/Landcover -2017, Pasol Gad Watershed

are most degraded, degenerated, and problematic ones. They are the best examples of tragedy of the commons where only target is to exploit the resources and not to manage them. This type of forests is found in many parts of study area. Among 'Van panchayat forest' of Gadkharak, Kamlya, Bungidhar, Bhatbo, Ukhliyon, Dulmot etc some van panchayats have done commendable jobs. But they suffer many problems like lack of fund, over control by government agencies, lack of proper authority and absence of regular election. Out of the 'village forests' area maximum is highly degraded due to personal interest to exploit as maximum as possible.

Forest Suitability Levels for forest plantation

To find out forest suitability levels and sites for forest plantation, seven different types of maps have been prepared. LULC map (Fig. 3), elevation map (Fig. 4), slope map (Fig. 5), landslide map (Fig. 6), soil (Fig. 7), soil loss (Fig. 8) and average precipitation (Fig. 9). All these thematic maps were rasterised and reclassified. The designated scores of sub

Table 2. Types of forest in Pasol Gad Watershed

Forest Type	Altitude	Characteristics
Temperate Zone (Lower altitudes)/ Warm temperate zone	Between 11000 mand 1600 m	Pine and Toon is found.
Temperate Zone (Mid altitudes)/Cool Temperate zone	Between 1600m and 2100 m.	Mixed-oak, Pine Ringal(a dwarf bamboo), Utis (*Alnus nepalensis*), Anyar, Rhododendron, Melu, Kafal (*Myrica esculenta*) etc.
Temperate Zone (Upper altitudes)/ Cold temperate zone	Above 2100 m	Coniferous: Cedar, fir and spruce. Rhododendron, Oak, Tilonz etc are also found

Source: Compiled by authors

criterion for the selected parameters were calculated based on Analytic Hierarchy Process and weighted were given using weighted overlay analysing in ArcGis 10.5.

Suitable potential map for forest plantation were generated (Fig. 10) and are classified into five levels (Table 3) i.e., very high level (501 hectare), high level (992 hectare), moderate level (1115 hectare), low level (688 hectare), very low level (1570 hectare).

It is observed that around 10.3 percent of land in the study area is classified into 'very high suitable level' for the potential forest plantation (Table 3). These lands have an elevation between 1300 and 2300m from mean sea levels and the main landuse/landcover are open forest, degraded forest, patches of dense forest, grassland, wasteland, and barren land. About 20 percent of lands are classified into 'high suitable levels' class. The main characteristics are stiff slopes with an elevation between 1500 to 2100m from mean sea level, having very sparse forests cove, degraded forest and summer cowsheds. An area of 22.92 percent of land comes in 'moderate suitable levels. It is specified by open forest, devoid of forest, barren, cultivation, settlement, grass land, rocky lands with dry slope having an elevation between1400 to 1900m from mean sea levels. These lands are more expose to soil erosion due to frequent interference of human activities. An estimation of about 14 percent of lands comes under 'low suitable level.

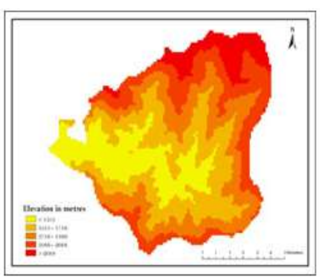

Fig. 4. Elevation

Fig. 5. Slope

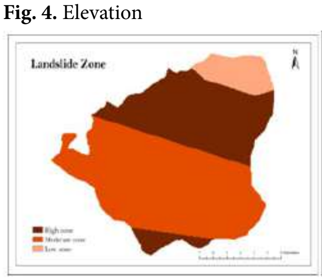

Fig. 6. Landslide

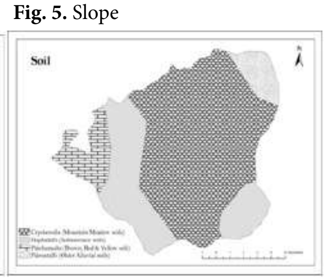

Fig. 7. Soil

Fig. 8. Soil loss estimation

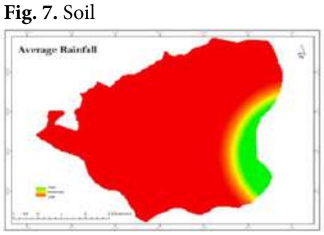

Fig. 9. Average Precipitation

It is found in an elevation between 1500 to 2200 metres from mean sea levels as this area are already under dense mix forest. Therefore, plantation of forest is not required in this level but forest planning is necessary for sustainable use.

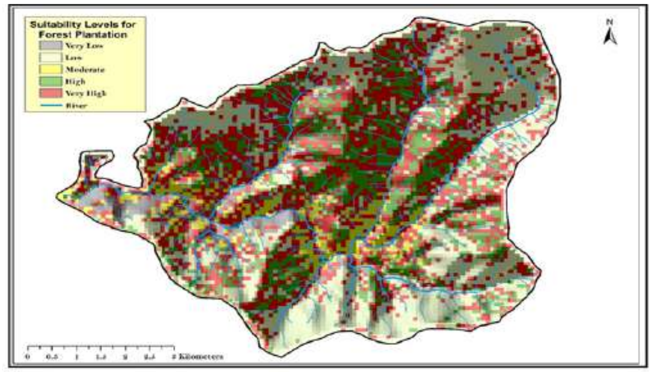

Fig. 10. Potential Site for Forest Plantation Zone in Pasol Gad Watershed

Table 3. Potential Site for Forest Plantation Zone in Pasol Gad Watershed

Suitability levels	Area in Hectare	Area in Percentage
Very Low	1570	32.26
Low	688	14.13
Moderate	1115	22.92
High	992	20.39
Very High	501	10.3
Total	**4866**	**100**

Source: Compiled by authors

The area which falls under the levels of 'very low' category is estimated about 32 percent with an elevation less than 1600m. from mean sea levels. These lands are mainly characterised by agriculture, settlement, roads, and water channel. Due to the occupancy of land for human activities, it is not suggested for potential forest plantation. But social and agro forestry can be done.

The forest suitability levels have further classified based on village location and main land use/land cover characteristics (Table 4). Forest plantation planning is possible by involving the local's community. This will also help address local economic and social problems by planning an appropriate and strategy sustainable effective management tool for conservation of the forest.

Based on the current landuse practices, sustainable development plan is generated in different levels of suitability site for forest plantation (Table 5). For example, in very low suitability level, cultivation of crop along the road side and the water channel is practiced. Therefore, forest plantation like social, agro and strip plantation can also be planned with small scale forest-based industries.

The role of forest has emerged as an importance aspect in terms of environmental and socioeconomic sustainable development. Therefore, sustainable forest planning for all types of forest products in the study area has become a priority interest to the locals. The term "sustainable development" according to World Commission on Environment and Development (WCED, 1987) is "to meets the needs of the present without compromising the ability of future generations to meet their own needs".

Table 4. Village Wise Forest suitability Zones in Pasol Gad Watershed

Suitability levels	Name of few villages	Remark
Very Low	Bharadidhar, Kanera, Budkot, Lower SeeliKamlya, Bungidhar bara, Ukhliyon lower, Tankhil, Siloli and Bungidhar	Area under cultivation, settlement, roads, and water channel.
Low	Upper parts of Dumlot,Kamlya, Narula Jhala, KuknalDulmot, Chyunrkot and SeeliKamlya	Dense mix forest and Pine forest (Pine forest is to be replaced into a mix forest with a spices such as Rhododendron, oak, Deodar, Cedar etc.)
Moderate	Chaundliya, Dandkhil, BatboandUkhliyon	Dense forest, grass land, waste land, barren land and scattered settlement
High	Nauksain, KaphalgairBhainsora, Dabar and Bhirkot	Degraded forest, pasture land, culturable wasteland
Very high	Bayera, Narsingh, Khaitoli and Maildhar	Open forest,degraded forest devoid of forest, barren, cultivation, culturable wasteland, settlement, grass land and Pine forest (Pine forest is to be replaced into a mix forest with a spices such as Rhododendron, oak, Deodar, Cedar etc.)

Source: Compiled by authors

Relationship between distance and dependency of Forest Resources

Forest use and forest reliance is an on-going livelihood strategy for the people of rural areas mainly in remote and mountains villages like Pasol gad watershed. Therefore, to understand the relationship between dependency and distance from the forest for the collection of the forest products, a detailed questionnaire-based interview was carried out for a random selection of 83 respondents from different villages of watershed. It is found that as the dependency on forest resources increasing, coupled with inappropriate management practices, it has exerted unprecedented pressure on forest resources, leading to degradation. It is also found that work of collection of forest products are mostly on women shoulders. They walk for 3km to 5km for the collection of forest products like fuel woods, fodder, wild flowers etc. Whereas the villages close to the dense forest need not to walk long distance. Therefore, to understand the relationship of forest and distances, all the villages in the Pasol Gad watershed are divided into two groups namely villages like Gadkharak and Dulmot participated in forest plantation programme and villages without having such programmes like Kanera and Bungidhar. The analysis shows an interesting result that the distance of forest was found between 1 and 2km in first category and 2 and 5km for second category.

Importance of Forest Resources

In order to assess the significant of forest resources, priorities index based on field survey is generated (Table 7). Each and every respondent were asked to give priority for the forest resources according to their requirement. Source of fodder is marked priority number one, source of timber priority is two and followed by water recharge, fuel, check soil erosion, organic manure, home to wild life and last priority is important to fight against negative impact of climate change.

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Table 5. Forest Strategy for sustainable Development in Pasol Gad Watershed

Anticipated impact on Social Aspect	Anticipated impact on Economic Aspect	Anticipated impact on Environmental Aspect
*People participation for sustainable development. *Provides herbs for cure from diseases. *Ideal place for animal rearing. *Provides social security in the form of supply of fuel wood, fodder, fruits etc. *Cultural-religious functionsbasedupon people-forest relationship exist in the area. Like HARELA function to plant tree and worship is celebrated with great enthusiasm.	*Agro-forestry to provide mainly fruit, food grains and pulses. *Social forestry to provide three "F" (fuel, fodder and fruit). *Provide fruits like wild berry, herbs and vegetables like mushroom for locals and the markets. *Create local employment for forest security and management *Potential for forest based small scale industries like basket making, organic manure, medicine from herbs and various parts of tree and gift items fromdry parts of tree. *Scope of forest based eco-tourism (Forest camp, trekking, adventurous and to understand man and environment relationship). *Creation of local supply chain and local sourcing of goods and services. *Assistance and finance to locals and private enterprises to promote afforestation, reforestation and sustainable forest sector management.	*Check soil erosion *Soil improvement *Check landslides *Help in occurring of more rainfall and snowfall. *Help in water recharge capacity. *Mitigation of forest fires. *Maintain bio diversity. *House of wild animals and birds. *Scenic resource.

Source: Compiled by authors

Role of Agencies for Sustainable Forest Planning and Management

In order to gets the idea for the role of different agencies on sustainable forest planning and management, priority-based questionnaire survey was carried out for 83 respondents. They were asked to give the priority to each agency and in total 8 choices were proposed based on observation and experiences (Table 8). The study shows that among all the priorities, the community participation is the first choice of the respondents as north east part of the watershed have witnessed the positive impact of community participation for forest and water management. It is followed by Joint Forest Management by government official and locals. As Van Panchayat, village organization and self-help groups include local participation they got third, fourth and fifth ranks priorities respectively. In all these priorities, local participation is must. The role of only government and private agencies have got sixth and seventh choices respectively. Management of Forest under reserved and protected forest has got last priority and simple reason behind it is the denial the right of locals on forests products.

CONCLUSION

The finding of the study shows, how these results can contribute to decision making process and can provides useful information to planners for the identification of suitable sites for forest plantation in Pasol Gad watershed, Pauri Garhwal District of Uttarakhand. The methods used in this study, also give the current status on the forest coverage and area where the planation of the forest is required for the future scenarios. GIS integrated AHP model which used, is one of the most challenging and widely used technique (Lee *et al.*, 2008) for such research work. This method is found to be more suitable for determining sites for reforestation, afforestation and strip plantation. The results show that around 10 and 20 percent of land consists of 'very high suitable' and 'high suitable areas and these are best suitable for forest plantation respectively. Around 32 percent of the study area has low potential for forestation.

In order to understand views of stakeholders regarding importance of forest resources and agencies for management of forest, analysis of the field survey is done for the 83 respondents and priority tables are generated. It is observed that source of fodder is mark priority one, source of timber priority two, followed by recharge water table, fuel, soil erosion, organic manure, home to wild life and last priority is to fight against negative impact of climate change. The obtained result shows that collection of forest products mainly fodder and timber from the forest are the main priority in the study area. One more priority table is prepared to understand the view of stakeholders to manage the forest resources. It indicates participation of locals in the form of community participation, joint forest Management and Van Panchayat are important ones.

Considering the certain limitations of the government, the obtained results of this study can be beneficial to the authority in contributing in decision making process and optimally

Table 6. Forest Strategy for sustainable Development in Pasol Gad Watershed

Criteria	Priority Importance									Total
	1	2	3	4	5	6	7	8	9	
Fodder	35	22	7	6	5	3	2	2	1	83
Timber	16	24	18	8	6	4	3	2	2	83
Water recharge	8	7	30	8	10	5	9	4	2	83
Fuel	10	11	14	27	11	4	4	1	1	83
Soil erosion	1	2	3	11	21	15	11	8	11	83
Wild fruits, vegetables &herbs	2	3	3	8	8	34	18	5	2	83
Organic manure	7	8	4	6	7	9	24	13	5	83
Wild life	3	3	2	6	9	5	5	37	13	83
Climate change	1	3	2	3	6	4	7	11	46	83
Total	83	83	83	83	83	83	83	83	83	

Source: Compiled by authors

manage the forest resources for the future reforestation by plantation trees in suitable potential site of the study area. To relate the study in real life situations, few suggestions for policy makers may be consider. For example, Pine forest must be replaced with mixed temperate forest, Fruit plantation of wild fruits (kaphal, berries etc) and other fruits like walnut, orange, malta etc should be planted in forest area to check the encroachment of wild animals in the village area, Forest plantation work may be done in the degraded and deforested land., Strip planation may be promoted along the river channels and roads, Community participation for forest resource management should be supported by the government agency.

Table 7. Role of Agencies for Sustainable Forest Planning and Management (Based on Priority)

Priority Role	1	2	3	4	5	6	7	8	Total
Community Participation	43	13	8	7	5	3	2	2	83
Joint Forest Management	18	41	17	2	2	1	1	1	83
Van Panchayat/ Forest Group	7	11	39	16	6	2	1	1	83
Village Organization/ sabha	5	8	4	40	19	4	2	1	83
Self Help Group	6	4	8	9	36	11	6	3	83
Govt. Agencies	2	4	4	6	13	38	8	8	83
Private Agencies	1	1	2	1	1	7	51	19	83
Reserve/Protected Forest	1	1	1	2	1	17	12	48	83
Total	83	83	83	83	83	83	83	83	

Source: Compiled by authors

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SOME IMPORTANT MULTIPURPOSE TREE SPECIES OF NORTH-EAST INDIA AND THEIR POTENTIAL FOR ECOSYSTEM RESTORATION

Kajoli Begum and Wishfully Mylliemngap*

North-East Regional Centre, G.B. Pant National Institute of Himalayan Environment, Itanagar, Arunachal Pradesh, India

***Correspondence:** wishm2015@gmail.com

ABSTRACT

In the North Eastern Region, degradation of soil and environment is a major concern. As the region is characterized by slopping hills and valleys, excessive deforestation coupled with shifting cultivation, heavy rainfall and other faulty agricultural practices have resulted in remarkable soil loss and poor soil physical health which makes the region highly vulnerable to erosion and accelerate land degradation. Ecological restoration through MPTs would not only help in conserving the productive soil, by reducing the soil erosion and restoring the soil properties and nutrients but would also enhance the productivity and fertility of highly degraded land resources. This paper presents a comprehensive overview of the potential MPTs of the North Eastern Region and highlights show these potential MPTs can be further utilized towards ecological restoration and reclamation of the degraded lands in the Region.

Keywords: Multipurpose Tree Species (MPTs), Land degradation, Ecological Restoration, North Eastern Region

INTRODUCTION

'Nasti ekopivanspatina vanaushadhi', which means all plant species on earth have medicinal value, which implies that every plant species is multipurpose in nature. Multipurpose Trees (MPTs) are defined as "all woody perennials that are purposefully grown toserve more than one significant contribution to the production and/or service functions of aland-use system. They can be classified according to the characteristics of the plant speciesas well as to the plant's functional roleunder consideration inthe agroforestry systems"(after Burley and von Carlowitz 1984). For example, *Alnus nepalensis* is grown by the local communities in Nagaland as inter-crop with tapioca, colocasia and later the trees are used as timber, fuel and fodder (Rathore *et al.*, 2010).

Ecological restoration is important for sustaininglife on Earth, and to establish a healthy ecological balance between man and environment. Ecosystem services such as soil formation and soil fertilitymaintenance, air and water purification, provisioning of fodderand fuel wood, NTFPs, biodiversity conservation, watershed protection and carbon sequestration is necessary for the sustenance of human life. Hence ecological imbalance, land degradation and its erratic impacts are directly connected with biological diversity, ecosystem services and livelihood of the local community (Negi and Dhyani 2014). Globally, it is estimated that about 2 billion ha area is under the extent of various land degradationforms,whereas annually about 5-7 million ha of arable land is lost due to degradation of land. In India, the extent of wasteland is estimated from 53Mha to 188Mha because of the various applications for defining the waste land or the various criteria applied (Sharda 2011).

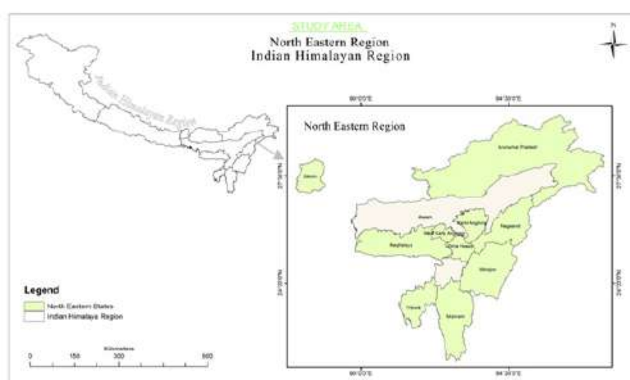

Fig 1. Study Area Map of North Eastern Region, Indian Himalaya

North East India, which lies between 22°05´and 29°30´ N latitudes and 87°55´ and 97°24´ E longitudes (Fig. 1) is one of the the 34 "Biodiversity Hotspots" of the world region. Spreading over an area of 203,036km^2, the region has about 65.05 % of the total geographical area under forests while the remaining area is either under non-agricultural uses or uncultivated land and total cropped area of this region is 3,226mha. from the total cropped area of India i.e., 198,969m ha (ISFR 2019 and Agri. Statistics 2012, Table 1). Because of natural corollary of the region physiographic attributes, the low lands are under agricultural crops. The land has more

Table 1. The extent of land degradation (Million ha) in North East Region (NER) of India

State Logging	Water Erosion	Water Logging	Soil Acidity	Complex Problem	Total Degraded Area	% of Degraded Area to Total Geographical Area (TGA)
Arunachal Pradesh	2.4	0.2	2.0	0	4.6	53.8
Assam	0.7	0	0.6	0.9	2.2	28.2
Manipur	0.1	0	1.1	0.7	1.9	89.2
Meghalaya	0.1	0	1.0	0	1.2	53.9
Nagaland	0.4	0	0.1	0.5	1.0	60.0
Sikkim	0.2	0	0.1	0	0.3	33.0
Tripura	0.1	0.2	0.2	0.1	0.6	59.9
NER	4.0	0.4	5.1	2.2	11.8	
India	93.7	14.3	16.0	7.4	146.8	

Source: NBSS & LUP-ICAR (2005) on 1:250,000 Scale

than 15% slope, high land erosion, undulating topography and secluded terrain (Saha *et al*., 2012).About 80 per cent of the population lives in rural areas and majority of them depend on agriculture and allied sectors for their livelihood (Bhatt and Verma 2002).

In North-East region, land degradation is major concern as the region is characterized by hilly terrains with steep slope making agricultural activities highly vulnerable to soil degradation varying across the states depending upon geological formations, topographical features, soil characteristics, climatic conditions, land use practices and other factors. The high annual rainfall ranging from 1500–12,000mm with hilly and slopping land makes the region prone to erosion by water causing losses of soil and nutrient. In addition, human-mediated escalation of land degradation has been caused by agricultural expansion, shifting cultivation, deforestation, buildings and road construction, excessive mining, and construction of hydro-power projects (Yadav *et al*., 2020). The extent of soil degradation as estimated by ICARNBSS & LUP is elaborated in Table 2 and Annexure-I. 7037152781

In NE India, about 37.1% of the total geographical area is under threat of land degradation and erosion is being considered as the major driver and hence ecological restoration and reclamations of degraded land is required. In this context, MPTs could form an integral component for wasteland restoration especially in areas where degradation is advanced. Besides, MPTs are also useful tool in agroforestry interventions such as crop sustainability, improvement of soil health and other ecological services. However, priority species vary among different states as well as among regions within a state depending on ethnic diversity and food habits of the tribal communities (Saha *et al*., 2012). Fast growing, native pioneer species with high productivity are recommended for the initial stages of restoration of degraded lands. However preference should always be given to indigenous species as they are more appropriate than exotics, because (1) they are often better adapted to local environmental conditions, (2) seeds may be more generally available, and (3) farmers are usually familiar with their use. Some parameters like pH tolerance, high concentration of toxic metals, resistance against pest and disease, ability to sprout and to respond to pruning and coppicing, seed production, germination characteristics, growth under different soil conditions are also should be monitored for a successful plantation (Negi and Dhyani 2014).

METHODOLOGY

The present review highlights the potential role of Multipurpose Tree Species (MPTs) for Ecosystem Restoration in NE

Table 2. Forest Cover Change 2017 to 2019, NE India(Area in sq.km) and Total Cropped Area

State	No of Hill District[1]	Geographical Area (GA)[1]	Total Forest Cover(2017)[1]	Total Forest Cover(2019)[1]	Change[1]	% of Geographical Area (GA)[1]	% of Change w.r.t ISFR 2017[1]	Total Cropped Area[2] ('000 hectare)
Arunachal Pradesh	16	83,743	66964	66688	-276	79.63	-0.41	276
Assam	3	19295	28105	28327	222	67.41	0.79	4,100
Manipur	9	22327	17346	16847	-499	75.46	-2.88	233
Meghalaya	7	22429	17146	17119	-27	76.33	-0.16	336
Mizoram	8	21081	18186	18006	-180	85.41	-0.99	487
Nagaland	11	16579	12489	12486	-3	75.31	-0.02	123

Sikkim	4	7096	3344	3342	-2	47.10	-0.06	144
Tripura	4	10486	7726	7726	0	73.68	0.00	309
Total	62	203,036	171,306	170,541 (65.05%)	-765	72.54	-3.73	3,226 (All India 198,969)

*Source: 1 FSI, India State of Forest Report, 2019. 2 Agricultural Statisticsata Glance2012, Directorate of Eco-nomics and Statistics,Ministry of A*griculture.

Annexure I. List of some common MPTs available in the NE Region

S. No	Multipurpose Species	Family	Uses	Distribution within NEH Region (source: field expert consultation& India biodiversity portal)	Reference
1	*Acacia catechu*	Leguminosae	Timber, katha, fodder, fuelwood, medicine, agricultural implements, tools & house posts	Assam, Sikkim, Arunachal Pradesh	Bhatt and Verma 2002
2	*Aegle marmelos*	Rutaceae	Wood, firewood, food, fodder, sacred tree	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Bhatt and Verma 2002
3	*Albizia chinensis*	Leguminosae	Fodder, wood & firewood	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Bhatt and Verma 2002
4	*Albizia lebbeck*	Leguminosae	Furniture, paneling, agricultural implements, tools, firewood, fodder & medicine	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Bhatt and Verma 2002
5	*Aquilaria malaccensis*	Thymelaeaceae	Fragrance oil, timber, religious	Assam, Meghalaya, Arunachal Pradesh, Nagaland, Tripura	Das 2013
6	*Artocarpus chama*	Moraceae	Fruit, timber, boat making,agricultural implements	Assam, Meghalaya, Arunachal Pradesh, Nagaland, Tripura	Das 2013
7	*Artocarpus heterophyllus*	Moraceae	Fruit, vegetable, timber, fodder,cash, agricultural implements	Assam, Meghalaya, Arunachal Pradesh, Manipur Tripura	Das 2013
8	*Artocarpus lacucha*	Moraceae	Fruit, timber	Assam, Meghalaya, Arunachal Pradesh, Nagaland, Tripura	Das 2013
9	*Averrhoa carambola*	Averrhoaceae	Medicinal, fruit, fuelwood	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Das 2013
10	*Azadirachta indica*	Meliaceae	Medicinal, religious, timber	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Das 2013
11	*Bauhinia purpurea*	Leguminosae	Wood, agricultural implements, fuelwood, fodder, rafters, vegetable (flower buds) & pickles	Assam, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram	Bhatt and Verma 2002
12	*Bauhinia racemosa*	Leguminosae	Wood, agricultural implements, fuelwood, fodder, roasted seeds are eaten & dye	Assam, Meghalaya, Arunachal Pradesh	Bhatt and Verma 2002

13	*Bauhinia vahlii*	Leguminosae	Fodder, cups-plates prepared (foliage), firewood & cordage are made from bark	Assam	Bhatt and Verma 2002
14	*Bauhinia variegata*	Leguminosae	Timber, fuel, fodder, vegetable (flowers) & medicine	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Bhatt and Verma 2002
15	*Bombax ceiba*	Bombacaceae	Timber, fibre, cash	Assam, Meghalaya, Arunachal Pradesh	Das 2013
16	*Cassia fistula*	Fabaceae	Timber, ornamental, shade tree	Assam, Meghalaya, Arunachal Pradesh, Manipur	Das 2013
17	*Citrus grandis*	Rutaceae	Fruit, fuelwood, cash	Assam, Meghalaya, Arunachal Pradesh, Nagaland, Tripura	Das 2013
18	*Dalbergia sissoo*	Leguminosae	Furniture, timber, fodder, firewood & medicine	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Bhatt and Verma 2002
19	*Delonix regia*	Fabaceae	Ornamental, timber	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Das 2013
20	*Dillenia indica*	Dilleniaceae	Fruit, medicinal, small timber	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Das 2013
21	*Erythrina variegata*	Fabaceae	Fencing, timber, nitrogen fixer,medicinal	Assam, Meghalaya, Arunachal Pradesh	Das 2013
22	*Ficus auriculata*	Moraceae	Fodder, firewood, fruits are edible & wood	Assam, Meghalaya, Arunachal Pradesh, Manipur, Tripura	Bhatt and Verma 2002
23	*Ficus hispida*	Moraceae	Fodder, firewood & wood	Assam, Meghalaya, Arunachal Pradesh, Manipur, Tripura	Bhatt and Verma 2002
24	*Ficus palmata*	Moraceae	Fruits are edible, fodder, firewood, vegetable (young shoot) & medicine	Assam, Meghalaya, Arunachal Pradesh, Manipur, Tripura	Bhatt and Verma 2002
25	*Ficus racemosa*	Moraceae	Fruits are edible, fodder, firewood, vegetable (young shoot) & medicine	Assam, Meghalaya, Arunachal Pradesh, Manipur, Tripura, Tripura	Bhatt and Verma 2002
26	*Ficus semicordata*	Moraceae	Fruits are edible, fodder, firewood, cordage are made from bark & medicine	Assam, Manipur, Meghalaya, Nagaland,Sikkim,Tripura	Bhatt and Verma 2002
27	*Ficus subincisa*	Moraceae	Fuelwood, fodder &wood	Arunachal Pradesh, Assam, Sikkim, Tripura	Bhatt and Verma 2002
28	*Flacourtia jangomas*	Flacourtiaceae	Fruit, fuelwood	Assam, Manipur, Meghalaya, Arunachal Pradesh, Tripura	Das 2013
29	*Gmelina arborea*	Lamiaceae	Timber, fodder, fuel wood and wastelandreclamation	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Das 2013
30	*Haldina cordifolia*	Rubiaceae	Timber, fuelwood, fodder & medicine	Assam	Bhatt and Verma 2002
31	*Holoptelea integrifolia*	Ulmaceae	Timber, fuel, furniture & fodder	Assam, Meghalaya	Bhatt and Verma 2002
32	*Kydia calycina*	Malvaceae	Fuelwood, fodder, timber & agricultural implements	Arunachal Pradesh, Assam, Meghalaya	Bhatt and Verma 2002

33	*Lagerstroemia reginae*	Lythraceae	Timber, Boat making, agriculturalimplements	Assam, Meghalaya, Arunachal Pradesh, Nagaland, Manipur	Das 2013
34	*Litchi chinensis*	Sapindaceae	Fruit, timber, fuelwood, cash	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Das 2013
35	*Litsea glutinosa*	Lauraceae	Timber, agricultural implements	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Das 2013
36	*Litsea monopetala*	Lauraceae	Timber, agricultural implements	Assam, Meghalaya, Arunachal Pradesh, Nagaland	Das 2013
37	*Magnolia oblonga*	Magnoliaceae	Timber, fuel wood, fodder and roadside plantation	Arunachal Pradesh, Assam, Meghalaya	Arunachalam *et al.*, 2020
38	*Mallotus philippensis*	Euphorbiaceae	Dye, fodder, fuelwood & medicine	Assam, Arunachal Pradesh, Meghalaya	Bhatt and Verma 2002
39	*Mangifera indica*	Anacardiaceae	Fruit, timber, religious, cash	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Das 2013
40	*Melia azedarach*	Meliaceae	Fuelwood, fodder, timber & medicine	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Bhatt and Verma 2002
41	*Morus alba*	Moraceae	Fruits are edible, fodder, fuelwood & silkworm rearing plant	Assam, Meghalaya, Arunachal Pradesh, Manipur	Bhatt and Verma 2002
42	*Pinus kesiya*	Pinaceae	Fuel wood, charcoal and building materials	Arunachal Pradesh, Assam, Manipur, Sikkim	Arunachalam *et al.*, 2020
43	*Psidium guajava*	Myrtaceae	Fruit, fuelwood	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Das 2013
44	*Pyrus pashia*	Rosaceae	Ripe fruits are edible, flowers used in apiculture, woods used in agricultural implements, fodder & fuelwood	Arunachal Pradesh, Assam, Manipur, Sikkim	Bhatt and Verma 2002
45	*Quercus oblongata*	Fagaceae	Fodder, fuelwood, wood & medicine	Assam, Meghalaya, Arunachal Pradesh	Bhatt and Verma 2002
46	*Rhus parviflora*	Anacardiaceae	Fodder, fuel wood, drupe is edible andwastelandreclamation	Assam, Meghalaya, Arunachal Pradesh	Bhatt and Verma 2002
47	*Sapindus mukorossi*	Sapindaceae	Fruits are substitute of soap, fodder fuelwood and wasteland reclamation	Assam, Meghalaya, Arunachal Pradesh, Manipur	Bhatt and Verma 2002
48	*Terminalia chebula*	Combretaceae	Religious, medicinal, timber	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Das 2013
49	*Toona ciliata*	Meliaceae	Timber, fodder, fuelwood and agricultural implements	Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura	Das 2013
50	*Vatica lanceifolia*	Dipterocarpaceae	Aromatic oleoresins, timber	Assam, Manipur, Meghalaya, Nagaland	Das 2013

India. The relevant information was collected mainly from secondary sources including journal articles, book chapters, reports of various task forces, formal and informal consultations with experts in the field (Annexure I). Some species that are widely used in certain agroforestry systems in NE region of India have been documented and their importance for ecosystem restoration is discussed.

RESULTS AND DISCUSSION

A. *Alnus nepalensis* D.Don

Family: Betulaceae,Common Name: Nepal Alder, Himalayan Alder, Indian Alder, Flowering: October-December, Distribution (NEH Region): Tripura, Meghalaya, Manipur, Assam, Arunachal Pradesh, Mizoram, Nagaland, Sikkim, Conservation Status: Least Concern (LC).

It is a large deciduous fast growing tree reaching a height of up to 30m tall with dark green or silvery grey bark. Alder is found in the Himalayas at altitudes of 1000-3000m. Areas receiving annual rainfall of 500mm to 2000mm and more are more suitable places for the tree species to grow (http://www.flowersofindia.net).

Alnus nepalensis economically important MPTs of North Eastern Himalayan Region which is valued for soil fertility built up, ecological restoration purpose for rehabilitation of the degraded lands and firewood purposes. Being a fast growing species, it helps to rehabilitate the abandoned lands of shifting cultivation which is mostly practiced in NEH region. Their nodule helps in activating nitrogen fixation process of the plants species (Bhatt and Verma 2002).

In silvi cultural practices, it tolerates both shade and poor drained soil which is why this species is also planted in the landslide prone area to resist the erosion by binding the exposed soil of the hilly region. The drought and frost resisting tree is also used for pollarding practices particularly in Nagaland region of NE India (Bhatt and Verma 2002). Alder is extensively used in sustainable farming system also grown in Tea Plantation. The light wood of the species is used in carpentry and construction. Fallen twigs and leaves act as a bio fertilizer which helps in soil restoration (Bhatt and Verma 2002). Alder based farming system is one of the major forms of traditional agroforestry systems practiced by different ethnic groups in Nagaland State (Rathore *et al*.,, 2010). In Kohima, Phek district of Nagaland, farmers practice Alder-based sustainable farming system to improve its crop yield, soil fertility and also for land restoration of jhum lands.

B. *Parkia timoriana* (DC.) Merr.

Family: Leguminosae, Common Name: Tree Bean, Flowering: August-September, Distribution (NEH Region): Meghalaya, Manipur, Mizoram, Arunachal Pradesh, Assam & Nagaland. Conservation Status: Least Concern (LC).

Parkia timoriana, popularly known as 'tree bean', is a fast-growing leguminous species bearing fruits of high economic importance reaching a height of upto 25-40m (http://www.flowersofindia.net). It is well adapted to grow in diverse agro-climatic regions from colder hilly regions to hotter plains and varied altitudinal range i.e., from 40 to 820m a.s.l. (Singh 2019). *P. timoriana* is distributed in south-east Asian countries like Burma, Bangladesh, Thailand and the Malaysian region. In India, it is found commonly growing in every house yard, Jhums and forests in Northeast states such as Arunachal Pradesh, Lushai Hills, Kolasib–Bukpui, and Sialsuk road in upper Thenzawl area of Mizoram, Nagaland, Imphal, Kangpokpi and Pachao of Manipur, Garo and Khasi hills of Meghalaya and Cachar hills of southern Assam (Singh 2019; Singha *et al*., 2021).

In NE India, it is considered as the costliest vegetable, **f**etchinga market value of Rs 100-120/kg andits timber isused for making boxes, decorative articles and light furniture. The bark contains 6-15% Tannin which is extracted and used by tannin industry and the wood can also be a source of paper pulp (Singh 2019). Moreover, the tree helps in maintenance of ecological balance by improving and enriching soil health (Angami *et al*., 2018). It is also associated with variousimportant bacterial species like *Agrobacterium fabrum, B. brubrevis, Pseudomonas fluorescens, P. putida, P. aeruginosa, Bacillus subtilis, B.cereus, Serratia marcescens, P. hibiscicol* etc. those colonize in their rhizospheric zone. Therefore, this species may help to prepare native bacterial bio-inoculants, which may improve the condition of the degraded land of the region and itcan also be used as a tool for the reclamation or restoration of degraded jhum land (Singh 2019). The tree also produces large quantities of green manure, which canbe used in soil fertility management. Devi *et al*., (2020) recently reported this species as an excellent supplier of soil nitrogen, acts as a carbon sink, has wider adaptability and can check soil erosion as a tool for the reclamation of degraded jhum land in the north eastern hilly region. The total biomass of *P. timoriana* was reported 2.24Mgha^{-1}, and the magnitude of carbon sequestration potential was 0.23Mgha^{-1} year^{-1}. *Parkia ameliorates* the soil by increasing soil organic carbon by 96.2%, improves aggregate stability by 24.0%, enhances available soil moisture by 33.2%, and reduced soil erosion by 39.5%. *Parkia* sp. is grown in combination with other crop for reclamation of degraded lands (degradation due to unsustainable practice of jhum cultivation). For example, in Mizoram, it is used as a shade tree in tea plantations where it is intercropped with banana, areca and other multipurpose tree species. In Southern Assam, it is integrated in pine apple cultivated areas. In Meghalaya, it is grown with different multipurpose tree species such as *Gmelina arborea* and *Michelia oblonga* (Singha *et al*., 2021)**.**

C. *Syzygium cumini* (L.) Skeels
Family: Myrtaceae, Common Name: Java Plum, Jamun

Flowering: March-May, Distribution (NEH Region): Tripura, Meghalaya, Manipur, Mizoram, Arunachal Pradesh, Assam & Nagaland,

Conservation Status: Least Concern (LC). *Syzygium cumini* popularly known as 'Java Plum or Jamun' is amedium-sized evergreen tropical and sub-tropical tree reaching a height upto 50 to 100ft. with oblong opposite leaves that are smooth, glossy and having a turpentine smell. Jamun has fragrant white flowers in branched clusters at stem tips and purplish-black oval edible berries. The evergreen jamun plant is originally from Indonesia and India (http://www.flowersofindia.net) and occurs in the major forest groups except in the very arid regions. It may grow in both moist and dry areas, occurring in the tropical wet evergreen, tropical semi evergreen, tropical moist deciduous, littoral and swamp, tropical dry deciduous, tropical dry evergreen, subtropical broadleaved hills, and subtropical pine forests (Roy *et al*., 2015). Being an evergreen species, abundant foliage of Jamun produces good shade, which has been used to shelter coffee trees, chicken yards and livestock pastures and when closely planted in rows, trees make good wind breaks. Jamun is successfully planted in waterlogged areas. Trees plantedclose together and topped regularly form a densehedge (Sarvade *et al*., 2014).

Sarvade *et al*.,(2014) also reported that Litter addition, decomposition and nutrient release, nutrient addition through root biomass and controlling soil erosion were important processes for improvement of soil properties and it produce 2.01-132.59t/ha total biomass in agroforestry systems and tree plantations and it also conserves 0.906-13.471t/ha total carbon. In conservation processes, it improves salt affected soils, produce biomass and store carbon in vegetation as well as in soil. It also helps in conserving biodiversity in traditional agroforestry systems and natural forests of India, which accelerates up liftment of small land holding farmers. Keystone species (e.g. *S. cuminii*) conserve high levels of nitrogen, phosphorus and potassium in highly infertile soils in northeast India.

ICAR, RC, NEHR, Barapani Centre proposed agroforestry based interventions for nutrient natural sump into deeper layer of soil which will enhance erosion control and reclaim soil degradation by practicing alley cropping with various MPTs like *Syzygium cumini* with *P. guajava* or *Assam lemonor* pear with pineapple in paired rows with fruit trees and nativegrasses on bunds (Arunachalam *et al*., 2020).

D. *Quercus serrata* Murray
Family: Fagaceae, Common Name: Indian Chestnut, Oak Tree, Flowering: April- May, Distribution (NEH Region): Meghalaya, Manipur, Arunachal Pradesh, Nagaland, Tripura & Assam, Conservation Status: Least Concern (LC).

Quercus serrata popularly known as 'Oak Tree' is a tallish fast growing deciduous broad-leaved tree reaching a height upto 8-14 m with a dense, full crown. The bark of the tree is rough and grey. The fruit is often fed upon by squirrels and the nuts are considered edible. The 'Indian Chestnut' or Oakis found in the Himalayas, to SE Asia and China, at altitudes of 300-2000m a.s.l(http://www.flowersofindia.net).It is found distributed in North Eastern Himalayan region particularly Nagaland, Tripura, Assam, Meghalaya, Manipur, Arunachal Pradesh etc. (Bhatt and Verma 2002).

Oak is a very promising agroforestry species besides its various other miscellaneous uses like wood, fuel, fodder for livestock, medicine (Gum) etc. in the Himalaya (Bhatt and Verma 2002). In Nepal the leaves are used to wrap things and the wood is locally used in construction and the bark can be used in tanning (http://www.flowersofindia.net).

Udawatta *et al*., (2002) reported that planting oak rows on a slightly sloping terrain was shown to reduce the pollution of non-point source from *Zea mays–Glycine max* rotations in them idwestern United States because of reduced run-off and leaching .Besides that it has the potential to augment production of foods, fodder and firewood without adverse impacts on environment and thus reducing the ecological pressure on the environment.

The Angami tribe in Mima village, Kohima district of Nagaland, observed that oak could satisfy some of the desirable properties of fallow trees, such as wider adaptability, less shading effect, good quality firewood and charcoal, and producing profuse coppices after pollarding. Oak shed their leaves profusely in winter, which mulch with soil and help to enrich soil fertility and reduce soil erosion with its root systems this tree species had been selected by the famers as the most popular MPTs in Mima village. The tribe further reported that cultivation of oak trees in jhum fields serve as sustainable agro-ecosystem as it helps to maintain soil fertility,reduces soil erosion, reclaim degraded land and restore ecological conditions (Singh and Teron 2019).

CONCLUSION
In conclusion, this paper lists out certain indigenous tree species of NE region useful for land restoration. For example, Oak cultivation by Angami tribe of Mima village, Kohima

district of Nagaland state of NE India, Alder based traditional farming system of local communities of Nagaland etc. has the potential for wastelandrestoration and provisioning of the five 'F' (fuelwood, fodderfood, fibre, fertilizer) while some are not so promising. It can also be concluded that proper utilization of MPTs stands is effective inecological restoration through improving the soil properties and controlling its erosion and participatory program in plantation of these MPTs can also be a promising approach for the restoration actions in the region as the plantations of these MPT species have the capability of turning degraded soils to normal soils by increasing the soil properties. The intensity of reclamation and the depth to which the changes tookplace depends on the type of MPTs to be used for the plantation.

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IMPORTANCE OF CINNAMOMUM TAMALA FOR RESTORATION OF DEGRADED LAND, WEST HIMALAYA

Amit Bahukhandi*, Indra D. Bhatt, Kuldeep Joshi and Dharam C. Attri

G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal Almora, Uttarakhand, India

***Correspondence:** amit.bahukhandi@gmail.com

ABSTRACT

Cinnamomum tamala belongs to family Lauraceae, commonly known as Tejpat or Indian bay leaf is an evergreen, moderate size, multipurpose tree species. The species is therapeutically and economically important medicinal tree species required conventional method for germination (cultivation packages). Based on the review, several multipurpose tree species gained much attention for rehabilitation of degraded land with supporting several components of the biodiversity such as restoration of ecosystem services, regulation of environmental services like carbon storage, productivity, biodiversity conservation, and improvement of soil fertility, livelihood enhancements. Therefore, present study was focused to optimize best seed germination conditions. In the study, 71.11% of seed germination with 34 days of mean germination time (MGT) was recorded in 70% shade net condition. While as, seeds germinated in open nursery condition were showed 40 days MGT with 53.33% seed germination. The mature seedlings of the species were used for large scale plantation in the degraded land of Chaudas valley, Pithoragarh district through participatory approach. Outcomes of the study suggested that species selection and management practices based on an understanding of natural succession and the forest plantations are promising tool for waste land rehabilitation in the Himalayan landscape.

Keywords: *Cinnamomum tamala*, Seed germination, Chaudas valley, Restoration

INTRODUCTION

Land degradation is a universal concern caused by diverse factors including soil erosion via water and wind, decline in physical, chemical and biological properties of soil. All over the world, about 2 billion hectare degraded land has chances of restoration. In India, degraded land varies from 30 to 175 million hectare. In the Indian Himalayan region, out of total geographical area, about 37% is covered by degraded forests and abandoned agricultural land. The land holdings as well as area of degraded land available to local people are very small (Kanchan and Krishan 2018). Himalayan landscape is extremely vulnerable to rapid changes in global climate which reflected fast changes for biological diversity, ecosystem services, loss of biodiversity, receding natural forest, land use transformation, migration, land sloping, frequent landslide zones, intense precipitation, degradation of forested landscape, etc (Rawat *et al*., 2017). Communities' residing in the Himalaya mainly relies on alpine pastures and forest landscapes for fulfilling their basic requirements, including seasonal grazing of livestock, collection of wild medicinal and aromatic plants (MAPs) and seasonal cultivation of food crops to sustain their livelihood. The over-exploitation of MAPs through illicit and unskilled manner increased pressure on natural populations (Zahra *et al*., 2020).

Among the other states of India, Uttarakhand exists on 20th rank in terms of area (23.91%) under degraded land. Although enormous amount of investments have been made to acclimatize degraded land in the Himalayan region by planting trees after year 1970. However, due to inappropriate technologies and insensitive or negative attitudes the impact is poor. The people of this region remains economically weak as income from timber is prohibited, natural regeneration of degraded land is ineffective. The people of Himalayan region needed safeguarding of their economic interests from tree planting in degraded land. Apart from enhancing ecosystem functions of the treated areas, tree planting in degraded land, contributes to conservation of lasting forests (Semwal *et al*., 2013).

The populace living in this region mainly depends on the forest resources occurred in the vicinity of villages. They used forest trees for fodder, fuel and non-timber forest products for traditional medicinal use as well as earning livelihood. The populations of many species from forests are being declined due to unsustainable use, overexploitation of economically important species and poor regeneration rate. Therefore, the cultivation of medicinally potential species can be subjected to enhance species population and provide the alternative livelihood source to the local people.

This approach is especially important because 80% of Uttarakhand population depends on agriculture, but their small land holding, traditional agricultural practices always affect their income generation (Maikhuri *et al*., 2001). Presently, the central and state government has initiated several policies for cultivation and conservation of medicinal plants as well as rehabilitation/restoration of degraded land through plantation of trees. Tree plantation in degraded lands, apart from enhancing ecosystem functions of the treated areas, contributes to conservation of the remaining forests, climate change mitigation and to socio-economic upliftment of local communities. Though huge investments have been made to rehabilitate degraded lands by planting trees since 1970s in the Himalayan region and farmers of Himalaya have been using and managing several multipurpose tree species viz. *Cinnamomum tamala, Quercus leucotricophora, Quercus glauca, Morus alba, Pittosporum eriocarpum, Juglans regia, Zanthoxylum armetum*, etc.

Cinnamomum tamala (Family Lauraceae; commonly known as Tejpat or Indian bay leaf) is an evergreen, moderate size, multipurpose tree species. It is an important species in the transitional evergreen forest and mostly occurred in shady and moist habitat of tropical and sub-tropical Himalayas (Subedi and Sharma 2012). *C. tamala* has whitish, small, bisexual flowers, although on the same plant (monoecious), required pollinators such as insects, honey bees for pollination during March to May and fruits are dark purple ellipsoidal drupe which required approximately one year for the maturation (Sharma and Nautiyal 2011). Leaves and bark is aromatic in odor, sweet aroma with hypoglycemic, carminative and stimulating properties. This species traded for spices, flavoring, beverages, food items and essential oil used for food preservation, ayurvedic (Sudarshan choorna, Chandra prabhavti) formulation (Rawat *et al*., 2009). Leaves and bark is good repository of diverse chemical constituents and essential oil reported to be a major source of terpenes (i.e. monoterpenes, sesquiterpenes and diterpenes), and the oxygenated compounds which are mainly esters, aldehydes, ketones, alcohols, phenols, and oxides. The various amounts of monoterpenes (65.6%), β-sabinene (2.3%), β-ocimene (17.9%), myrcene (4.6%), trans-sabinene hydrate (29.8%), cinnamaldehyde in the essential oil and showed antioxidants, anti-microbial, anti-fungal, anti-bacterial, hypoglycemic, stimulant, carminative properties (Dash *et al*., 2020). It is therapeutically and economically important medicinal tree species and required conventional method for germination (cultivation packages). Furthermore, their large scale cultivation and plantation in the degraded land will be helpful for restoration of the Himalayan landscape.

METHODOLOGY

G.B. Pant National Institute of Himalayan Environment (GB-PNHE) Almora, initiated field oriented activities for the promotion of medicinal plants cultivation, sensitization of diverse stakeholders, and participatory approach for plantation and restoration of degraded land at Chaudas valley, West Himalaya. The valley is situated between Kali and Dhauli rivers in the border region of two countries (Nepal and China) in Dharchula Tehsil, Pithoragarh District of Uttarakhand. The region is rich in biodiversity, culturally similar to Nepal and Tibet. The topography and higher elevation range make the valley difficult in terms of agriculture and continuous exploration of several high value medicinal plant species of wild substantial loss of their habitats and population decline over the years.

AGRO-TECHNIQUE: NURSERY BED PREPARATION AND SEED GERMINATION

The soil is well ploughed before fifteen days of planting and then left opens for decaying crop residue and weeds, etc. After that the nursery beds with 2m×1m length (3 feet height.) were prepared. The width of nursery beds lies 80-120cm with 1-1.5 feet wide path between two beds. The Farmyard Manure (FYM) and sand was mixed with soil in equal composition. About, 15 kg (75,000 Indi.) mature seeds of Cinnamomum tamala were purchased from Jyolikot (700m asl). The seeds were dried under sunlight for two days, and kept for water soaking (24hr) before using for germination. These seeds were propagated in 4 inch above the ground in the month of May-June at the depth of one and half inch. To maintain the appropriate moisture content in soil, beds were irrigated on alternative days. The distance between lines to line maintained 3-4 inch (Fig. 1). The soil nursery beds were covered with 70% netlon (net) for retaining moisture in the soil. A total of 30 seeds were used in triplicate manners for analyzing germination percentage and mean germination time. Seeds in open condition used as a control. Germination percentage (GP %) and mean germination time (MGT) were calculated using equation 1 and 2 respectively.

GP (%) = (Number of germinated seeds/Total number of seeds sown) ×100 eq. (1)

$$MGT\ (d) = \Sigma\ (ti \times ni) / \Sigma ni \qquad eq.\ (2)$$

ti = number of days starting from the day of sowing

ni = number of seed completing germination on day ti.

RESULTS AND DISCUSSION

Globally, land degradation is an alarming situation caused by several factors including, deterioration and erosion of soil, losses in soil productivity, natural climatic disaster, landslide, flooding and anthropogenic pressure (i.e. forest fire, grazing, over-harvesting of forest, invasive species), losses of springs/

streams, etc. Approximate, 2 billion hectare of degraded land has opportunities of restoration over the world. However, 30-175 million hectares degraded land reported from India out of that 23.91% area is reported in Uttarakhand (Kanchan and Krishan 2018; Negi and Rawal 2019). Further more, restoration of degraded land has received considerable attention in the last few decades through R&D intervention of multipurpose tree species (i.e. *Acacia, Eucalyptus, Alnus, Salix, Hippophae*, etc). It gained much attention for rehabilitation of degraded land with supporting several components of the biodiversity such as restoration of ecosystem services, regulation of environmental services like carbon storage, productivity, biodiversity conservation, improvement of soil fertility, livelihood enhancements and expanding market of timber (Negi and Joshi 2001). Restoration is actually for improving landscapes that are deforested, degraded or underutilized. Boosting the productivity of these landscapes helps take pressure off the world's remaining forests while also providing a host of tangible benefits from food security to clean water to carbon sequestration.

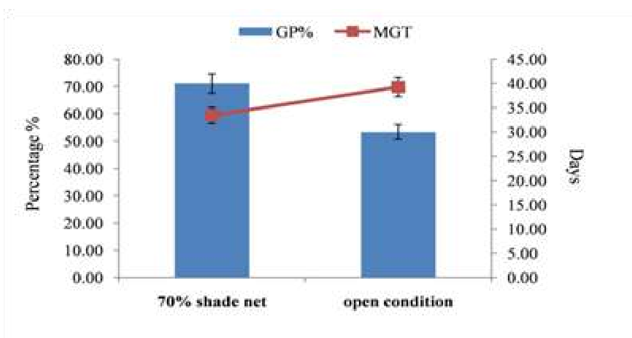

Fig 1. Graphical representation of seed germination of *C. tamala*

Fig 2. Seed germination of *Cinnamomum tamala* at Surya-Kunj, GBPNIHE Almora

The seed germination was started after 23 days of sowing, recorded 71.11% of germination and low mean germination time (MGT) of 34 days fewer than 70% shade net, however, 53.33% of germination with 40 days of MGT was recorded in the open condition (Fig. 1). The germinated mature (53,000 ind.) seedlings when attain a height of 15 cm were transferred in polybags. These mature seedlings were transferred to lower altitude viz., Jaykot, Ghasku and Pangla in Chaudas area for mass scale plantation in agriculture and degraded land (Fig. 2).

The local inhabitants of the Chaudas valley prepared 5000 pits of 60 cm^3 at 2m x 2m spacing in the degraded land during July-August. The seedlings are dibbled in the pits and then filled with top soil and FYM (farmyard manure) 10kg/individual plant. Immediately after transplanting, the plants are provided with temporary shade and weeds are removed. The planted seedlings were protected through wire gauge or stumps of young trees. This species is affected by leaf spot that can be controlled by spraying 1% Bordeaux mixture or 0.25% copper oxy chloride in the seedlings. Ambitious efforts are being mounted to restore forests, ecosystem services and biodiversity throughout the world (Chazdon 2008). However, community participatory approaches for restoration of degraded forest reported successful case studies of rejuvenation of springs, regeneration of forests, returning of rare and endemic indigenous mammals. Today, several reforestation/restoration projects focus on plantation of fast growing, short lived species. Similarly, few plantations have a high rate of failure if few tree species are planted and they are not well suited to site conditions. These short-term solutions are attractive, but forest regeneration and restoration is a long process and takes a century or more (Diaz *et al.*, 2004). So, it is essential to plan for long term returns on restoration investments for future through experimental intervention (R&D) approaches for prioritization of the most appropriate path toward restoration. The local knowledge of tree characteristics, planting of diverse species of ecological and economic importance, community participation and integration of rehabilitation programs with regional development strategies are essential elements of restoration success. Restoration of degraded forest landscape would also enhance the mitigation and adaptation potential of landscape and local communities to climate change. Therefore, large scale plantation of *Cinnamomum tamala* in the degraded land will be helpful for conservation of biodiversity, reducing the pressure on natural population, fulfilled the market demands, and uplift the economic condition of mountainous populace. In the process, these efforts will also restore new relationships between people and forests. As so clearly stated by William R. Jordan (2003), a founder of the field of restoration ecology, "Ultimately, the future of a natural ecosystem depends not on protection from humans but on its relationship with the people who inhabit it or share the landscape with it".

CONCLUSION

Cinnamomum tamala is a multipurpose tree species, and study reported that 70% shade net condition is best for seed germination. The large scale cultivation/plantation will be vital for fulfilling the market demand/requirement, reducing pressure on natural populations and uplifting the economic status of the local communities in the mountainous region. Restoration of degraded land through community participatory approach will be supportive for conservation of biodiversity and developed relationships between local people and forest staff. Outcomes of the study suggested that species selection and management practices based on an understanding of natural succession and the forest plantations are promising tool for wasteland rehabilitation in the Himalayan landscape.

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TRADITIONALLY USED RELIGIOUS PLANTS OF KUMAUN HIMALAYA, INDIA: RESTORATION AND CONSERVATION IMPLICATIONS

Renu Rawal*[1], Vikram S. Negi[1], Kapil Bisht[1] and Lalit Mohan Tiwari[2]

[1]G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand, India
[2]Department of Botany, D.S.B. Campus Kumaun University, Nainital, Uttarakhand, India

***Correspondence:** renu.rawal93@gmail.com

ABSTRACT
Present study is an attempt to document the unique plant species indigenously used in different ceremonial practices in the Kumaun region of Uttarakhand (Western Himalaya), India. The study has documented a total of 71 plant species belonging to 41 families and 66 genera used in ceremonial practices. Of these, maximum species are herbaceous (36) followed by trees (26), shrubs (6) and climber (3). Analysis of data revealed that seeds and leaves (20 each) arewidely used in ceremonial practices, followed by fruits (18) and flowers (14). The use pattern of the documented species in different ceremonial practices could be useful in understandingthe conservation implications of the recorded species in the region.

Keywords: Ceremonial plants, Rituals, Threat categorization,Kumaun Himalaya

INTRODUCTION

India is known for its diversity in religion, customs, myths, languages, culture, etc. and has deep-rooted traditional worshiping of plants (Gadgil 2000). The culture and biodiversity are associated with each other since ancient time. Among various biodiversity elements, the plants attain an important role in cultural activities. Plant parts have been used as a source of medicine in different system of healthcare (Bisht *et al*., 2009; Mehra *et al*., 2014; Bajpai *et al*., 2016). Higher plants have played key roles in the lives of tribal people living in the Himalaya by providing forest products for food, medicine and other purpose. Indigenous and forest dwellers have good knowledge about the use and specific qualities of plants (Negi 2012). Numerous wild and cultivated plants have been utilized as curative agents since ancient times, and medicinal plants have gained importance. The life saving nature of plants and their role in healthcare system, food and many religious occasions may be the basis of conserving and worshipping these plants (Mehra *et al*., 2014). Folklore, culture, food and medicinal practices are greatly associated with various plant and animal species (Badoni *et al*., 2001). On the basis of ancient scriptures, a wide variety of plants like *Ficus religiosa* (L), *Azadirachta indica* (A Juss), *Ocimum tenuiflorum* (L). etc. having divine qualities, therefore, are used in number of religious activities (Negi 2012).

Despite of having such traditional ceremony, literature regarding these beliefs and worship is very limited. Therefore, the present study is the first attempt to document the plants used in various ceremonies in Kumaun region, Uttarakhand that has conservation implications.

METHODOLOGY

The study was conducted in Bageshwar district of Uttarakhand, which is well known for traditional and cultural diversity. An extensive survey was carried out in different villages (Ratayish, Papon, Dungari, Kapkot, Pharshali, Sangar, Kanda, Garur, Surajkund, Mandalshera etc.) of the district covering wide elevation gradient and rural areas. The survey was focused on collecting information on plant species being used by local inhabitants during various ceremonies in the region. The information gathered from the inhabitants comprised local name of plant species, plant part used and mode of application. Individual interview of the informants were organized for names and uses of plants during in the particular ceremonies. This was followed by group discussion for validation of the information. Further the list of used in ceremonies was prepared and categorized in habit, plant part used and IUCN threat categories.

RESULTS

The study revealed a total of 71 plant species being used in different ceremonies in Bageshwar district. A detailed description of the plant part used with respect to ceremonies is provided in (Table 1).

Table 1. Detail description about the ceremonially used plants and their use pattern in the Kumaon Region of Uttarakhand

Botanical Name	Local Name	Life Form	Plant Part Used	IUCN status	Ceremonial Uses of Plants
Aegle marmelos (L.) Corrêa (Rutaceae)	Bel, Bel Patri	Tree	Leaves, fruits etc.	NE	Leaves are used to worship lord Shiva in Shivratri and Parthiv Puja in the month of Shrawan. A twig bearing two fruits of this species is offered to Devi on the occasion of Ashwani Shukla Saptami or Bilva Saptami.
Amomum subulatum Roxb. (Zingiberaceae)	Badi eliachi	Herb	Fruits	NE	The fruits are used to worship Lord Shiva in Parthiv Puja.
Ananas comosus (L.) Merr. (Bromeliaceae)	Ananas	Herb	Fruit	NE	The fruits are used to make fruit basket which are used in wedding as a gift from the groom family to bride and vice versa. It is an important ritual in wedding to exchange the beautifully decorated fruits baskets (locally called Shagun ki tokari).
Azadirachta indica (A.) Juss. (Meliaceae)	Neem	Tree	Whole plant	LC	Twigs of the plant are used for the treatment of Small Pox (Choti mata) because it is believed that the disease, small pox is related to Mata, therefore, the plant is used to worship the mata and to cure the disease also.
Benincasa hispida (Thunb.) Cogn. (Cucurbitaceae)	Kumin, Petha	Climber	Fruits	NE	The fruits are used in some occult activities in local areas.
Berberis asiatica Roxb. ex DC. (Berberidaceae)	Kilmora	Shrub	Fruits, roots	NE	People place the twig in their houses to keep evil spirits away.
Betula utilis D.Don (Betulaceae)	Bhojpatra	Tree	Bark, stem	LC	The bark of this species is used as the substitute to paper in ancient time to write Vaidik scripture and preparing horoscope etc. The bark is also used to get rid away from the negative energy.The mascot made up of the bark of this species is used to wear by people.
Brassica rapa (L.) (Brassicaceae)	Sarsoon	Herb	Leaves, flowers, seeds	NE	The flowers are used on the festival of Fuldai which is celebrated in every year in the month of March. Another use of seeds is in hawan, namkarn shanshkar, wedding ceremonies etc. The oil obtained from its seeds is considered as pure oil and used for lightning lamps as well as in cooking.
Brassica juncea (L.) Czern. (Brassicaceae)	Rai	Herb	Seed, leaves	NE	Its seeds are used for the protection against the evil spirits (Tantra-Mantra).
Butea monosperma (Lam.) Taub. (Leguminosae (Fabaceae))	Dhak	Tree	Flowers, leaves, bark	NE	Leaves are used in Janeu Sanskar and flowers are used to worship Lord Shiva in Shivratri. The flowers are also used to make a traditional Holi color

Calotropis gigantean (L.) Dryand. (Apocynaceae)	Aak	Tree	Flowers, leaves, bark	NE	Leaves are used to worship Sun, whereas, the flowers are used to worship Maruts on Saturday
Cannabis sativa L. (Cannabaceae)	Bhang	Herb	Leaves, seeds	NE	It is specially used to worship lord Shiva during Shivratri and Parthiv Puja etc. During holi celebration, people consume Bhang which contains cannabis flowers.
Capsicum annuum L. (Solanaceae)	Mirch	Herb	Fruits	LC	The smoke of red chili with rai is used as a protection from evil spirits and the chilly with lemon is used to protect from evil's eye.
Chrysopogon zizanioides (L.) Roberty (Poaceae)	Kush	Herb	Whole plant	NE	Flowers are used in Khatadu festival. Leaves are also used to make lord Brahmas image, on the occasion of Shradha(deathceremony), also,kush grass is widely used for taking Sankalpa in puja-path rituals.
Cicer arietinum L. (Leguminosae)	Chana	Herb	Seeds	NE	The seeds mixed with gaggery are eaten in the fast of Friday to worship Goddess Shantoshi.
Cinnamomum tamala (Buch. Ham.) T. Ness. & C.H. Eberm. (Lauraceae)	Tejpata	Tree	Leaves	NE	It is used to worship 'Lord Shiva'.
Cinnamomum verum J. Presl. (Lauraceae)	Dalchini	Tree	Stem, bark	NE	It is one of the main ingredients of five spices which are used in Parthiv Puja to worship Lord Shiva.
Citrus aurantifolia (Christm.) Swingle (Rutaceae)	Kagaji nimbu	Tree	Fruits	NE	Its fruits are used to keep evil spirits away in Tantra-Mantra. Hanging lemon with chilly at the enterance of house is used to protect form evil's eye on houses, building, vehicles etc.
Cocos nucifera (L.) (Arecaceae	Narial, Jatanarial, Gaula (without mesocarp)	Tree	Seeds	NE	It is used in many ritual, ceremonies and to worship the God. Sometimes, it is used in some Tantrik activities. While others are used to give as return gift in wedding ceremonies in Kumaun region.
Cucumis sativus (L.) (Cucurbitaceae)	Kheera, Kakdi	Climber	Fruits	NE	The fruit of kheera is devoted into the fire, on the occasion of Khatadu
Curcuma longa L. (Zingiberaceae)	Haldi	Herb	Rhizome	NE	Its paste is applied on bride and groom on the occasion of marriage. During Janeuceremony, the paste is applied on boys. It is also used to form kumkum and pithiya.

Cynodon dactylon (L.) Pers. (Poaceae)	Doob ghash	Herb	Whole plant	NE	Leaves are offered to daughters during bidai in marriage. And the terminal leaf-buds are offered to lord Ganesh. Further, its 108 or 1100 apical buds are used to worship Lord Shiva during Parthiv Puja.
Dendrocalamus strictus (Roxb.) Nees (Poaceae)	Baans	Tree grass	Stem, leaves	NE	Its stem is manly used in funeral. It is used as stretches for dead body of a person during funeral rituals. Its stem is also used as a flag sticks (Nishan) during marriages.
Datura stramonium L. (Solanaceae)	Dhatura	Herb	Leaves, fruits, flowers	NE	It is used in the rituals related to Lord Shiva like in Parthiv Puja in month of Shrawan or Kartik.
Elettaria cardamomum (L.) Maton. (Zingiberaceae)	Chhoti eliachi	Herb	Fruits	NE	Used to worship Lord Shiva.
Phyllanthus emblica (L.) (Phyllanthaceae)	Amla	Tree	Whole plant	NE	The twigs are used in Shradha(death ceremony). On the occasion of Amla Ekadashi or Holi Ekadashi(11th day of Falgun Shukla) the twig with fruits is used to worship. Further, women go on fasting that day, worship and tagmany bright, colored small parts of cloths on the Amla tree thatis locally known as Chir Bandhna.
Euryale ferox Salisb. (Nymphaeaceae)	Makhana	Herb	Seeds	LC	It is used to prepare Panch-mewa, used in many rituals and ceremonies.
Fagopyrum esculentum Moench. (Polygonaceae)	Kuttu	Herb	Seeds	NE	The flour is used during fasting like in Navratri etc.
Ficus auriculata Lour. (Moraceae)	Timul	Tree	Leaves, fruits	NE	The leaves are used to make plates in various celebrations like death anniversary, marriage, janeu etc.
Ficus benghalensis L. (Moraceae)	Vat	Tree	Whole plant	NE	The whole plant is worshiped by the married women in 'Vat Savitri puja'. The plant is made married with the plant of peepal (Ficusreligiosa) and then worshiped together.
Ficus religiosa Forssk. (Moraceae)	Peepal	Tree	Whole plant	NE	The garlands made up of leaves are placed around the premises of house during Grah-pravesh. Another use of the leaves is that often the young girls are symbolically made to marry with peepal tree to avoid future widowhood. Further, the plant is also regarded as holy therefore; it is worshiped in each Saturday at early morning.
Foeniculum vulgare Mill. (Apiaceae)	Saunf	Herb	Seeds	NE	The seeds mixed with sugar, gaula(*Cocos nucifera*)andSupariand servedduring many celebrations like Holi and weddings as a mouth freshener.

Glycine max L. Merr. (Leguminoseae)	Bhatt	Herb	Seeds	NE	The seeds are used to make Birud Prasad.
Gossypium sp. (Malvaceae)	Kapas	Shrub	Seeds, fruits	NE	Cotton threads are used to make 'Janeu' (dyed in yellow color of Curcuma longa) and 'RakshaDhaga' (dyed in red color). Another, use of it is in making baati for Aarti.
Helianthus annus L. (Compositae)	Suraj-mukhi	Herb	Flowers	NE	It is regarded as a sacred image of Suraj Devta.
Hordeum vulgare L. (Poaceae)	Jau	Herb	Seeds,	NE	Seeds are used in Hawan, puja etc. on the occasion of Basant-Panchami. People often use the seeds of Barley with cow's dung and tag this on the top of the main door.
Jasminum sp. (Oleaceae)	Chameli	Shrub	whole Flowers	NE	The flowers are used to worship Goddess Saraswati.
Juglans regia L. (Juglandaceae)	Akhrot	Tree	Fruits	LC	It is one of the components of a combination to make 'Panchmewa' (combination of 5 dry fruit)which is widely used in many religious ceremonies. Another use of fruits is in Shradha (death anniversary) ceremony.
Juniperus communis L. (Cupressaceae)	Bhitara	Shrub	Stem, seed	LC	Mansi (*Valeriana jatamansi*), Tagar(*Valeriana hardwickii*), Bhitara(*Juniperus communis*) all three are grained and mixed with ghee and Dhoop and sticks are made for religious rituals.
Lawsonia inermis L. (Lythraceae)	Hina, mehndi	Herb	Leaves, flowers	NE	Themehndi is used to worship Lord Krishna on the occasion of Krishna Janmashtami. Further, it is mainly used in weddings, Raksha-Bandhan and in the month of Shravan.
Macrotyloma uniflorum (Lam.) Verdc. (Leguminosae)	Gahat	Herb	Seeds	LC	The seeds are used in 'Rahu Daan'.
Mangifera indica L. (Anacardiaceae)	Aam	Tree	Whole plant	DD	Its wood is used in worshiping and to perform fire sacrifice (Hawan) especially in Janeu. Moreover, the leaves are weaved on thread and used to decorate the new houses during the Grah-pravesh and wedding ceremonies.

Musa balbisiana Colla (Musaceae)	Kela	Herb	Whole plant	NE	The whole plant is mainly worshiped on Thursday as it is associated with planet Jupiter to worship lord Vishnu or Brihaspati Deo. Further, the whole plant is worshiped during Satyanarayan Puja. The trunk of banana tree is used to erect welcome gates. In Nanda festival the plants are used as Kadalii Vriksha and to make the statue of Goddess Nanda-Sunanda.
Nicotiana tabacum L. (Solanaceae)	Tabocco	Herb	Leaves	NE	It is used to worship Lord Shiva, and some local spirits like Masan, Chhal etc. Further, in regional weddings the Beedi (formed by Tobaco) and cigarette are used as a local ritual at the time of Shuwal Pthayi.
Ocimum tenuniflorum L. (Lamiaceae)	Tulsi	Herb	Leaves, seeds, stem	NE	Leaves and stems are offered to people at their funeral ceremony. It is a sacred plant; water mixed with Tulsi petals is given to the dying to raise their departing soul to heaven. Further, the plant is worshiped by the women especially on 'Tulsi Ekadashi' which is celebrated each year in July.
Opuntia sp. (Cactaceae)	Nag-Phani	Herb, shrub	Whole plant	NE	It is planted at the front of the houses to keep the evil spirits away. Also, it is used to protect the house from the natural lightning strikes.
Oryza sativa L. (Poaceae)	Dhan, (Chawal)	Herb	Seeds	LC	Its flour is used to make the statue of Lord Shiva (Shiv-Ling, Nandi, Nag and his 108 or 1100 ganas) in Parthiv Puja. Moreover, the paste of rice in water, is used to decorate the worshiping places, doors etc. this is traditionally known as Aipan or Alpana, which is mainly made on Diwali, grahpravesh, wedding and janeu ceremony etc. Further, the seeds of Dhan are soaked in water then grind and soaked in mustered oil this formation is locally known as Chyuda (a kind of prasada).
Pinus roxburghii Sarg. (Pinaceae) (Coniferae)	Chir, Bunni	Tree	Leaves, stem, twig etc	LC	The plant is commonly used in weddings (During Pheras), a bushy twig of the plant is put on a Kalash and bride-groom takes 7-Phere around the *Pinus roxburghii* twig. Further, during wedding rituals they also devote the leaves of the *Pinus roxburghii* plant on the head of one another. A tall and long branch of the tree is devoted at the front of the newly constructed houses at the time of Grah Pravesh, likewise 9 same branches are also devoted around the temple at the time of Navratra festival locally called Naurat.

Piper betle L. (Piperaceae)	Pan patta	Climber	Leaves	NE	The leaves are used in many ceremonies like marriage, Janeu etc. used in 'Lakshmi pujan' on the occasion of Deepawali.
Piper nigrum L. (Piperaceae)	Kali mirch	Shrub	Fruits	NE	Its fruits are used in Tantrik activities also used in Parthiv Puja.
Pisum sativum L. (Leguminosae)	Mater	Herb	Seeds	NE	The seeds are used to make a traditional prasad used in the Gaura Puja locally called Birud, at the time of Nanda-Sunanda festival.
Prunus cerasoides D.Don (Rosaceae)	Payan, Padam	Tree	Flowers wood, twig	LC	The leaves and branches of padam are worshiped during Katha, Bhagwat, Janeu and in marriage ceremony. The sticks of the padam are regarded holy. Therefore, many people use these sticks in their houses to protect against evil spirits.
Punica granatum L. (Lythraceae)	Dadim, Khatta Anar	Tree	Fruits	LC	The fruits are used in Shradha ceremony to worship Pitra (fore fathers).
Pyrethrum sp. (Compositae)	Paati	Herb	Flowers, leaves	NE	Its leaves and flowers are used in many rituals to worship God and Goddess like in Shradha, weddings, Janeu other puja-path ceremonies.
Pyrus malus L. (Rosaceae)	Seb	Tree	Fruit	DD	The fruits are used to make fruit basket which are used in wedding as a gift from the groom family to bride and similarly from the bride family to groom, it is an important ritual in wedding to exchange the fruits baskets (locally called Sagun Ki tokari).
Quercus leaucotrichophora A. Camus (Fagacear)	Banj	Tree	Whole plant	NE	The tree near the natural water resources like Naula, Dhara etc. is worshiped. It is regarded as the plant of Shesh-Nag that believed to live in the Naula.
Reinwardtia indica Dumort. (Linaceae)	Pyoli	Herb	Flowers	NE	The beautiful yellow colored 5- petal flowers are used on the occasion of Fuldai. Further, the blossoming of the Pyoli plant is a sign of the commencement of spring season (Nawal Ritu Basant).
Rhododendron arborerum Sm (Ericaceae)	Buransh	Tree	Flowers	LC	The flowers are used in the month of March on the occasion of Fuldai. Besides that, the flowers are also used to worship Nanda Bhagwati, Lord Shiva etc.
Saccharum officinarum L. (Poaceae)	Ganna	Herb	Stem	NE	The herb is used to make the statue of Goddess 'Lakshmi' on the occasion of Deepawali. Also, it is used as prasad in many festivals especially on Diwali.
Santalum album L. (Santalaceae)	Chandan	Prasitic tree	Wood	VU	The wood is considered holy and pure. So, it is used in many ceremonies and rituals like in wedding, Parthiv Puja, Durga Puja etc.
Saussurea obvallata DC. Edgew. (Compositae)	Brahma - kamal, Kaul - padam	Herb	Flowers	NE	The flowers are used to worship Lord Shiva (in Bagnath temple and Baijnath temple) and Goddess Nanda Bhagwati.

Sesamum indicum L. (Pedaliaceae)	Til	Herb	Seeds, oil, leaf	NE	The seeds mixed with barley, ghee and dhoopare used in many rituals like in havan etc. Further, it is used to give Tilanjali (offering) to the dead person, after the 9th day of death. Moreover, its laddus are formed mixed with Ghee and Gud in wedding and Janeu ceremony.
Skimmia laureola Franch. (Rutaceae)	Nair, Nair Dhoop	Shrub	Leaves, flowers stem	NE	The dried leaves are crushed and mixed with Ghee used as a dhoop and burned with charcoal. The flowers are used to worship many local God and Goddess.
Syzygium aromaticum (L.) Merrill & Perry (Myrtaceae)	Laung	Small size tree	Unopen flower	NE	It is used in Parthiv puja and in some Tantra-Mantra activities.
Tagetes erecta L. (Compositae)	Hajari, gainda	Herb	Flowers	NE	The flowers are used to worship God and decorating houses in Deepawali and other festivals.
Toona ciliata M. Roem. (Meliaceae)	Tun	Tree	Wood	LC	The wood is used to form a small sized table (locally called chauki) which is decorated with the red and white paint by making Shwashtik and other ritual designs. Specially, during Phere and Dhurr-Argin wedding ceremonies.
Triticum aestivum L. (Poaceae)	Gehun	Herb	Seeds	DD	Its flour is used to form a traditional papad known as 'Shwang' which is mainly made in weddings (in local weddings it is one of the important ceremonies, locally known as Shuwal Pathayi. Also, it is used in Janeu ceremony. Further, its grains are used to fill karwa on Karwa Chauth.
Valeriana jatamansi Jones ex Roxb (Caprifoliaceae)	Mansi	Herb	Root, leaves	NE	Used as "hawan samagri" in ceremonies locally called 'Mansik Dhoop'.
Vigna mungo (L.) Hepper. (Leguminosae)	Maas, uraddaal	Herb	Seeds	NE	A mixture of maas and paddy locally called 'khichadi' is used as an offering to Van Devta against evil spirits (Chhal, Masan etc.). It is also offered to Shani Dev on Saturday in order to get his blessings. Further, the seeds are used in Shani Daan and Ketu Daan.
Zanthoxylum armatum DC. (Rutaceae)	Timur	Tree	Bark, seeds, sticks	NE	Its shrubby branches are worshiped in Janeu shanskar and in a folk dance which is locally called Jagar. Further, it is also considered as symbol of 'Narsingh'. Moreover, The twigs are kept in houses to keep away evil spirits.
Zea mays (L.) (Poaceae)	Makka	Herb	Seeds	NE	Used in the Harela festival.

Note: NE- Not Evaluated LC- Least Concern, DD- Data Deficient, VU- Vulnerable

The documented plants (71 species) were represented by 41 families and 66 genera.Out of 71 species, maximum was herbaceous (36) followed by trees (26 including 1 parasitic tree (*Santalum album*), shrubs (6) and climber (3) (Fig. 1). The species were also categorized on the basis of plant parts used in particular ceremonies. Seeds and leaves (20 each) were reported to be used in most of the ceremonies, followed by fruits (18), flowers (14), whole plant (10), bark (10), root/rhizome (2) and flower buds (1) (Table 1). The documented species were further categorized into IUCN categories of threatened plants. This categorization revealed that the maximum species (54) were under the category Not Evaluated; 13 (*Azadirachta indica, Betula utilis, Capsicum annuum, Euryale ferox, Juglans regia, Juniperus communis, Macrotyloma uniflorum, Oryza sativa, Pinus roxburghii, Prunus cerasoides, Punica granatum, Rhododendron arborerum and Toona ciliata*) were Least Concerned; 3 (*Mangifera indica, Pyrus malus* and *Triticum aestivum*) were Data Deficient and 1 (*Santalum album*) was Vulnerable.

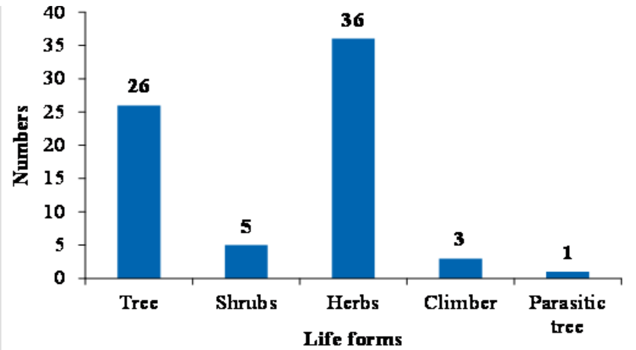

Fig. 1. Distribution of different life form numbers used for ceremonial purpose

Betula utilis, Juniperus communis, Toona ciliata, etc., are the ecologically and economically important species to the Himalayan region and on the basis of IUCN threat categorization they fall under the category of least concerned, if these species used in larger amount in different ceremonies as well as in other activity there are chances that they face threat or might fall in any other threat category. Three species (*Mangifera indica, Pyrus malus* and *Triticum aestivum*) are economically important and have been categorized under data deficient category. This kind of information motivated for proper documentation of these species for better management and conservation strategy.

DISCUSSION

The utilization of locally available plants in different ceremonies is a valuable example ofsustainable use of natural resources at local level. Due to their sacredvales some plant speciesalso got protection from the anthropogenic activities such as cutting and lopping, But it is also an indication of threat tothe endemic or rare species or species having less number of individuals at present in the Himalayan region, particularly those species which are in regular use or used in larger amount, they may face some risk in near future. On the other hand the use of these plants in different ceremonies highlights the importance and commercialization of these species within the region. In traditional societies, the use of nature and conservation of resource is motivated by the beliefs, and local cultures are strengthened by their close linkages to the natural resources that sustain those plant species (Negi *et al.*, 2017). It was also observed that the traditional communities have setup several rules and regulations to support conservation and management of biodiversity in the region as also reported by some other workers (Negi *et al.*, 2012). For example, Bhotiya tribes in Kumaun region have developed a unique system of forest management by promoting the concept of sacred forests and groves, which reflect a symbiotic relationship between culture and biodiversity (Negi *et al.*, 2012).

This study also observed that many plant species used in religious ceremonies are under the threat category of IUCN. Various ecologically and economically important ceremonial plant species including *Betula utilis, Juglans regia, Juniperus communis, Prunus cerasoides, Rhododendron arborerum* and *Toona ciliate* are categorized as Least Concerned speciesand Santalum album, which categorized as Vulnerable according to IUCN. However, the species Betula utilis was recognized for its multipurpose applications since ancient period and in current scenarios the species have been overexploited by anthropogenic pressure, habitat degradation, soil erosion, landslide, and snow drift that effects the regeneration. Therefore,the species iscategorized as critically endangeredwithin the Himalayan region (Ved *et al.*, 2003). The restoration and conservation practices should be taken in consideration for the vulnerable (*Santalum album*) and critically endangered (*Betula utilis*) species. These species needrestoration practices, nursery development and conservation practices like establishment of protected area network in particular to *B. utilis* and development of convention and in vitro propagation protocols for mass multiplication of the species. Besides this, some of them are endemic to the Himalaya and are also overexploited species i.e. *Betula utilis* and *Juniperus communis* (Negi *et al.*, 2018) in the higher altitude zone of the Himalaya due to less availability of the fuel wood, even in some of the areas stem of *Rhododendron arborerum* is also consumed as fuel wood, all these species are ecologically important to the ecosystem. Species such as *Juglans regia, Prunus cerasoides* and *Toona ciliate* are economically important and are used in edible purposes, making agricultural implements, and also used in timber industry in larger scale. Further *Santalum album* (vulnerable) which is a multipurpose plant species in ceremonial as well as used in aromatic and pharmaceutical industry. Species such as *Prunus cerasoides*, only found individually near the villages or agricultural lands have very less numbers of individuals in the forests. Considering all these issues the restoration of some of the highly valued ceremonially used plant species is required to achieve long term benefits of economy as well as ecological balance of the ecosystem along with the fulfillment of the conservation and management implications also to the fulfillment of goals of ecosystem restoration.

CONCLUSION

The study reveals that the indigenous inhabitants in Uttarakhand have maintained a symbiotic relationship between natural resources and their cultural belief system. Nature worship and management has remained a key force in shaping human attitudes towards sacred conservation and sustainable utilization of natural resources. As a result, the inhabitants' community has protected a number of plant species at different locations in the region, and contributing towards their conservation. However, restoration, conservation and management practices of vulnerable and critically endangered species should be taken in consideration for their sustainable utilization. We strongly believe that the traditional knowledge and cultural belief can be used for the sustainable utilization and long-term conservation of frequently used bio-resources including medicinal plants.Thereby also addressing the goals of eco restoration.

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EX-SITU CONSERVATION- A BEST METHOD FOR RESTORING ACONITUM SPECIES IN INDIAN HIMALAYAN REGION

Jaidev Chauhan*, **Rajeev Ranjan, V.K. Purohit and P. Prasad**

High Altitude Plant Physiology Research Centre, HNB Garhwal Central University, Srinagar, Uttarakhand, India

***Correspondence:** jaidevchauhan678@gmail.com

ABSTRACT

Himalayan Mountain Ecosystem provides diverse goods and services to humanity, both to people living in the mountains and to people living outside mountains. Especially the great Himalaya which serves as a rich source of hotspots of biodiversity and from a social point of view, mountains are of global significance as key destinations for tourist and recreation activities with ecosystems play a key role in maintaining hydrological cycle with feedback to regional climate and by modulating the runoffs regime along with this mountain vegetation and soil play a significant role in reducing or mitigating risks from natural hazards. More encroachment of anthropogenic pressures at higher Himalayan region leads to threat to many Medicinal and Aromatic plants shifting them towards endangered mark. Since Himalaya is a cradle of many economically rich medicinal plants but unfortunately many of them are now comes under the RET category and also one among them is a *Aconitum* species its now comes as Endangered in IUCN Red List.

Key words: Mountain ecosystem, Anthroprogenic pressure, Biodiversity, Heterozygosity

INTRODUCTION

Aconitum is the botanical name of the genus commonly known as aconite, monkshood etc. The genus *Aconitum* belonging to the family Ranunculaceae is widely distributed in the alpine and sub-alpine regions of tropical parts of northern hemisphere. There are over 250 species that have been reported in this genus. These are herbaceous perennial plants growing in moisture retentive but well draining soils of mountain meadows. They are mainly cultivated for their tubers. Aconite produced from the roots/tubers of a number of different species of *Aconitum* is used in curing a wide range of diseases. Different species of Aconitum with their medicinal properties and distribution pattern in Himalayas have been listed in Table 1. The genus Aconitum finds the key position in the field of research. Many species of this genus have been listed in the Red Data Book, (Gopi *et al.*, 2018) due to which many conservation programs came into existence, these include in situ, ex situ in vitro mode of conservation. Ex-situ gardens are the way of ecological restoration which is regarded as a major approach for increasing the provision of ecosystem services as well as reversing biodiversity losses. Inspite of various policy measures, excessive illegal collection of medicinal plant continues to take place on a large scale for gaining more and more financial gains (Chand *et al.*, 2016; Gaire *et al.*, 2011). This includes the collection of species considered endangered also and whose collection is prohibited by law. Red Data Book has a long list of many endangered medicinal plants in which genus *Aconitum*, is one of them but there are many species which are economically important among them is *A. heterophyllum, A. baulfourii, A. vioalaceum, A. chasmanthum, A. ferox* etc.

The degree of threat to natural population of these medicinal plants has increased due to many reasons, overgrazing. Prolonged seed dormancy, high seedling mortality and ecological constraints, but the main and important reason is unsustainable exploitation of the medicinal plants for viz., the drug industry and local medicinal use. Also, raw material supply cannot cope up with the demand of the different herbal drug industries. Therefore, initiatives for their conservation and mass multiplication through various modes have been taken and more advanced technologies are being developed. These modes include seed based regeneration, clonal propagation and micro– propagation.

STUDY AREA AND METHODOLOGY

At present only few villages are cultivating *Aconitum heterophyllum* one among them is village Ghesh (30.1166° N, 79.7007° E) of Chamoli District is one of them which is due to the continuous efforts of motivation done by the Department of HAPPRC, H.N.B. Garhwal University. Since cultivation through seed in most of the species of *Aconitum* is difficult for eg., *Aconitum heterophyllum, Aconitum moschatum, Aconitum deinorrhizum* etc. due to poor seed availability and lack of superior germplasm. Also the seeds of many *Aconitum* species are dormant.

RESULTS AND DISCUSSION

Germination is said to be complete when the structure called radicle penetrates the area surrounding the embryo, rest of the events including mobilization of major storage reserves are associated with the growth of seedling. Since ex-situ gardens can also plays an important role in restoring Himalayan Ecology. Because they plays the primary steps for making any alpine crops under cultivation. Since cultivation is the only key step towards conservation (Purohit *et al*.,2021) (Table 1).

Table 1. Detailed list of some RET species of *Aconitum*

Aconitum Species	Location (Himalayan Range)	Medicinal Properties	Mostly Harvested from (Wild/Cultivation)	Status
Aconitum chasmanthum	North West to Kashmir Himalaya	Antirheumatic, useful in heart diseases, neurasthenic and fever, diaphoretic, diuretic, anodyne	Wild	Endangered
Aconitum heterophyllum	North West to Central Himalaya	Anti-inflammatory, Antipyretic, Diarrhea, Vomiting, Cough and Cold	Cultivation (20%) (80% From Wild)	Endangered
Aconitum falconeri	West Himlaya	Antipyretic, Paralysis,Diarrhea	Wild	Critically Rare
Aconitum moschatum	Jammu and Kashmir Himalaya	Antirheumatic, useful in heart diseases, neurasthenic and fever, diaphoretic, diuretic, anodyne	Wild	Endangered
Aconitum balfourii	North West to Central Himalaya	Extrmely Poisonous butin little doses its medicnally important	Wild	Endangered
Aconitum deinorrhizum	West-East Himalaya	Antirheumatic, useful in heart diseases, neurasthenic and fever, diaphoretic, diuretic, anodyne	Wild	Endangered
Aconitum violaceum	North West to Central Himalaya	Antipyretic, abdominal Pain, antidote, Antiinflamatory	Wild	Endangered
Aconitum leave	North West to Central Himalaya	Antiinflammatory, antipyretic	Wild	Endangered
Aconitum rotundifolium	North West to Central Himalaya	Tubers used as tonic in Jammu-Kashmir	Wild	Endangered
Aconitum ferox	North West to Central Himalaya	Antipyretic, anti-rheumatic, Paralysis, Snake Bite	Wild	Endangered
Aconitum bisma	East Himalaya	Antirheumatic, useful in heart diseases, neurasthenic and fever, diaphoretic, diuretic, anodyne	Wild	Endangered
Aconitum spicatum	Central to East Himalaya	Antirheumatic, useful in heart diseases, neurasthenic and fever, diaphoretic, diuretic, anodyne	Wild	Threatened
Aconitum laciniatum	Central to East Himalaya	Antirheumatic, useful in heart diseases, neurasthenic and fever, diaphoretic, diuretic, anodyne (heavy doses are poisonous)	Wild	Endangered
Aconitum kashmiricum	Kashmir Himalaya	Anti-inflammatory,antipyretic, Diarrhea, Vomiting, Cough, Cold	Wild	Endangered

Prance *et al*., (2000) and Kuniyal *et al*., 2021 had been reported that the worldwide destruction of floral diversity is continuing at an alarming rate due to multiplicity of causes like grazing, logging, lopping, illegal collection of herbs, cutting of trees for fuel wood and fodder, and forest fires etc. Mayaux *et al*., (2005) had been observed a number of species have been eliminated from areas dominated by human influences. From last few decades unprecedented destruction of global forest cover. Malik *et al*., (2014) had been reported that Despite of inaccessibility, remoteness and limited employment opportunities, forests and other natural resources are the important source of income in this part of Western Himalaya. *A.spicatum* is used for fever and head ache, cuts and wounds and musculo-skeletal problems, *A. ferox* is used for the joint pains Shyaula (L.S 2011). The anti-inflamatory properties are due to the alkaloidal extract had been reported by Uprety *et al*., (2010). A. naviculare is used for high blood pressure, cold,

Fig. 1. Steps taken to restore *Aconitum heterophyllum* through Ex-situ Conservation

fever and jaundice Shrestha *et al*., (2007) and Bhattarai *et al*., (2006). *A. heterophyllum* is reported to have antidiarrheal activity when taken with fine powder of dry ginger, Bael (Baelpatra in India) fruit, or Nutmeg (jaiphal in India). The juice of the root when taken with milk acts as an expectorant. The seeds are used as a diuretic. Further more, the plant is used to treat patients with reproductive disorders and is known to have hepatoprotective, antipyretic and analgesic, antioxidant, alexipharmic, anodyne, anti-atrabilious, anti-flatulent, anti-periodic, anti-phlegmatic, and carminative properties (Paramanick D *et al.*,2017)

CONCLUSION

Generally two methods (in situ and ex situ) plays an important role for conservation of medicinal and aromatic plants. However, in situ conservation is achieved by setting nature reserves and national parks. Plants could also be conserved in ex situ that is, to grow outside their habitat in controlled environment. Its advantage is that it is usually easier to supply plant material for propagation, for research and for educational purposes as compared to in situ reserves. The disadvantages of ex situ conservation is only that the plants conserved ex situ have to be taken more care so that there will be less homozygosity of genetic variation hence skilled human care is needed. Ex- situ conservation is only one choice for conservation of medicinal and aromatics plants and maintain biodiversity, because in these areas medicinal and aromatic plant attains more regeneration capability.

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ASSESSMENT OF COMMUNITY DEPENDENCE ON FOREST RESOURCES, RESTORATION OF COMMUNITY BASED FOREST MANAGEMENT AND SCOPE FOR BIOMASS BRIQUETTES IN UTTARAKHAND

Mahika Phartiyal[1] and Harshit Pant Jugran[2]*

[1]Ph.D. Scholar, Centre for the Study of Regional Development, Jawaharlal Nehru University, New Delhi, India
[2] Scientist, Centre for Socio-Economic Development (CSED), G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand, India

***Correspondence:** harshit.pantj@gbpihed.nic.in

ABSTRACT

The Himalayan ecosystem forms an integral part of the global ecosystem. The rural Himalayan communities are very close to nature and have high and direct dependency on forest resources for sustenance and livelihood. Abundant natural wealth and direct dependence on resources for livelihood and sustenance necessitates efficient local governance in the rural areas. Due to the topography and terrain constraints the mountain communities face accessibility issues. The mountain communities till date depend on wood for fuel or energy. Fuel wood burning is extremely harmful as it causes indoor pollution and increases health risks. There is an immediate need for energy substitute strategy which utilizes locally available renewable energy resources. This can be achieved through efficient conversion technologies that can mitigate health risks due to fuel wood burning. The present study draws an understanding of the functioning of the local forest managing body also known asVan Panchayats or the forest councils, in Uttarakhand, India. The study was conducted in two villages of Almora district, Uttarakhand. It identifies a sustainable technology which is efficient, simple, cost- effective and which can generate energy on a local scale by internalizing the available resources. The study also recommends strategies the local governing body can adopt to mitigate health risks due to fuelwood burning by promoting alternative energy sources. There overall this paper attempts to identify the relation of rural mountain community with forest resources, the functioning of local governing regimes and the scope for renewable energy.

Keywords: Himalayan communities, Forest dependence, Van Panchayats, Natural Resource Governance, Renewable energy, Bio-briquette and Bio-globules

INTRODUCTION

The Indian Himalayan Region (IHR)is inhabited by 4% of the total population of the country (Garkoti *et al*., 2018) which accounts for approximately 51 million people. The IHR has a predominant rural population. The rural population approximately 80.29% of the total population of the IHR (Nandy *et al*., 2000). The Himalayan range has several important geological, climatic and socio- economic implications on India. The region is geographically fragile as the region is susceptible to natural disasters due to seismicity and tectonic stress (Valdiya 1985). The weather conditions and susceptibility to natural disasters varies spatially across the Himalayan region. The spatial differentiation is due to the variation in altitude, latitude and terrain it influences ecology, livelihood patterns, livelihood opportunities and sources of vulnerability. Despite its fragility the region is socially and ecologically diverse and it is a habitat to many economically deprived communities (Pandey *et al*., 2017). The communities inhabiting in the Himalayan region are considered to be among the poorest and most vulnerable (Shukla *et al*., 2016; Gerlitz *et al*., 2017).

Most of the mountain communities till date practice traditional integrated crop-livestock farming system (Bisht *et al*., 2018). The mountain communities depend on their immediate ecosystem to sustain themselves (Gerlitz *et al*., 2017; Koirala 2015; Sandhu and Sandhu 2015; Tsering *et al*., 2010). These communities traditionally have relied on wild edible plants, medicinal plants, mushrooms, wild and other forest products (Tag *et al*., 2014). However, there is a problem of accessibility, the infrastructure is under-developed, land holdings are small and unconsolidated, agricultural output is low, there is an issue of human-wildlife conflict, forest fires etc. (Tag *et al*., 2008; Tewari and Bhowmick 2014; Bisht *et al*., 2018; Kuniyal *et al*., 2021).

Uttarakhand is one of the major Western Himalayan states, it has a total geographical region of 53,483km^2 inclusive of the forest area which is spread over 24,272km^2. The forest covers 45.43% of the State's geographical area (FSI 2017).

Uttarakhand is a rich repository of biodiversity (Upadhyay *et al.*, 2018) with more than 7000 species of medicinal plants and 500 species of fauna. Uttarakhand has a unique and very well-developed local forest management. The community forestry management is taken care of by the forest councils, locally known as the Van Panchayats (Barola *et al.*, 2016). The power to manage forest resources on daily basis rests with the Van Panchayats, the renowned local village institutions which were formed in 1931.

In Uttarakhand, the State owns the forest but the Van Panchayats are authorized and responsible to control management and supervision of the forest resources. The Van Panchayat management was proved to be a better and effective management than private and government management systems. The decentralization management catered the socio-economic needs and ensured natural resource sustainability (Aggarwal 2006). Community forestry in Himalayan region represents one of the oldest examples of decentralization initiatives around the world (Agrawal and Ostrom 2001) and the community forestry in Himalayas has been largely successful in managing these forests at least until the past two decades. The Van Panchayats have powers of exclusion, monitoring, sanctioning, and enforcement. Rules were carved according to the prevailing conditions. Villagers are responsible for the plantation, management and development of the forest, ensure that there is no encroachment in the forest by the community members. With the help of forest department and community they demarcate village and village forest by constructing boundaries and carry out directives of sub-divisional magistrate they also distribute products among right holders in an equitable manner. The Van Panchayat was also authorized to imposed small fines for unlawful act, seize cattle grazing in protected land, they could sell grass twigs and stone slates to people for household purposes and could even auction trees with prior permission from the forest department. According to the forest department records in 2019 about 12,089 Van Panchayats have been established in Uttarakhand state. These Van Panchayats manage a forest area of about 7350.857km^2 (Uttarakhand Statistics 2013) forming about 14 percent of the total area of state in eleven hill districts in the state of Uttarakhand: Chamoli, Pauri, Tehri, Uttarkashi, Dheradun, Rudraprayag, Nainital, Almora, Pithoragarh, Champawat and Bageshwar.

However, the revised Van Panchayat Act of 1976 that replaced the 1927 Act affected many aspects of local management, making forest councils increasingly dependent on the government (Singh and Ballabh 1991). After 1997 approximately 8000 Van Panchayat were established but the control was over the civil forest. The role and authority of Van Panchayat over village forest has declined after the amendments in the years 1976 and in 2000 as Van Panchayat was remained no more as an autonomous body, rather it functioned along with forest department. In 2001, the Uttaranchal Panchayat Forest Rules were revised again. Under the revised rules, each forest council was expected to develop a five-year micro-plan, annual implementation plan, and an annual report for the community forests. However, the forest department had the upper hand as it indirectly managed the forest. In 2005 the Panchayat Forest rules were further amended which facilitated greater representation of the marginalized groups (women and the lower caste) in Van Panchayat or the forest councils, these rules served to further increase forest council management and administrative responsibilities. The latest amendment was done in 2012 in which Van Panchayat had to function with the Gram Panchayat, 50% women participation was mandatory. The revised election guideline stated that the elections have to be conducted at a prior notice to forest department. When the villagers sell forest products in the market the surplus amount has to be deposited in the Van Panchayat fund which is used for community welfare. Therefore, according to the latest rule, the Van Panchayat cannot spend the funds and neither can sell the forest products without the permission of the forest department. This has disrupted the decentralized system that was in existence before, snatching the autonomous powers of Van Panchayats. The actual powers rest with the forest department even though number of Van Panchayats has increased considerably but on ground level their functionalities has decreased or have become stagnant in most of the cases.

Objectives of the study

To conduct a scoping study for the assessment of community dependency on natural resources.

To understand the functions of local resource management

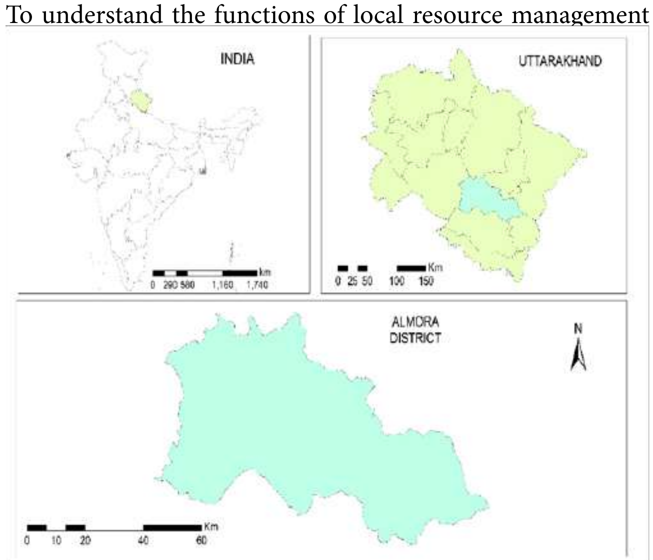

Fig. 1. Study Map

associations.

To identify the most efficient and appropriate means of renewable energy through biomass and natural resource utilization.

METHODOLOGY

Study area

The state of Uttarakhand has a total geographical area of 3,144km^2 including 1,718km^2 forest area. It comprises of two broader regions, Garhwal and Kumaun which together encompass 13 districts. Kumaun Himalayas are spread over a distance of 320 kilometres and have diverse species of flora and fauna. The Kumaun Himalayas are an integral part of the western Himalayan region and form the catchment area of the Indo-Gangetic plains (Rawat 1999). The study area was located in Almora district that is a part of the Kumaun Himalayas. According to Census data (2011) Almora ranked second in rate of outmigration. For the study two villages Jyoli and Dhamas were purposively selected on the basis of type of forest in the proximity of the villages. In one of the village, the community was dependent on Pine forests whereas in the other village the community was dependent on Oak-Pine mixed forests.

Table 1. Administrative division and Geographical characteristics

Village name	Jyoli	Dhamas
Block	Hawalbagh	Hawalbagh
Van Panchayat	Jyoli	Dhamas
District	Almora	Almora
State	Uttarakhand	Uttarakhand
Latitude	29˚38'23.40" N	29˚35'54.69" N
Longitude	079˚37'23.37"E	079˚39'24.89" E
Elevation	1388	1460
Slope	60˚	45˚

Data Sources

Data was collected through both primary and secondary sources. For primary data collection two villages Jyoli and Dhamas were purposely selected on the basic of forest type. The basic idea was to understand the dependency of community on different forest type. It was also done to understand what differences exists in terms of procurement of forest products differentiate and compare the procure, roles and practices, changes in trends, major problems and functioning of local governing associations. Primary data was collected by conducting household surveys. For the study a total number of 40 household surveys, 20 open ended interview and 4 focused group discussions were taken from Village 1- Jyoli and Village 2- Dhamas. Random sampling was conducted to selection of houses for survey. Both the villages were divided into two social groups in terms of caste, general caste and schedule caste. For secondary data sources government reports such as Census data reports, Reports of Forest Survey of India, Forest Department of Uttarakhand, Van Panchayat riles and duties handbook, Uttarakhand Rural Development and Migration Commission were studied.

ANALYSIS

Site Overview, **Village 1- Jyoli**

Jyoli is a medium sized village in Hawalbagh block of Almora district, Uttarakhand. It is 24.2 kilometers away from district headquarters of Almora. Jyoli is spread across an area of approximately 60 hectares. It is situated at an elevation of 1388asl with the average slope, 60˚. The terrain is undulating and terrace farming is practiced in Jyoli. Jyoli is a habitat to 121 household with 588 people, 67% of the total population belong to the general class and the remaining are Scheduled caste. There are no Scheduled Tribes. 17.20 hectares area is forest area which falls under the Van Panchayat. Almost 90% of the houses are electrified and have sanitation facilities. Approximately 40 households have LPG connection still they are highly dependent on fuel wood.

Village 2- Dhamas

Dhamas is a large sized village also situated in the Hawalbagh

Table 2. Demographic profile

Village Name	Village 1: Jyoli	Village 2: Dhamas
Population	588	1280
Male	285	560
Female	303	689
Household	121	500
General	67%	70%
Scheduled Caste	33%	30%
Scheduled Tribes	0	0
Religion	Hindu	Hindu

block of Almora district, Uttarakhand. Dhamas is double the size of Jyoli which is spread across an area of approximately 120 hectares. It is situated at an elevation of 1460asl with the average slope, 45˚. The terrain is undulating and terrace farming is practiced in Dhamas. Dhamas is a habitat to 500 household with 1280 people, 70% of the total population belong to the general class and the remaining are Scheduled caste. There are no Scheduled tribes. The forest cover under Van Panchayat is 32 hectares, civil forest is spread across 32 hectare and it is looked after by the village Pradhan, the forest department looks after a separate forest area, and apart from this the scheduled caste community also has an ancestral forest spread across 40 hectares. Almost 80% of the houses are electrified and around 50% of houses have sanitation facilities. Approximately 100 households have LPG connection but they are highly dependent on fuel wood as well (Table 2).

OBSERVATIONS AND RESULTS

Based on the Participatory rural appraisal tools, field survey and focused group discussions the following results in various aspects were observed in Jyoli and Dhamas.

Forest resources

Both Jyoli and Dhamas villages have forest cover in their vicinity. The villagers use wood for fuel, to make agricultural tools and furniture for houses, they use leaves for fodder or as bedding for livestock, they also derive other non-timber forest products like fruits, bamboo, medicinal plants etc from the forest. In Jyoli 17.2 hectares of area is covered by forest which is managed by Van Panchayats. Chir Pine tree (*Pinus roxburghii* is the dominant species in Jyoli. The pine trees shed needle leaves which are highly inflammable in nature. The high inflammablenature is due to the acidic properties of the pine needles and high resin content which makes it susceptible to fire. Resin is no more collected in Joyli, apart from that the forest is not economically very resourceful. Therefore, the Van Panchayat is not is a very active state at Jyoli although the micro plan has been proposed by the Van

Table. 3. Major tree species and their uses

Village Name	Local Name	Name in English	*Scientific name*	Habit	Use
Jyoli	Chir	Pine	*Pinus roxburghii*	Tree	Fuel, construction, animal bedding, manure and resin
	Tun	Indian Mahogany	*Toona ciliata*	Tree	Construction
	Nimbu	Lime	*Citrus limon*	Tree	Edible fruits, medicinal value
	Bans	Bamboo	*Dendrocalamus strictus*	Tree	Construction
	Pangad	Cheastnut	*Aesculus indica*	Tree	Edible fruits, medicinal value
	Malta	Orange	*Citrus sinensis*	Tree	Edible fruits, medicinal value
	Bhimal	Crossberry	*Grevia optiva*	Tree	Fodder and construction
	Padam	Himalayan Cherry	*Prunus cerasoides*	Tree	Religious, fodder
	Kharik	Honeyberry	*Celtis australis*	Tree	Fodder and construction
	Kweral	Mountain Ebony	*Bauhinia variegata*	Tree	Fodder and construction
Dhamas	Chir	Pine	*Pinus roxburghii*	Tree	Fuel, construction, animal bedding, manure, chiluka(fire torch) and resin
	Banj	Oak	*Quercus leucotrichophora*	Tree	Fodder and construction
	Bans	Bamboo	*Dendrocalamus strictus*	Tree	Fodder and construction
	Kharik		*Celtis australis*	Tree	Fodder and construction
	Bhimal	Honeyberry	*Grevia optiva*	Tree	Fodder and construction
	Mehul	Wild Himalayan Pear	*Pyrus pashia*	Tree	Fodder, edible fruits
	Kafal	Bayberry/ box myrtle	*Myrica esculenta*	Tree	Edible fruits, fodder and medicinal value

	Burans	Rhodo-dendron	*Rhodo-dendron arboreum*	Tree	Edible fruits, fodder and medicinal value
	Khu-mani	Apricot	*Prunus armeniaca*	Tree	Edible fruits, fodder and medicinal value
	Silfar	Winter Bigonia	*Berginia ciliate*	Herb	Medicinal value

Panchayat members.

In Dhamas the forest type is mixed Chir Pine (*Pinus roxburghii*) is one of the predominant species of this forest followed by Oak (*Quercus floribunda* and *Quercus leucotrichophora*). The forest ecosystem is more diverse in Dhamas as compared to Jyoli. The forest area is also immense in Dhamas which clearly defines the dependence on forest is higher than Jyoli and the Van Panchayat is also stronger as it has a richer resource base. The villagers are charged 600/ Rs and 500/Rs for different sizes of logs that they collect from the forest village. Therefore, in most of the cases they bring woods from the fallen trees covertly from the forest guard which is assigned by the forest department. The forest department yearly provides the village their 'rightful wood' in specific quantity. Forest resource are mainly use for fuel wood, fodder, edible fruits, household and agricultural purposes; pine needles are used as bedding for animals which is later used as manure. The people also procure medicinal plants from the forest.

DISCUSSION

Himalayan communities are highly dependent on the natural resources for subsistence. The targeted village communities are dependent on agriculture as the basis of primary subsistence. Almost 90% of the people use compost or farmyard manure and practice organic farming. However, the region is rain fed and the only source of irrigation is rainfall. The change in climate has resulted in decrease in rainfall over the years which have adversely affected the crop yield. In both the villages wheat yield has been substantially less for two consecutive years and the villagers have stopped cultivating wheat. This has affected the village economy. Adduced to this the land reforms have not been implemented therefore there is no provision for Gherabandi/ Chakbandi or land consolidation. Due to which land holdings are dispersed this makes the labor intensive farming in such undulating topography all the more difficult and un-remunerative. The crops grown are at times not sufficient for self-consumption, crops usually last 4-5 months on an average. No surplus is generated and hence there is no income generation which has compelled the men of the villages to migrate. There is no scope for employment rather than agriculture on which every family is dependent. Bamboo crafting which is only limited to scheduled caste since they own less land as compared to the general castes. The employment dearth has compelled the male to temporarily migrate out in search of job. The crop yield is also adversely affected due to the wildlife conflict which has increased in the village, the monkey and wild boar population is rising with every passing day. Earlier the village communities used to pool out money and hired a guard who would look after their crops during night. However, in the present there is limited profit which is being incurred form agriculture, the families are resistant in hiring a guard because as such the crop yield is low. High male out-migration has not only led to an additional burden on women in terms of physical work but has also implied their active involvement in the village household economy and common life.

The major dependence of rural communities on forest is for the extraction of wood or twigs for fuel wood. Fuel wood still remains to be a cheaper and the most utilized fuel as compared to LPG, kerosene, diesel and even other alternatives. Although burning wood is an unsustainable fuel as it causes indoor pollution which has adverse health implications causing cardiac and respiratory diseases, it lowers the life expectancy of the people and it also inflicts obstacles in education of children as they are preoccupied with the chores of collecting fuel wood from distant forest regions.

WAY FORWARD

For effective forest conservation, reforestation and recovery, we must strengthen our local forest governance mechanisms. The terms of reference for state REDD plans clearly says that their preparation and implementation must be overseen by joint forest management committees, community forestry groups, van panchayats and village forest protection committees. National plans have a strong component of capacity building, including training youth from local rural communities to build a large cadre of community foresters. As these plans show, the importance of local institutions for forest management is now returning to centre stage. Across India, communities have always used forests as common pool resources, though in a de facto manner that lacked legal recognition for centuries. Historically, most forests in the country were common property regimes, used, managed and maintained by local communities. It is also suggested that for the restoration of community based forest user rights, the management strategy should be linked with the state REDD plans. Moreover the rural energy assessment elucidates that there is enough scope for solar energy and wind energy in most of the mountainous areas but these incur high cost, technological barriers and lack of interest of people in using new resources. However, the excessive fuel load or biomass from the pine forest can be sustainably utilized in order to curtail the problems of Pine Forest which imposes critical threats to bio-diversity due to the intensive fuel load in form of leaf litter. Various projects have been established which utilizes pine needles in various forms this can impede the high CO_2 emission to a considerable scale. Biomass energy from these pine needles can be generated by using simple technology of biomass briquetting. Under the niche of G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora the manufacturing of Bio-briquettes and Bio-globules under its RTC (Rural technology Complex) one seeks to involve lower and marginalized group of villagers to provide them with resource utilization training and furthermore livelihood generating capacity.

Bio-briquettes and bio-globules are sustainable alternative of fuel wood as they are low smoke emitting fuels as opposed to fuel wood which is used profusely in house hold activities, like cooking food, heating water and for warmth. It reduced indoor pollution to a considerable extent. The bio-briquette burns efficiently and continuously for 1.5 to 2 hours. The pine needle briquetting would diminish the biomass load from the forests which would further contribute in ecological restoration by reducing the probability of forest fire. It is easily adapted by the women folk of the area and being used for their household chores as well as providing the livelihood generating opportunities. The method of preparing Bio-Briquettes and Bio-globules is much simplified and can be easily incorporated at the rural level with the help of the rural communities and is also beneficial to provide the forest floor a breathing space for the ample growth of herbaceous species.

Steps for the preparation of Bio-briquettes and Bio-globules are as follows- Pirul (Pine needles) is collected in huge amounts from the forest. Then the collected needles are ventilated and dried underneath the sun so that the moisture evaporates. When the pine needles are dried the entire mass is put in a pit and is ignited, the pit is then covered with a tin sheet, this step is the anaerobic Pyrolysis of Pirul. Thereafter the burnt material which has become charcoal is powdered and is mixed with soil in a ratio of 5:1. The soil is used as a binding agent. The dough is then either molded with an iron container for making bio-briquettes or it can be shaped manually as well. The final products are dried for 3-4 days and then are ready to use. The RTC imparts regular trainings regarding preparation of Bio-briquettes and focuses on women and weaker section for capacity building for sustainable utilization of these bio-resources and many of the women headed SHGs (Self-help groups) have been imparted with these trainings.

Bio- briquettes are cost effective as they are cheaper than coal and also has high calorific value. They are small in size and can be used in the traditional stoves also if the furnaces are not bought. It is safe and can be used for cooking, heating food and warming the rooms. The people can enhance the production on a large scale and become self-sufficient. All the resources are available in abundance the only additional requirement is the iron rolling molder, which is also not very expensive. An average cost of bio-briquette is 10/-Rs and that of bio-globule is 1/-Rs. There is high demand of Bio-briquettes and bio-globules in the market during the winter season which can lead to enhanced livelihood opportunities for the suppressed and unemployed section of rural population. Considering the unambiguous nature of Himalayan ecosystems technology should be prescribed or suggested, gender roles should be neutral and stable considering long term goals and objectives. Focus should be on simple, sustainable and cost-efficient technology which can also help the villagers to enhance their socio-economic status in the long run.

CONCLUSIONS

The present study focuses on the assessment of community dependency on forest resources, local governing associations and their possible linkage to REDD and scope of renewable energy in the Himalayan villages. The study was conducted in two villages of Almora district which have known for being dependent on forest resources for their energy consumption. There is a decline in forest management scenario which compiles of community management aka Van Panchayat which are not functioning as per they had been envisaged due to regular changes in their rules and regulations which are more in the favour of government instead of community, which suggests for the implementation of REDD and $REDD^{++}$ action plans for restoration of decentralized forest management.

The study tries to understand the most suitable and sustainable utilization of pirul or pine needles which are in abundance across the forests. The biomass of pine needles is being utilized for preparation of Bio-Briquettes and Bio-Globules which has been up-scaled during the present years. However, this needs to expand since it will not only minimize indoor pollution and facilitate efficient burning but it will also decrease fuel load to some extent. It can also provide sustainable livelihood opportunities to the rural communities. This intervention leads to the capacity building of rural communities and inspires them to take up the livelihood generation activities like this so that their requirement of energy is also fulfilled and on the other hand they can be sensitised enough to understand the importance of natural resources, their carrying capacity and sustainable utilization of these resources. Moreover, it is also suggested that if the local communities are incorporated in this kind of capacity building interventions, their out migration can also be checked and the life quality can be enhanced. This can be done at local village level, block level and even at district level with the help of Van Panchayats.

The intervention of local community to preserve and sustainably utilize and manage natural resources has high success rate and it directly helps them to overcome ecological disasters and threatened livelihoods. Every village has a peculiar social system which is formed by unique ideas, beliefs, traditions, interactions and social interactions etc. Therefore, it is essential to understand the functioning of society and impact of its historical heritage on a local scale to understand community governance dynamics. Bio-ecological inputs and social inputs and can effectively minimize depletive forest (Pandey 1996). This can be further catalyzed by simple technology and physical process with the help of external agents. In the broader picture, this will intensify renewable intrusion in the global energy mix through decentralized energy plans executed in different regions of the world and based on the self-motivated collective actions of local people it will be an additional part of larger picture of restoration work for the Himalayan region.

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SOIL MICROBIAL STRATEGIES FOR HIMALAYAN ECOSYSTEM RESTORATION

Supriya Pandey[1], Sumit Rai[1]* and Diksha Pandey[2]

[1]GB Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand, India
[2]GB Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India

***Correspondence:** sumitssac101@gmail.com

ABSTRACT

Soil microbes play an essential role not only in functioning and maintenance of ecosystem but also in biogeochemical cycles. As the scenario of microbial diversity has become more ostensible, the need to preserve them has become equally important. Depletion in soil quality due to decrease in microbial population is not uncommon, and in case of Himalayan region due to slow growth rate, difficulty of handling, relatively little attention has been given to microbes of Himalayan soil. Shift from natural to agricultural ecosystems alter soil microbial communities through long-term tilling and fertilization. But very little is known about changes in the composition and functional groups of soil bacterial communities during different restoration stages. During the restoration influence of aboveground vegetation and belowground soil properties on soil bacterial communities is also unclear. The practice of ecological restoration is a primary option for increasing levels of biodiversity by modifying human-altered ecosystems. Thus, in this review we aimed to assess the soil microbial community for land restoration strategies of the Himalayan region.

Keywords: Ecorestoration, Himalaya, Climate change, Soil

INTRODUCTION

Soil microbial biomass acts as a vital soil component and acts as a source and a sink for plant available nutrients, as well as catalyze the transformation of these nutrients in soil (Dwivedi and Soni 2011). Many anthropogenic activities, such as construction activities, agriculture, mining, use of pesticides and pollution etc. can potentially affect soil microbial diversity of Himalayan soil. Intensive agricultural practices and cultivation of exhaustive crops has deteriorated soil fertility and its quality in agro-ecosystems (Tiwari *et al.*, 2020). According to an estimate, such practices will convert 30% of the total world cultivated soil into degraded land.

Depletion in soil quality due to decrease in microbial population is not uncommon. In the Himalayan ecosystem due to slow growth rate, difficulty of handling, relatively little attention has been given to microbes of Himalayan soil such as cold adapted psychrophiles or psychrotolerant species. Psychrotolerant microbes have been reported to be important in high altitude agro-ecosystem due to the reason that they survive and retain their functionality at low temperature while growing optimally at warmer temperature (Skendzic *et al.*, 2021). The investigation on soil microbial community in soil undergoing restoration provides fruitful insights into how pristinely ecosystem work as well as restored areas. Microorganisms have critical roles in functioning of soil in nutrient cycling, structural formation and plant interaction. Such roles are crucial for reestablishing the function and biodiversity in restoration of ecosystem. But the question arises does the soil microbial community could be a key player in facilitating restoration? Microorganisms are essential to soil function; hence they could be an important part of any program aimed at restoration of an ecosystem. Western Indian Himalaya ecosystems are unique for their microbial community structure where altitudinal gradient is major factor determining the soil physiochemical properties and microbial community composition (Kumar *et al.*, 2019). Ecological restoration may be a prime alternative for modification of anthropogenically altered ecosystem (Kuniyal *et al.*, 2021)

METHODOLOGY

Literature Search and Eligibility Criteria

The Google Scholar database was searched for studies published with the following keywords: “Eco-restoration of Himalaya”, “Climate change and Himalaya” and “Soil microbial eco-restoration”. Manual revision was conducted on all displayed publications and first selections were based on information in the titles and/or abstracts. Selected publications had to be available for downloading and had to contain extractable data in English about the presence of eco-restoration, soil microbes and Himalaya. Selection of studies and extraction of data was done independently and then compared. Furthermore, the collected data were reviewed for discrepancies.

RESULT AND DISCUSSION

Factor affecting soil microbial population and Himalayan ecosystems

Himalayan Himalayan ecosystem faces number of serious issues, most significant of which are climate change habitat loss, species loss, and day by day conversion of natural ecosystems for human land uses which is one of the leading threats and leaving long-lasting legacies on Himalayan ecosystem. Humans have drastically transformed Earth's protective soil layers, with agriculture and mining where mining being the most damaging land uses that cause harmful effect on soil health and present microbes. The other dominant form of soil degradation are erosion and salinity, where the causative factors are improper agricultural practices, deforestation and overgrazing (Kuniyal *et al*., 2021). Severe disturbances to soils result failure to hold water and recycle nutrients, these are two vital soil functions to mitigate biogeochemical and hydrological instability on a global scale.

Microorganisms are the important life form of earth having strong impact on global processes such as nitrogen, carbon and sulphur biogeochemical cycles. Through decades of fertilization, tilling, and agrochemical use, soil microbial communities in agricultural systems have become so altered that they are thought to reach an alternative stable state (Docherty *et al*., 2019). Kumar *et al*., (2019) reported that altitude has confounded effects on the both biotic and abiotic factors of the ecosystem psychrophilic diazotrophs in Gangotri soil (Western Indian Himalaya). Altitude is the major factor which has confounded effects on both biodiversity and soil physiochemical properties (Kumar *et al*., 2019). High altitude ecosystems are generally characterized by low temperature, variable precipitation, decreased atmospheric pressure and soil nutrient stress which have major impact on biodiversity (Kanwal *et al.* 2019). High altitude cold environments represent the majority of the biosphere on Earth and have been successfully colonized by cold adapted microorganisms that are able to thrive, better survive and even maintain metabolic activity at subzero temperatures (D'Amico *et al*., 2003). Collectively, despite harsh environmental conditions, many specially adapted microorganisms are able to thrive in alpine environments. Their community structures strongly correlate with climatic, vegetation and soil properties.

A. Rising Temperature

Over the last 100 years, the average rise in temperature for the Himalayas is significantly large than the global average of 0.74 °C. Mountains are considered as an important indicator of climatic change (Fort 2015). Rising temperature has affected the agriculture, forestry, tourism, livestock, etc. as well as human health (Kanwal *et al*., 2019). Cold environments like in Himalayas represent a major portion of the Earth's biosphere where cold-adapted microbes are abundantly colonized, which are generally termed as "psychrophiles". These changes ultimately influence the microbial diversity from the Himalayan ranges.

B. Variation in Precipitation Pattern

Natural water resource of the major river systems of the Indian region are originate from Himalayas During the last few decades, variable rainfall trend has been prevalent across Asia. Both increasing and decreasing precipitation patterns were detected in the Himalayan region. Unfortunately, a vast reduction in rainfall has been recorded for the Central Himalayas. These variations have imposed the harmful effects on natural ecosystems and, therefore, created great threat to indigenous microflora.

It is widely accepted that climate change is the major factor behind the decline in ecosystem related to Himalayas. Climate change present an increased urgency to the restoration of belowground ecosystem soil microorganisms exhibit changes in physiological properties when they are warmed, including less resource allocation to biomass and degradative enzyme production. These physiological changes are counteracted by shifts in carbon-use efficiency and changes in community, which leads to the observed reduction in temperature sensitivity over time.

Soil Microbial restoration

Soil microbial communities plays several important ecological functions such as soil organic matter decomposition, regulation of mineral nutrients availability, atmospheric nitrogen fixation, formation of mycorrhiza, production of biologically active substances that stimulate plant growth. They are also important for ameliorating soil physical and chemical conditions and soil habitability of plants. Thus, microbial conscious restoration processes can help in restoring ecosystem, thus possibly creating ecosystem that are more resilient to climate effects. It was found that interactions between the plant and soil microbial communities, including both bacteria and fungi disturbance can alter plant–microbial interactions, leading to permanently altered soil carbon dynamics.

Approach for the restoration of Himalayan microbial diversity

A. Harvesting restraint– Protecting sacred pastures and landscapes would ultimately lead to protection of microbial diversity residing in these areas.

B. Protection of resourceful species– It involves protection of resource species to conserve associated microflora effectively.

C. Regulating harvests– It involves the conservation of

Table 1. Overview of studies on soil microbial ecology in mountain ecosystems

Geographical location	Altitude (m)	Findings	References
Gangotri soil ecosystem Western Indian Himalaya	3,048	Altitude has confounded effects on the both biotic and abiotic factors of the ecosystem psychrophilic diazotrophs in Gangotri soil which have good potential to fix nitrogen even at 2°C	Kumar *et al*., 2019
Indian Himalayan region Mana village (Chamoli district,Uttarakhand,	3,238	Extensive colonization of soil by the major groups of microorganisms, environment under snow cover is likely to act as a limiting factor for survival of the soil microflora.	Sati *et al*., 2013
Different regions (Himalayas, Rocky, Andes)	3660- 6330	Diversity is little at high altitudes with some yeasts (Filobasidiales) and Dothideomycetes; zoosporic fungi (e.g. Spizellomycetales) are dominant after snow melt	Schmidt, Naff and Lynch 2012
Changbai Mountain, China,	2000–2500	Bacterial communities differ with elevation and microbial richness decreases with elevation	Shen *et al*., 2015
Swiss Alps, Damma glacier	2100	nitrification and denitrification activity high at older soils where plants dominated	Brankatschk *et al*., 2011
Italian Alps	2400	Floristic composition structures bacterial communities along transect; plant species effect on bacterial communities	Ciccazzo *et al*., 2014
Swiss Alps, Damma glacier	2100	Contrasting microclimatic conditions along the depth gradient in Unvegetated soils; convergence of depth-related differences of Community structures in later stages (homogenization due to the impact of plants)	Rime *et al*., 2015
California (White mountains)	3100–3800	Native range expansions (sagebrush) affect soil microbial communities	Collins *et al*., 2016
Colorado Rocky Mountains	3500	Plant richness and P and N treatment drive microbial community structures	Yuan *et al*., 2016

microorganisms by confirming the number of harvests of the sacred plants involved in the rituals.

Importance of Bacterial and Fungal Diversity in Himalayan Soil Ecosystem and Mechanism for restoration of degraded soil

Bacteria and fungi are important mediators of biogeochemical processes and play essential roles in establishing plant communities. Both bacteria and fungi play essential roles in ecosystem functions, and information about their recovery after extreme disturbances is important for understanding whole-ecosystem development. Land degradation is a worldwide problem caused by number of anthropogenic activities that result in loss of soil fertility and productivity. The major causes of the land degradation include deforestation, improper agricultural practices, (intensive cultivation, unbalanced fertilization, poor quality irrigation and chemical inputs in the form of fertilizers or pesticides) and industrialization. Microorganisms living in soil ecosystem control carbon and nitrogen cycle and establish a link between plant diversity and soil ecosystem. Similarly, plant diversity also has its influence on the microbial community structure of the soil around the plant roots. Plants root secrets root exudates which are used by microorganism for their growth and development. Due to rich source of nutrients the region around the vicinity of root (Rhizosphere) harbours rich bacterial diversity. Suyal *et al*., (2015) studied soil bacterial diversity in rhizosphere of *Phaseolus vulgaris* from Western Indian Himalaya using unculturable approach and found that Soil bacteria, which represent the most abundant and diverse group of microorganisms in soil, serve a vital soil ecosystem function in nutrient cycling, soil structure formation, and establishment of sustainable plant communities. As a consequence, soil bacterial communities have evolved different strategies in response to changes in environmental conditions, such as soil pH, nutrient contents and vegetation type. For this reason, soil bacterial community composition and abundance have become increasingly important indicators of soil quality (Schloter *et al*., 2018), as well as more specifically in the context of land degradation and restoration. Soil microorganisms and nutrients change after restoration, varying from vegetation patterns (Liu *et al*., 2021). In the past few years, several studies have addressed the succession of soil bacterial.

Rashid *et al*., (2014) observed that application of solid cattle manure increased organic matter, N, pH, microbial biomass and soil fauna in sandy soil compared to that of slurry manure fertilization. Application of urban waste increased soil microbial activities in degraded soil of semi-arid region. In addition to these studies, use of poultry manure and wheat straw in degraded soil of Himalayan region increased organic matter content (Khaliq and Abbasi 2015). Wang *et a*l., (2021) reported enhanced ecological restoration treatments in plant and soil microbial diversity in the degraded alpine steppe in Northern Tibet, and also investigate that the improved soil microbial diversity could facilitate the biological communities in degraded alpine for development of better ecological functions. Donhauser and Frey (2018) reported alpine permafrost soils, harboring a surprisingly large unknown microbial diversity and alpine habitat climate change studies showing shifts in microbial community structures and function in response to warming and altered moisture. Sharma *et al*., (2019) reported seabuckthorn forest helps in improving other forests and increases soil microorganisms which enhance soil biodiversity leading to conservation and restoration of fragile ecosystem.

CONCLUSION

For the success of vegetation restoration establishment of plant cover and amelioration of soil physicochemical properties is not enough but regeneration of soil microbial communities is equally important or somehow more important than all, which have been ignored from past long time. More work needs to be donewhich enlighten the role of microbes in generating soil structure in flustered systems and their potential. Yet, our understanding of soil microbial restoration and the role of active restoration for mitigating harmful effects remains unresolved for several reasons.Consumers related to soil ecosystem and their related microflora should consideradditional measures to counteract these effects and their prime focus should be on restoration efforts in areas where restoration strategies are less pronounced.

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RESTORATION OF SOIL MICROBIOTA FOR PROMOTING CLIMATE RESILIENT ECOSYSTEMS IN THE HIMALAYAN REGION

Diksha Pandey[1], Nikhil Savio[1], Sumit Rai[2*] and Supriya Pandey[2]

[1]GB Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India
[2]GB Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand, India

***Correspondence:** sumitssac101@gmail.com

ABSTRACT
In the face of rising climate change and anthropogenic impacts, the Himalaya deserves special attention in terms of conserving and preserving the resources and services it has bestowed upon civilization such as water resources, biodiversity and dependent livelihood options, among other key ecosystem services. Himalayas are a rich natural habitat with great variations in altitude, geology and soils across short distances. In any biological habitat, microorganisms account for the majority of the biodiversity of living organisms. They have a significant impact on the functioning of any ecosystem as well as the health of our planet and inhabitants. Moreover, Microorganisms play a pivotal part in the food, medical and biotech industries and that have a broad range of environmental applications. As a result, not only for the preservation of natural ecosystems but also for study and biotechnological applications, the characterization and preservation of Himalayan microbial biodiversity is imperative. Soil microbial restoration strategies are one of the commonly used practices for the conservation of Himalayan biodiversity.

Key Words: Climate change, Ecorestoration, Himalaya, Soil ecosystem

INTRODUCTION
Mountains encompass about 25% of the Earth's surface with about 915 million people residing there. Mountain regions account for 12% of the global population and 90% thereof are in developing countries. Mountains, on the other hand, give sustenance to a far larger number of people in downstream areas. Associated rivers fed by snow and ice melt critically and contribute to life-support systems as well as social and economic welfare. Mountain systems are highly sensitive to climatic variability and change. This is especially true for the mountain cryosphere with respect to glaciers, snow, and permafrost– all interacting and responding to the climate in a distinct way. Himalaya is one of the biodiversity hotspot. The unusually wide altitudinal range (over 3000m), rapid change in altitude and high endemism (Chitale *et al.*, 2014) make it an interesting area for microbial studies. The microbial diversity of the Himalayan soil has been widely studied due to the unique conditions of the Himalayas and its sub-regions. The necessity to conserve microbial diversity and gene pools has become increasingly crucial as the status of microbial diversity in the Himalayan region has grown more apparent. Cold environments make up a significant percentage of the Earth's biosphere that has been colonized by cold-adapted microbes, also known as "psychrophiles". These microorganisms not only survive at low temperatures but they have also maintained their viability. These microorganisms play significant roles in their habitats and include a variety of representatives of all three domains of life. The temperature has a significant impact on whether a given organism can live and/or grow, and this influence can be both indirect and direct, depending on how it affects water and/or the chemical molecules that make up living cells. For their survival, psychrophiles have developed a comprehensive set of morphological and physiological adaptations. As a result, there are shreds of evidence of diverse metabolic activities in cold ecosystems.

Microbes make up the majority of living forms found in severe environments. pH, heat, salinity, pressure, radiation, and other severe Physico-chemical conditions may be present. rRNA comparative sequencing techniques can be used to describe these microorganisms. These microorganisms may be capable of manufacturing a wide range of enzymes in harsh conditions, including lipase, protease and DNA polymerase, which can be used in a variety of industrial applications (Tripathi *et al.*, 2007). These bacteria have numerous secrets including genetic instructions that allow them to generate these enzymes under harsh environments.

METHODOLOGY
Literature Search and Eligibility Criteria
The Google Scholar database was searched for studies published with the following keywords: "Eco-restoration of Himalaya", "Climate change and Himalaya", "Soil microbial eco-restoration" and "Soil ecosystem". Manual revision was conducted on all displayed publications and first selections were based on information in the titles and/or abstracts.

Selected publications had to be available for downloading and had to contain extractable data in English about the presence of eco-restoration, soil microbes and Himalaya. Selection of studies and extraction of data was done independently and then compared. Furthermore, the collected data were reviewed for discrepancies.

RESULT AND DISCUSSION

Microbiology of Himalayan soil ecosystem

Microorganisms have evolved for about four billion years and can use a wide range of energy sources and flourish in a variety of environments including extremes of cold, heat, radiation, pressure, salt, acidity and darkness. Microbial diversity is abundant in the Himalayas. Thousands of psychrophiles or cold-adapted bacteria have called it home owing to its climatic and topological properties. Extreme environmental variables are prominent in Himalayan regions and studying the microbial diversity of these locations is significant because it allows researchers to better understand how these microorganisms adapt to these environments. Even though the Himalayan region is extensively explored for the study of microbial biodiversity, numerous plant growth-promoting rhizobacteria (PGPR) and economically important microorganisms. Microorganisms in the soil ecosystem regulate the carbon and nitrogen cycles and relate plant variety to the soil environment. Similarly, the Himalayan Ecosystem's Microbiome has an impact on the microbial community structure of the soil surrounding plant roots. Root exudates are secreted by plant roots and are utilized by microorganisms for growth and development. Because of the abundant nutrients, the area surrounding the root has a diverse bacterial population (Lugtenberg and Kamilova 2009).

The Himalayan cold environs are known to harbor a wide variety of microorganisms, including bacteria, archaebacteria, unicellular algae and fungi. Consistently cold conditions in this habitat result in decreased nutrient bioavailability, decreased enzyme activity, altered soil pH and water activity. Psychrophiles have evolved distinct adaptations to cope with cold stress and flourish in cold conditions. Cold shock proteins (CSPs) are found in these microorganisms and give resistance against cold stress. At cold temperatures, psychrophiles thrive and divide. This shows that at temperatures as low as 2°C, certain enzymes or supramolecular structures have displayed conformational changes that have a deleterious impact on metabolic flow. Psychrophilic bacteria present in the Himalayas have two major physical obstacles to overcome: low heat and high viscosity, which both limit metabolic flow but the sluggish development rate of these psychrotolerants makes the study of these psychrotolerants challenging (Suyal *et al*., 2014; Kumar *et al*., 2014). Fungi, in addition to bacteria, are the most common microorganisms found in Himalayan soil. According to numerous researches, Ascomycota is the most common phylum followed by Zygomycota, Basidiomycota and Heterokontophyta.

Chloroflexi, Actinobacteria, Acidobacteria, Gemmatimonadetes, Planctomycetes, Bacteroidetes, Firmicutes, Nitrospira, Cyanobacteria, Verrucomicrobia and Chlorobi are the bacterial groups which are generally found in himalayan region. Soil bacterial diversity was reported by (Yadav *et al*., 2015) from different altitudes (3978–4069 m) of Rohtang Pass (Himachal Pradesh), which is located in the northwestern Himalayas. Proteobacteria were the most prevalent, followed by Firmicutes and Actinobacteria. These bacteria had amazing plant growth-promoting abilities. Similarly, bacterial diversity in the Himalayas of Sikkim revealed the existence of bacteria, actinomycetes and fungus, which was shown to be decreasing as altitude increased (Rai *et al*., 2015). According to researchers at Palampur's Institute of Bioresource Technology, Pseudomonas species dominated the rhizospheres of sea buckthorn (*Hippophae rhamnoides* L.), tea (*Camellia sinensis* L.), black gram (*Vigna mungo* L.), and carnation (*Dianthus caryophyllus* L.)A repository has also been established at the Ranichauri Hill Campus of Govind Ballabh Pant University of Agriculture and Technology (GBPUA&T) Pantnagar, Uttarakhand, to preserve the diversity of cold-adapted fluorescent Pseudomonas (Negi *et al*., 2005).

Factors responsible for the functioning of soil microbial diversity in the Himalayan region

Species richness, functional and phylogenetic diversity and changing abiotic and biotic factors are responsible for the normal functioning of microbes of the Himalayas. Microbial diversity focused at biological diversity at three levels: genetic diversity within species, species diversity in terms of numbers, and community ecological diversity.

Soil microbial diversity restoration strategies in Himalayan region

Various microbial species are thought to exist in the Himalayan region, but only 1-10 percent have been identified, preserved and used for diverse purposes. We must conserve microorganisms in their natural environments in order to fully utilize the genetic riches of uncharacterized bacteria. For various types of conservation, microbial conservation strategies have been used "in-situ," "ex-situ," and "in-factory." In situ conservation ('on site', 'in place') ties microorganisms to their natural habitats and is the most effective way to sustain viable populations in their ecosystems and natural habitats (Fig 1.). Ex-situ (off-site) conservation involves preserving and maintaining diverse wild/isolated/cultivated species, as well as their genetic resources, in artificial media that are taxonomically well documented. The "in-factory" method of conservation is an intermediate method that is primarily used in the agricultural and industrial sectors.

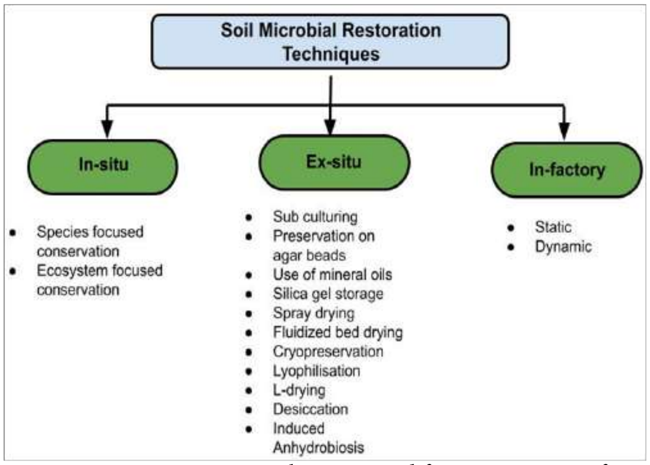

Fig. 1. Various restoration techniques used for conservation of microbial diversity in Himalayan region

In situ Conservation

In situ conservation strategies offer the ability to conserve ecosystems, species and populations for the long term in the face of ongoing adaptations. In regions where the microbiome has not been fully inventoried like Himalayan region, in situ conservation is critical. In situ conservation refers to a set of conservation strategies that involve naming, managing and monitoring biodiversity within the context of the environment in which it is present. In situ management practices might be aimed at specific populations of species (species-focused) or entire ecosystems (ecosystem-focused) (Heywood and Dulloo 2005). Protected areas have long been considered the cornerstone of in situ conservation. Conservation methods that are more flexible to individual circumstances and usable outside of protected areas are becoming more prominent. By in situ method of conservation, Specific microorganisms that live in specific ecosystems, particularly those that are on the edge of extinction, must be saved as soon as possible. In situ conservation strategies offer the ability to preserve ecosystems, species and populations for the long term in the face of ongoing adaptations.

Ex-situ Conservation

In Ex-situ Conservation microorganisms are conserved in laboratories utilizing specialized procedures for their current and future use. Microbial activities are decreased or prevented in ex-situ conservation approaches by imposing conditions. Sub-culturing, preservation on agar beads, use of mineral oils, silica gel storage, spray-drying, fluidized bed drying, cryopreservation, lyophilization (freeze-drying), L-drying, desiccation, induced anhydrobiosis, sterile distilled water, and gelatin discs are among some of the methods used to preserve and maintain microorganisms. The most valuable and widely used methods for long-term, stable storage of microorganisms are cryopreservation and lyophilization. Ex-situ conservation is rarely sufficient to prevent extinction.

In-factory Conservation

The in-factory approach of microbial preservation entails retaining them in their usual operating conditions. There are two types of conservation that can be used: dynamic and static conservation. Except for the introduction or mixing of cultures of different origins, dynamic conservation imposes no significant limits on the use of strains. Static conservation is quite rigorous and aims to sustain strains in such a way that any changes are avoided.

Organizations associated with conservation of microbial diversity

The World Federation for Culture Collections (WFCC), which is a federation of the International Union of Microbiological Societies (IUMS) and a commission of the International Union of Biological Sciences (IUBS), is responsible for promoting and developing microorganism and cultured cell collections on a global scale. Many microbial resource centres for conservation exist in many countries across the world, where microorganisms are collected, identified, classified and conserved according to the Organization for Economic Development and Cooperation's best practice recommendations (OECD). Chandigarh's Microbial Type Culture Collection and Gene Bank (MTCC) have established itself as an important microbial resource culture collection centre in India. It is registered with the World Data Centre for Microorganisms and is a member of the World Federation for Culture Collections (WFCC). The Microbial Culture Collection (MCC) and International Depository Authority (IDA) at the National Centre for Cell Science in Pune houses the country's largest collection of microbial cultures. In these repositories, individual microorganisms can be protected and used in a long-term manner. National Agriculturally Important Microbial Culture Collection (NAIMCC), ICAR-National Bureau of Agriculturally Important Microorganisms (NBAIM), Kushmaur, Mau, Uttar Pradesh is a Designated Repository (DR) recognized by National Biodiversity Authority (NBA), Government of India, for conservation of agriculturally important microbial wealth of the country.

Constraints in restoring microdiversity of Himalayan region

In today's environment, research is mostly focused on lucrative and producible projects where one can build a future for oneself. The hard core taxonomy initiatives connected to micro diversity are not being carried out on a large scale due to funding restrictions. If this mentality persists, several unknown microorganisms will lose their role and identity. Major ecological changes have already taken place, with the potential to wreak havoc on ecosystems. Apart from this, some of the constrains in restoring microbial diversity of Himalayan region are increasing temperature, variations in precipitation pattern and melting of glaciers.

Increasing Temperature

Mountains are important indicators of climatic change (Singh *et al.,* 2010). Temperatures have risen as a result of the greenhouse effect and the increase during the last 100 years (Cook *et al.,* 2014) has been more than the global average of 0.74°C (Joshi *et al.,* 2015). The fundamental problem is that it is unpredictable, which has long-term detrimental implications and effects. The metabolic activities of numerous psychrophiles in the Himalayan region are being affected by the unpredictability of temperature fluctuation, which has been reducing the diversity of soil microorganisms.

Variation in precipitation pattern

For India's major river systems, the Himalayas supply a considerable natural water resource (Nandargi and Dhar 2011). Asia has had a tendency of fluctuating rainfall during the last few decades. Both increasing and decreasing precipitation trends were seen in the Himalayan region which affect the properties of soil and microbial activity.

Retreating glaciers

The Himalayan glaciers are receding at an alarming rate (Kulkarni *et al.,* 2011). It's frequently a combination of precipitation loss and temperature rise in the Himalayas. According to a study, if global warming continues for an extended period of time, glacier retreat will increase, with many glaciers retreating significantly more in the coming years while smaller glaciers may entirely vanish. The natural microbiota will be seriously harmed.

CONCLUSION AND FUTURE PROSPECTS

Microbial diversity is ubiquitous in natural settings. Despite the fact that microorganisms play a critical role in ecosystem function and human survival, many of these "small living creatures" have been largely overlooked in extreme environmental conditions. Little is known about the potential contribution of Himalayan microbial diversity to the national economy, capital investment and improvements in the quality of life when it comes to the function of microorganisms in sustainable development.

Species richness of microorganisms must be researched, exploited, and protected throughout the Himalaya for the betterment of human beings and the environment. Elevational losses in richness in the Himalayan region are driven by mechanisms comparable to those that cause declines in richness throughout the latitudinal gradient such as reduced resource availability, cooler temperatures and higher extinction rates at regional scales as well as climate change. Only those species with the necessary features and adaptations will be able to establish and thrive in these habitats due to a loss in resources and colder temperatures at high altitudes, which can limit the number of individuals and select for species with certain niche attributes. Microbial evolution has entered a new era, with microbial culture collections around the world being pushed to develop new and better bioprospecting approaches for these novel microbes.

Apart from that, just a few culturable microorganisms have been kept in various collections around the world. There are likely to be significant gaps in knowledge about conservation techniques as well as knowledge of the distribution and quantity of microorganisms. The protection of soil microorganisms in their habitats with extreme environmental circumstances as well as endangered plants and animals harbouring specialized microbes should be the focus of a comprehensive strategy.As a result, global policies for the conservation of hidden microbial resource must come from microbiologists, researchers and research institutes, and must be backed up by the government as a national policy to ensure the survival of life on the planet.

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SEABUCKTHORN (*HIPPOPHAE* SP.): MEDICINALLY, ECONOMICALLY AND ECOLOGICALLY VALUABLE PLANT OF TRANS INDIAN HIMALAYA

Sarla Shashni

G. B. Pant National Institute of Himalayan Environment, Himachal Regional Centre, Mohal-Kullu, Himachal Pradesh, India

***Correspondence:** sshashni@gbpihed.nic.in

Seabuckthorn (*Hippophae* sp.) is one of the most important medicinal plant of Elaeagnaceae family with its geographical distribution in Europe, Asia, Central Asia, Siberia, China and Tibet. Indian Himalayan Region has been second abundant source of seabuckthorn worldwide after China. In Indian subcontinent, it is widely available in Trans Himalayan Region with its90 percent of population in Ladakh followed by Himachal Pradesh, Uttarakhand and North Eastern states (Masoodi *et al*., 2020). In Himachal Pradesh it is mainly available in Lahaul & Spiti, Kinnaurand parts of Chamba district from altitude range of 2500 to 3500m above mean sea level (Bali *et al*., 2016). The term *Hippophae* is derived from two Latin words, 'Hippo' means Horse, and 'Phae' means to shine. Globally, 7 species and 8 subspecies of the seabuckthorn has been recorded till date from which 4 species are recorded in India as; *Hippophae rhamnoides* sub sp. tukastanicaL., *Hippophae salicifolia* D. Don., *Hippophae tibetana* Sch. and *Hippophae rhamnoides* sub sp. gyantsensis Rousi (Swenson and Bartish 2002). Recently, seabuckthornis emerging as a potentially suitable plant species for socio-economic upliftment and environmental protection especially in the Cold Desert areas of Himachal Pradesh. Seabuckthorn is multi branched thorny shrub species with yellow and orange berries and survives in extreme climatic conditions of the region (Singh and Dogra 1996). The different parts of plant such as berries, seed, pulp, fruit, juice, leaves etc reported to have 200 bioactive compounds (Gupta *et al*., 2011). The bioactive compounds include 22 fatty acids, 42 lipids, organic acids, amino acids, carbohydrates, vitamins (A, B1, B2, B6, B12, C, E, K, folic acid, tocopherols), flavonoids, phenols, terpenes, tannins, and 20 mineral elements. It also consists of a decent amount of omega 3, 6, 7, and 9 (Alam 2004). It stands alone in the plant source that offers all fatty acids, including omega 6 &7 due to which it is considered as most nutritious plant found in plant kingdom (Zielinska and Nowak 2017). It is also called as 'Wonder Plant' 'Ladakh Gold' 'Golden Bush of Himalaya' 'The Super Plant' 'Gold of Cold Desert' etc. Seabuckthorn is locally known by different names like Charma, Salla, Nak-tser, Shishu-lulu, sTarbu, tsermang, tsesta-lulu, Tser-Nak, Tserkaretc. in the different regions of Ladakh and Himachal Pradesh (Stobdan *et al*., 2011).

Several countries are commercially and ecologically harnessing seabuckthorn for livelihood enhancement. In India, the species of *Hippophae* the Himalayan species of *Hippophae rhamnoides* is very less explored in terms of its processing. Therefore, it has a great potential to develop an enterprise while ensuring multipurpose benefits to the communities living in the Cold Desert areas of Himachal Pradesh. It is also reported that plant which grows naturally in the region can withstand -40°C to +40°C and acidic soils and its roots with microbes'interaction can enhance the soil fertility and are useful in checking soil erosion (Tamchos and Kaul 2015). It can also offer nutrition, food, medicine, cosmetics and overall socioeconomic development of the communities living in the regions. People residing in the cold desert area of the region are using the species for various indigenous uses like fuelwood, small timber, agriculture implements and also used by the 'Amchi/Larje' (traditional healers) for treating various diseases and ailments since time immemorial (Singh *et al*., 2021). Currently, various products such as jam, jelly, tea, biscuits, Vitamin C tablets, medicines, cosmetics, berries, seed oil, leaves tea and extracts, etc have been developed by researchers all over world. The various studies in terms of ecology, morphology, ethnobotany, fuelwood, traditional system of product development has been carried out by different researchers. Recently, seabuckthorn is also considered as horticulture plant and new initiatives are also implanting to expend the forest of seabuckthorn in large extend by Himachal Pradesh State Government. At present fresh seabuckthornberries are sold in regional or national market by different stakeholders at INR 100 per kg and its value-added products such as dry leaves upto INR 1000 per kg, pulp Juice at INR. 800 per litre, squash at INR 250 per litre bottle, dry berries at INR 1500 per kgs, seeds at INR 400 per kgs, dry hull at INR 300 per kgs, jam at INR 300 for 250 gm bottle, and seed oil can fetch an amount upto INR 20000 per litre.

Seabuckthorn plant has a strong root system with an ability to hold the soil in the slopes of mountainous regions. Due to these unique properties, it checks the soil erosion and surface runoff during rainfall. It is also a fast-growing with wide ecological adaptation and efficient nitrogen fixing plant species. These characteristics makes it well suited for the conservation, land reclamation and ecological restoration of the cold desert area. Seabuckthorn also plays a significant role in conserving wildlife by providing an excellent habitat for many wildlife in the region. The region has a scarcity of resources and during winters there is a huge demand for fuelwood for warming the houses and seabuckthorn is also a very good alternative source of fuelwood.

Despite of ecologically and socio-economically highly valuable plant, seabuckthorn is still a neglected or very less harnessed plant in the region. It is because of the lack of knowledge on the species and lack of technological interventions at local level. The berries of the species are highly perishable in nature and needs processing within few hours of its harvesting. Therefore, in order to harness the potential of the species for its primary processing aspects establishment of the Technological Incubation Centre in Lahual Valley of Lahaul & Spiti district has been done by the G.B. Pant National Institute of Himalayan Environment, Himachal Regional Centre. The intervention was done in the region under the National Mission of Himalayan Studies (NMHS) funded project to explore the possibilities of developing value added products and improving the resource base of this multipurpose plant of seabuckthorn. It is also to address issues related to economic growth in terms of its processing by tribal population of the region and its environmental sustainability.

Seabuckthorn plant helps in improving the soil fertility which leads to conservation and restoration of fragile ecosystem of the Cold Desert areas of Himachal Pradesh. For overall environmental, ecological and economical security of the region following recommendations are made;

i. It is suggested to tame the river sides open areas, community land and marginal land in the region for the cultivation of seabuckthorn.

ii. Sustainable collection and harvesting practices of berries through technological interventions is also needed.

iii. Ensuring quality processing of leaves and berries and good packaging, labelling for market acceptability.

iv. Quick primary processing of the berries at regional level through introducing low cost-effective technologies are also recommended.

Fig. 1. Seabuckthorn Plant

Fig. 2. Seabuckthornplant carrying berries

Fig. 3. Value added products of Seabuckthorn

v. Diversification in product development of seabuckthorn is also suggested for wider marketing and economic benefit.

vi. Geographical Indication (GI) of the seabuckthorn is also recommended for its uniqueness in the region.

vii. Collaborative efforts among farmers group, government organisation and scientific research organisation is also very important for its overall sustainability in the region.

viii. Government should come up with the policies and incentives to promote cultivation of seabuckthorn in the barren areas of the region for overall environmental and socioeconomic security of the tribal communities in Cold Desert areas of Himachal Pradesh.

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PROMOTINGRUBIACORDIFOLIALINN.THROUGHAGRO-TECHNIQUE FORLIVELIHOODSECURITYANDECORESTORATIONINUTTARAKHAND

Deepti Tiwari* **and I. D. Bhatt**

G. B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand, India

***Correspondence:** pandeydeepti1990@gmail.com

ABSTRACT
Rubia cordifolia Linn. (Family - Rubiaceae) is a valuable medicinal plant in Ayurvedic medicinal system. The extracts and biologically active compounds of the plant are reported for various therapeutic activities. It is a key ingredient in various Ayurvedic medicinal and cosmetic formulations. This species is also extensively used in textile, inks and food industries as natural colorant. The present work is an attempt to provide detailed information on conservation of this valuable herb through agro-techniques, so that the demand of raw material could be fulfilled. This will also help in economic upliftment of the inhabitants who are facing challenges in livelihood security due to COVID-19 pandemic in Uttrakhand.

Keywords: *Rubia cordifolia* Linn., Uttarakhand, Agro-technique, Conservation, Pandemic.

INTRODUCTION
Rubia cordifolia Linn. commonly known as Indian madder belongs to the family Rubiaceae and is well known plant in Ayurvedic medicinal system (Fig.1). It is widely distributed in Japan, Indonesia, Ceylon, Malay, Peninsula, Java, India, China, Mongolia, Vietnam, Philippines and tropical Africa (https://tropical.theferns.info/). In India, this species is found throughout the lower hills of Himalaya, Western and Eastern Ghats, Assam, Sikkim, Aruranchal Pradesh, Uttarakhand, Manipur and other hilly districts of India at an altitude of 800-2800m asl and grow well in sandy, loamy and clay soils (Wealth of India 2002). *R. cordifolia* is considered one of the most valuable plants in Ayurvedic medicine and has been largely used by herbal healers since ancient times. Several biologically active chemical constituents such as alizarin, mollugin, furomollugin, dihydromollugin, munjistin, purpurin, pseudopurpurin, xanthopurpurin, ruberythric acid, rubiadin, cordifoliol, cordifodiol and rubiatriol have been extracted from different parts of *R. cordifolia*. The isolated compounds and plant extract possess various pharmacological activities including anticancer, anti-inflammatory, antioxidant, hepatoprotective, radiation protection, antimicrobial, wound healing, antidiabetic, neuroprotective (Son *et al.*, 2008; Deshkar *et al.*, 2008; Bhatt and Kushwah 2013). Purpurin, alizarin and munjistin are the coloring pigments present in the roots and have been used for extraction and preparation of dyes utilized in textiles, inks, cosmetics and food industries (Sertoli *et al.*, 1994; Devi Priya and Siril 2014). Uttarakhand is known for its rich biological diversity including high valued medicinal plants. Majority of medicinal plants are collected from wild in an unscientific and unskilled manner which has led to depletion of valuable plants species from the region. Therefore, State Medicinal Plants Board (SMPB), Uttarakhand prioritized about 26 high valued medicinal plants and developed protocols for their cultivation to restrict the wild extraction. Among them *R. cordifolia* is heavily traded medicinal plant with estimated annual demand 100-200 MT (https://nmpb.nic.in/). The present study is an attempt to provide in-depth information about the agro-technique for *R. cordifolia* in Uttarakhand.

METHODOLOGY
The three popular search engine, such as Google scholar, Microsoft academic and Scopus were used to retrieve the articles. The keywords used were "Rubia cordifolia", "Manjistha" AND "Indian madder"; "Morphology"; "Traditional uses" OR "Ethnomedicinal uses"; "Cultivation" AND "Agro-technique"; "Economic potential", "Livelihod security" AND "Cost-benefit".

MORPHOLOGICAL CHARACTERISTICS
Plant Height: Perennial, herbaceous climbing plant with stem upto 10m long.

Roots: Long, cylindrical, flexuose with a thin red bark often have a long, rough, slightly woody base.

Leaves: Heart shaped, 5–10cm in size, blade lanceolate, cordate or ovate, base cordate or rounded, apex acute or acuminate, margins and veins below with recurved prickles, glabrous to hairy, five-nerved from the leaf base and occur in whorls of four.

Petiole: Roughly triangular with many sharp recurved prickles on the edges.

Inflorescence: Axillary or terminal cyme up to 2.5cm long, lax or dense, peduncle 1–2.5cm long.

Flowers: Small, bisexual, greenish-white to yellow, scaly, occur in terminal cymes, bracts are ovate and leafy, calyx is tubular, less than 1 cm long, corolla is greenish, divided to the base, tubular with five lobes, and about 3mm long, anthers exserted, disk small and swollen, ovary inferior and 2-celled, styles 2, short, stigmas head-shaped.

Fruits: Globose, smooth, shining, 4–6mm in diameter, violet or purple black in colour with single grey black seeds.

Seed: Globose, 1–3 mm in diameter.

ETHNOMEDICINAL USES

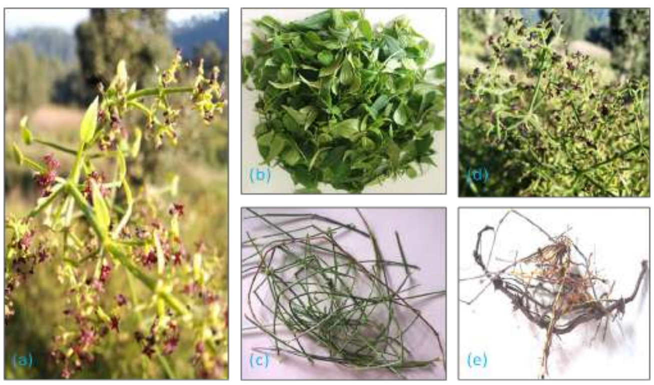

Fig. 1. (a) A flowering twig (b) Leaves (c) Stem (d) Fruits (e) Roots

The use of *Rubia cordifolia* in treatment of jaundice, dropsy, paralysis, amenorrhoea, visceral obstructions, dysentery, snake bite, liver problems, ulcer, stomach pain, and fever and skin diseases is reported in traditional cure system (Nadkarni and Nadkarni 1976; Singh and Attri 2014; Singh *et al*., 2014; Maiti *et al*., 2022). Roots of *R. cordifolia* possess blood purifying, pigment stimulant, tonic, astringent and deobstruent properties (Patil *et al*., 2009; Kala 2015; Pandey *et al*., 2017). An energy drink prepared from R. cordifolia in combination with *Aegle marmelos, Phyllanthus emblica* and *Beta vulgaris* showed nutritional as well as pharmacological potential (Jha and Gupta 2016). Besides, roots of the plants extensively used as important ingredients in various ayurvedic formulations such as Mahamanjisthadi Kwath, Manjistha Ark, Manjisthadi Tailam (oil), Manjistha Tea and Rakta Shodhana Blend, Mahamanjisthadi Kadha, Septilin Syrup, Manjistha Skin Wellness, Manjistha Powder, Manjistha Chooran, Candana Sava etc. which are used for various skin ailments, gastrointestinal problems, blood purification, kidney and liver diseases, urinary tract infection and other general illness.

Table 1. Activity details of cultivation

Operations	Months	Activity details
Seed sowing	Dec-Jan	Seeds obtained from ripe fruits sown in nursery beds either in rows or randomly by broadcasting, Pretreatment of seeds with 0.02% Bavistin gives better planting material, The plants can also be raised through cuttings containing two or three nodes, treated with commercially available hormones indole-3-butyric acid (IBA) for rooting, A thin layer of soil and organic manure is spread over the seeds, Irrigation of the beds should be done regularly
Seed germination	Jan-Feb	After 20 days of sowing, the seeds start germinating,Seedlings with two to three leaves transplanted in polybags for establishment
Transplantation of seedlings into field	Apr-May	Field should be prepared prior to transplantation of seedlings, The soil is properly ploughed, harrowed once or twice, and planked lightly to make it porous and weedfree, Seedlings /rooted cuttings are transplanted to the main field with optimum spacing of 60cm × 75cm, Irrigation should be done if necessary
Crop Maturity	Aug- Nov	Flowering and fruiting start after one year in August-September, Seeds mature in October- November
Harvesting	Oct-Dec	Roots harvested after two years at preflowering stage in October or late fruiting stage in November-December, The crop can, however, be allowed to stand in the field for three year
Post-harvest management	Dec- Jan	The hard roots cut into small pieces and dried in the shade, The dried root pieces packed in gunny bags, Stored in cool and dry place

AGRO-TECHNIQUE OF *Rubia cordifolia*

The Plants mainly propagated in nursery through seeds obtained from ripen fruits during December-January. Propagation can also be achieved by two-node root cuttings. The loamy soil rich in humus is preferable for *R. cordifolia*. Proper manuring and regular irrigation should be done. Germination starts after 20 days of seed sowing. Seedlings / rooted cuttings with two to three leaves transplanted in properly ploughed and harrowed field. Crop matures after one year. Flowering starts in August-September and seeds mature in October-November. Harvesting of roots can be done after two years. The detailed cultivation operations and field activity is provided in Table.1.

Table. 2. Cost- benefit analysis of *R. cordifolia*

Crop	Part used	Altitude	Cultivation through	Plants / Nali*	Average production / Nali	Cultivation cost Rs. / Nali	Net Benefit Rs. / Nali
Rubia cordifolia (Manjistha)	Roots	800 -2800	Seeds, cutting	2500	62kg dried roots	1000	3720

Source: State Medicinal Plants Board; (1 Nali=0.02 hectares)*

YIELD AND COST – BENEFIT ANALYSIS

The marketable part of *R. cordifolia* is its roots which are sold for 229-374Rs/Kg. (http://www.echarak.in/). The cultivation of R. cordifolia provides a net benefit of 3720Rs./Nali. The cost and net benefit associated with cultivation of *R. cordifolia* depicted in Table 2.

DISCUSSION AND CONCLUSION

State Medicinal Plants Board (SMPB), Uttarakhand is established as nodal agency for overall co-ordination and implementation activities in medicinal & aromatic plants (MAPs) sector. Presently, two separate units namely Herbal Research & Development Institute (HRDI), Mandal, Gopeshwar and Centre for Aromatic Plants (CAP) Selaqui, Dehradun are working for development of MAPs sector in Uttarakhand. The major functions of these institutes are promoting cultivation and ex-situ/ in-situ conservation of MAPs, development of cultivation protocols, provide trainings to farmers, researchers and entrepreneurs, registration of cultivators, provide subsidy for cultivation, issue transit pass through HRDI, selling of cultivated produce at herbal mandis, establishment of buy–back system with manufacturer companies and trader directly with cultivators. In the present scenario of COVID-19 pandemic, many people migrated back to their native villages. Due to this reverse migration, the state is facing challenges for livelihood security of the migrant returnees. The traditional agricultural system in Uttarakhand is not able to fulfill the daily food and economic requirement due to the various constraints such as small and fragmented land holding, unproductive land use, lack of irrigation facilities etc. and the net benefit is very low as compared to the cultivation cost. Hence, cultivation of MAPs could be adopted as an alternative source of income generation. The diverse agro-geo climatic conditions are most suitable for MAPs cultivation in Uttarakhand that houses more than 179 unique and high value MAPs (https://www.investuttarakhand.com/). Cultivation of MAPs will not only create livelihood opportunity in the region but also reduce the pressure on the natural habitat of the species. *Rubia cordifolia* is one of the prioritized species by SMPB, Uttarakhand and is a very adaptable plant which can grow in a range of climatic conditions, supports a wide altitudinal distribution and soil types. So, this species could be selected as a suitable medicinal crop for cultivation in Uttarakhand. Its cultivation provides a positive net benefit (Table1). Besides, SNPB also provides 50% subsidy along with quality planting material (seeds) to boost up its cultivation. Therefore, it is important to select the target groups and provide necessary facilities, awareness and training for cultivation of *R. cordifolia*. Specially the migrant returnees who are facing challenges in livelihood generation due to COVID-19 pandemic needs to be sensitized towards the cultivation of the selected species and its significance to improve economic potential. Successful cultivation of this crop will not only generate income but also conserve biodiversity of the region.

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TRADITIONAL ECOLOGICAL KNOWLEDGE AND PRACTICES OF ECO-RESTORATION BY DIFFERENT COMMUNITIES IN ARUNACHAL PRADESH, INDIA

Pritom Saikia, Kesar Chand* and Mahendra Singh Lodhi

G.B. Pant National Institute of Himalayan Environment, North East Regional Centre, Itanagar, Arunachal Pradesh, India

***Correspondence:** kesar1982@gmail.com

ABSTRACT

Traditional knowledge of the indigenous communities plays a critical role in conserving the biodiversity and also maintain the ecosystem services. The present study was conducted using available literature to understand and compare the traditional ecological knowledge of 8 indigenous communities of Arunachal Pradesh. The study recognised the traditional knowledge, creativity and innovativeness of the indigenous people who have been practicing it for generations. The study identified the unique ways of biodiversity conservation, natural resource management and eco-restoration through traditional knowledge.

Keywords: Traditional knowledge, Biodiversity conservation, Communities, Management

INTRODUCTION

As human population continue to grow and demand for food, land and natural resources increases, the extent of the world's forest continue to decline. The increasing pressure on forests has gradually led to losses of biodiversity and forest resources, which results in decrease in capacity of forest to provide the environmental goods and services that underpin food security and other basic human needs (Parrotta *et al.*, 2016). In India, millions of people are directly or indirectly associated with forests and live nearby or within forest areas (Kothari *et al.*, 1989). But, the increasing population and demand for forest resources can lead to forest loss and ecological degradation (Ganesan 1993; Maikhuri *et al.*, 2001; Arjunan *et al.*, 2005) that contribute to climate change (Van der Werf *et al.*, 2009), reduce soil fertility, loss of flora and fauna (Foley *et al.*, 2007; Dudley *et al.*, 2014).

Measures have been taken to reduce dependency levels of the local communities upon forests by creating alternative livelihoods (Badola 1999) and biodiversity plays a major roll in it as it has social, ecological and economic significance at local as well as global level (Nayak *et al.*, 2020). Many scientific and traditional knowledge are being utilized for forest conservation. In this paper we have discussed mainly about the traditional ecological knowledge (TEK) practices and systems by the different communities in ensuring the sustainable utilisation and conservation of ecosystem services. International bodies have accepted and highlighted the importance of TEK practices in the protection of biological diversity (Sinthumule *et al.*, 2020). The indigenous TEK practices havecontributed to forest conservation and management in various parts of the world. The aim of this study is to identify and describe the key indigenous practices used by the different communities of Arunachal Pradesh in forest conservation and eco-restoration.

METHODOLOGY

The current research is based on the reports of original investigations as well as reviews. The literatures were reviewed mainly from journals and google scholar, and Research gate. All the relevant publications were sorted and stored to facilitate future accessibility. The conclusions are based on author's interpretation of the reviewed articles(Table. 1).

Table 1. List and reference of the communities

Communities	Geographical Region	Reference
Adi	Upper Siang, Siang, West Siang, Lower Dibang Valley, Lohit, Shi Yomi and Changlang	Singh *et al.*, 2018
Aka	West Kameng	Nimachow *et al.*, 2011
Apatani	Ziro Lower Subansiri	Tangjang *et al.*, 2016; Patnaik 2020
Nyishi	Lower Subansiri, Papum Pare and East Kameng	Deb *et al.*, 2009; Srivastava *et al.*, 2010; Kuldip *et al.*, 2009
Lisu	Changlang	Sarmah *et al.*, 2008
Galo	West Siang, Leparada and Lower Siang	Bora *et al.*, 2013
Khampti	Namsai and Changlang	Das *et al.*, 2006
Monpa	Tawang, Dirang and Kalaktang.	Saha *et al.*, 2007

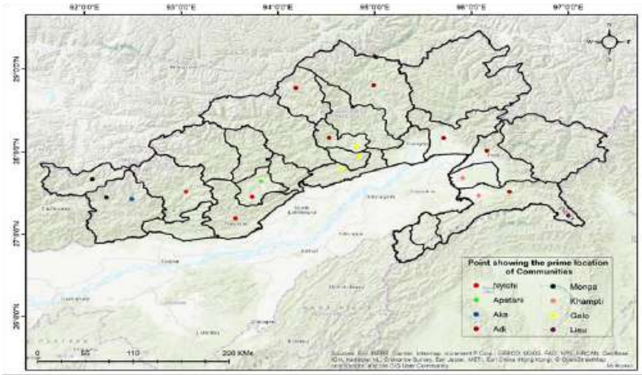

Fig. 1. Map of Arunachal Pradesh showing the locations of the studied communities

Based on literature survey some important TEK systems of the communities in Arunachal Pradesh is discussed.

STUDY SITE

The study site is the state of Arunachal Pradesh in the easternmost part of India. The state lies between 26.28°N and 29.30°N latitude and 91.20°E and 97.30°E longitude and has an area of 83,743km^2. Arunachal Pradesh has among the highest diversity of mammals and birds in India. There are around 750 species of bird and more than 200 species of mammals in the state. The state is mainly inhabited by the indigenous communities or tribes who are known for their traditional and cultural practices. In the present study we have listed and discussed the TEK practices of the eight major communities –Adi, Aka, Apatani, Nyishi, Lisu, Galo, Khampti, and Monpa.

RESULT AND DISCUSSIONS

In this section we have discussed the different TEK practices of the communities for ecological conservation. The traditional ecological knowledge of each communities has been discussed in detail.

The Adi Community

The Adi people is one of the major tribe in the Indian state of Arunachal Pradesh. They are mostly located in Upper Siang, Siang, West Siang, Lower Dibang Valley, Lohit, Shi Yomi and Changlang districts. The Adi tribe depends mainly on local natural resources for sustaining their livelihood that plays a critical role in shaping and managing ecosystem functions and services. They have much knowledge of the social and ecological systems, which makes them climate resilient and adapt sustainable agricultural practices and forest management strategies. Adi community classifies the community forestlands into various categories based on use, management, and accessibility. Again on the basis of landscape and topography, forests are further classified into 'diteyomrang' (forest in mountainous areas) and 'mootamyomrang' (forest on the plains). Adi community further distinguishes the forests into healthy and productive forests from the less productive ones so that suitable management practices are employed to safeguard the forests. The Adi community also practices shifting cultivation in regpi (jhum lands). The head priest along with village kebang (socio-political indigenous institution) of the village decides in selecting the regpi and the priest is also responsible for prayers and rituals to ensure good forest growth and bumper harvests. The jhum practices are only allowed by the Kebang members only after proper discussions on factors like the distance from residence, economic status of the farmers, family type, and quality of land and forest and family members. The village Kebang led by the GaonBura ensures democratic, inclusive and informed decision-making; resolve disputes; and sustain forest resources. Morang forests (forests with higher subsistence values) are demarcated by village Kebang by using natural ecological edges and stones to avoid conflicts. The norms set by the village Kebang and overseen by the GaonBura helps in conservation of forest diversity and also of the rivers and streams. Womens of the Adi community also plays an important role in conserving local biodiversity through local institutions like rilam and reglep. The Adis also celebrate various festivals for sustainable forest and other natural resources management (Singh *et al*., 2018). Festivals such as solung, kiiruk, koson, and folk dances called ponung and tapu are also interlinked with the use values and conservation of forest resources.

The Aka Community

Tke Aka community is a small group of people in West Kameng district of Arunachal Pradesh. The Akas have their own indigenous knowledge system useful in the conservation of forest resources. To conserve the biodiversity the Akas do not extract numerous species of plants and many animals are also not killed and eaten. They even spare immature and pregnant animals in the forest. Only required parts of the plants are collected and small saplings are not destroyed. These people have developed an eco-friendly relation with the surrounding forest ecosystem.Akas, while making use of plants always think of assured future supply. The traditional faiths and beliefs of the Akas help in conservation of forest resources. The Akas also have sacred groves which they call as NowuHusuYiew. It means the forestland and lakes which are believed to be sacred and have vital significance to the mankind. It is believed that any sort of interference to such grove would lead to the death of the person involved. They also believe in the presence of super natural powers, urbo or urbam in such groves(Tangjang *et al*., 2016; Patnaik 2020). Visiting and extracting of any kind of material from such groves are strictly prohibited. The Akas also have Sacred Mountains, where extraction of forest materials, collection of stones, hunting, etc. from the mountains are strictly prohibited (Nimachow *et al.*, 2009). The belief in sacred forest and sacred mountains have directly helped in conservation of forest resources in the area.

The Apatani Community

The Apatani community is an ethnic group belonging to the Tibeto-Mongoloid stock and confined to the Apatani group of villages in the Ziro valley of Lower Subansiri district in Arunachal Pradesh. The forests in the Ziro valley is protected and managed by the village administration and therefore could be termed as 'sacred groves'. The Apatani community is characterized by their unique land-use practice, rich traditional ecological knowledge of resource management and conservation acquired over ages through informal experimental methods. Their unique biodiversity conservation knowledge and practices makes them one of the most advanced tribal communities. The traditional farmers are the key players in conservation of biodiversity, particularly the agro-biodiversity and protection of local knowledge systems through traditional institutions. The Apatanis have eight informal group of farmers assigned with definite duties that contributes towards the sustainable preservation and management of the agro-system. The Apatanis is also rich in ethno-medicinal knowledge system. Previous literature has listed about 158 species of plants in the Ziro valley used for its medicinal values. The Apatanis also practice plantations of Bamboo+Pine in the villages where they have been living since generations. The Bamboo+Pine agroforestry traditions represent a fine tuning of knowledge concerning the interaction of plants and their environment and involve interactions between agricultural and social systemsas well. These afforestation technique is practiced by the community since generations. Agriculture by the Apatani has multiple functions integrating social, cultural, ecological, environmental, occupational aspects as well as a place of solace and attraction for the tourists. The traditional paddy-cum-fish cultivation showcases the rich TEK of the Apatanis as well as the rich cultural heritage (Saikia *et al.*, 2021). The Apatanis also celebrate two major festivals–Dree is celebrated with prayers for a bumper harvest and prosperity of all humankind and Myoko is celebrated to celebrate friendship.

Nyishi Community

The Nyishis are one of the major tribes of Arunachal Pradesh scattered over the mountainous terrain of Lower Subansiri, Papum Pare and East Kameng districts. The Nysihis have tremendous traditional knowledge to use the natural resources. The community is mainly engaged with agriculture and they have customary laws that accommodate socio-cultural patterns, land tenure system and cultivation practices. A large number of different traditional crops (trees, shrubs and herbs) are grown in the agro-forestry systems practiced by the Nyishi community. The Nyishis also has extensive knowledge on ethno medicinal plant species. They have recorded about 80 species of such plants. Based on traditional ecological knowledge, Nyishis have classified the soil into 5 major categories viz. Uttola, Kanla, Kannam, Lengching and Ponglung. Nyishis have a significant knowledge on understanding the relationship between soil characteristic and topography (Deb *et al.*, 2008; Srivastava *et al.,* 2008; Kuldip *et al.*, 2009). Soils located on higher altitude have different variety of crops than those at lower elevation.

The Lishu Community

The Lisu community are dominant in the southeastern periphery in Changlangdistrict, Arunachal Pradesh. Agriculture is the primary occupation of the Lisus. Traditionally the Lisus have developed good knowledge of agricultural as well as horticultural crop production. They have learnt grafting technique on the horticultural crops for early production of fruits. The Lisu community collect medicinal plants from forests and also cultivatesthem in the abandoned jhum land (Sarmah *et al.*, 2008). They also know the art of tea cultivation in the fallow lands and prepares tea traditionally. For irrigation, they divert the hill streams through forests which carries a lot of nutrients and organic matter in it to the agricultural fields. The force from the flow of water is used to run the indigenous rice mills and the same water is used for domestic needs. In difficult terrains, they make overhead bamboo pipelines to carry water from the source to the homes. The Lisu community that is still separated from the modern world have developed sufficient traditional knowledge in agriculture, water management and biological conservation. They have their own fishing and hunting gears, which they use very effectively. They have also built hanging bridges completely made of wood, bamboo and canes. They also practiced carving messages on stone slabs or on tree boles for communication.

The Galo Community

The Galo community are descendants of Abotani and speak Galo language. They primarily inhabit West Siang, Leparada and Lower Siang districts of Arunachal Pradesh. Bosfrontalis (Mithun) has deep importance in Galotribe's customary, cultural and social life. The traditional marriage system as well many ritual activites cannot be performed without Mithun. To rear Mithun the Galo community has developed a community sponsored, community based, welfare oriented forest area called as 'Lura'. It is a vast forest area that is well fenced from all the sides for keeping mithuns. The Luras are maintained in such a way that sufficient water is available for Mithuns through streams. The Galo people have unique traditional rights over land, water and forests within their jurisdiction and have control over the natural resources (Bora *et al.*, 2013). They do not have written land records but they traditionally demarcate their land boundary through streams, hills or other natural features according to their villages and clans. The Galo people also keep interest in afforestation activities for conserving natural flora and fauna and carry out special conservation programmes. There is also a tradition of imposing fines on violation of rules in conserving natural resources and biodiversity. The farmers of Galo community control pests and diseases through eco-friendly practices. They uses leaves from Pummlo as insecticides and pesticides.

The Khampti Community

The Khampti community is one of the major tribe of Arunachal Pradesh inhabited mainly in the Namsai and Changlang districts and some parts of Assam. Among all the tribes in the state, the Khamptis are known for their knowledge in the field of herbal medicine. They have learnt the knowledge of medicinal plants through Buddhist literature from one generation to another together with various magical religious beliefs. The Khamptis uses various type of plants and its materials as medicines. They use five plants for curing malaria and fever, four types of plants in bone fracture, three plants in Anemia, two plants each in snakebite, cancer, reproductive health and rabies, and one plant each in tuberculosis, diabetis, jaundice (Das *et al*., 2006). Unlike other tribes the Khampti people do not practice shifting cultivation and are mostly engaged with agricultural activities. They conserve bio-resources in their natural habitat through clean forest management.

The Monpas

The Monpas in Arunachal Pradesh are inhabited in and around Tawang, Dirang and Kalaktang. The Monpas have prioritized the use of traditional knowledge and practices for the management of natural resources like water, soil and forest. For agricultural purpose gravitational force is used in irrigation to divert the water to the agricultural fields. This method of irrigation minimizes soil erosion and checks surface runoff. The Monpas also traps the stream water from the surrounding hills and channels it by a network of primary, secondary and tertiary channels (Saha *et al*., 2007). The people managed water in such a way that it always kept water layer on the soil at the permissible depths, which is one of the most important aspect of scientific water management. The Monpas also has Ghatta System (water mills) which uses the force of water for various local uses such as grinding of grains, alarm device for landslides and flash floods and also for purification of water. The Monpas also manage the forest areas by using age-old traditional methods. The forest areas are allotted to each household by the village headman. There are local customary laws for the use of forest products like medicinal plants, dye yielding plants and fuel wood etc. The Monpa community also have sacred landscapes called as "Phu" where people never practiced any hunting or felling operations. They believe it as the abode of local deities whom they have been worshipping.

CONCLUSION

In this article we have reviewed the traditional ecological knowledge of the eight main tribes of Arunachal Pradesh viz. Adi, Aka, Apatani, Nysihi, Lisu, Galo, Khampti, and Monpa that contributes to the eco-restoration of the ecosystem. It is to be noted that all the tribes are rich in TEK and have their own unique way of nature conservation and utilization of natural resources. All the tribes have learnt and developed their unique TEK from their ancestors as well as from various experiences and livelihood needs. It is to be noted gaonbura (headman or head of the village) has an important role especially in the Galo community. Along with TEK they follow their gaonbura strictly in use of natural resources. In this way the jhum cultivation is controlled among the Adi community. The Aka community is unique from the other communities. Although they are a small group of people they have managed in conserving forests and other natural resources through sacred forests and sacred mountains. They only use the required resources and conserve the rest. The Apatani community of Arunachal Pradesh is well known for their traditional way of paddy-cum-fish cultivation. The sustainable agriculture practice by the Apatani people uses natural methods for irrigation of paddy fields and also cultivates rice along fish organically in the beautiful Ziro valley. Apart from it the Apatanis also practices plantations of Bamboo+Pine to conserve their forests. The Nyishi community also have valuable TEK practices and utilises natural resources wisely. They have customary laws in natural resource utilization and also have extensive knowledge on ethno medicines. The Lisu community resides in the most remote part of the country. Although they are separated from the modern world they traditionally practice grafting and have built bridges, weapons, irrigation systems with their traditional knowledge. The Galo community have unique traditional rights over land, water and forests. They have strict rules and also impose fines on violating those rules. The Khamptis of Arunachal Pradesh are very rich in medicinal plants. They have developed medicines for many diseases through their traditional knowledge. The Monpa community are also rich in TEK practices anduses the force produced by the flow of water forgrinding the food grains and also have developed techniques for water purification and flood warning system through the same force of water.

All the communities have their own unique TEK practices and natural resource management practices. Although these TEK are documented in various publications still requires attention for continuation by the next generations. The modern development technologies are making the TEK fade away gradually. For example the use of chemicals in agriculture have started in some areas instead of organic fertilizers. The TEK of all the communities must be documented and preserved for a sustainable future.

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SPRINGSHED RESTORATION IN THE MID-HILLS OF THE HIMALAYA: A PARTICIPATORY APPROACH FOR ADAPTATION TO CLIMATE CHANGE

Rajesh Joshi*, Mayank Joshi, Ninchhen Dolma Tamang and Moon Moon Das

G.B. Pant National Institute of Himalayan Environment, Sikkim Regional Centre, Pangthang, Sikkim, India

***Correspondence:** dr.rajeshjoshi@gmail.com

ABSTRACT

Spring water, emerging naturally from confined and unconfined aquifers, is the primary resource for sustenance of life in the Himalayan region. The subsistence of these natural sources is vulnerable to changing climate and various other natural and anthropogenic factors. The growing population in midhills of Himalaya is further escalating demands on these springs. The shared impacts of all these factors are realized in terms of drying up of large number of springs in this region and thus adversely affecting the life of dependent communities. In this article, we present effectiveness of integrated and participatory Spring-Shed Management (SSM) approach for augmenting the spring recharge at a pilot site in Uttarakhand which was extended to other parts of Himalaya by various researchers. The pilot level implementation of the approach in midhills of Uttarakhand shows that springshed can be restored effectively through SSM that can rejuvenate the drying springs leading to sustainable water resource management and adaptation to climate change.

INTRODUCTION

In Indian scenario, ground water forms a backbone of the country's water supply with nearly 85% of all rural water supplies are met from groundwater (The World Bank 2010). While, wells supply groundwater to large parts of rural India, the springs forms the main source of water supply to rural (and often to urban) population in the Himalayan region (Mahamuni and Kulkarni 2012) as a common source of local community. It is estimated that, more than 5 million springs support communities residing in mountain range from Nilgiri to the Himalaya in the country, and more than 40 million people of Himalayan region are dependent on natural spring water for fulfilling their domestic and livelihood needs (Rawat 2017, 2018). The study by Mahamuni and Kulkarni (2012) reported nearly 8,000 villages in Indian Himalaya under acute water shortages due to drying up of springs. In the Kumaun region of Uttarakhand, 75% of the springs have gone dry with an average decline of ~40% of discharge during 1951 to 1986 primarily due to changes in land-use patterns and vegetation (Valdiya and Bartarya 1989).

Changing land use, hydrological patterns, and climate is making adverse impacts on springs and ground water storage, and thus directly affecting the water security in the Himalayas. Spring shed are drying up and being degraded due to increasing water demand, urbanization, demography, environmental degradation and climate change (Buono *et al*., 2019; Tambe *et al*., 2013). Pressure on springs in Himalaya has increased manifold due to growing human population and the steep rise in tourist influx in the midhills of Himalayan region. The drying of springs in the mountains also have larger impacts on women and children by enhancing drudgery, health issues, poor livelihood options, and reduction in consumption of water for domestic use which forced communities to take adaption measures in some areas (Tambe *et al*., 2012; Joshi *et al*., 2016; Unpubl. Report). Research based evidences shows that the discharge rate and water quality of springs is declining in several parts of the country (Vashisht 2013). The impacts of rapid climate change is greatly felt over the Himalaya with winters becoming increasingly warmer and drier (Seetharaman 2008), reduction in the temporal spread of rainfall, increase in the intensity of rainfall, with a marked decline in winter rain (Tambe *et al*., 2011). The subtropical belt (at altitude <1000m) experiences very less rainfall for the 6 months (October to March), resulting in frequent and ascending forest fires, and drying of ground water sources (Chaudhary *et al*., 2011). Drying up of springs and increasing demand of water supply has raised a great concern for the sustainability of the natural resource and the livelihoods in the Himalaya (Ranjan and Pandey 2021).

To address these issues, emphasis is being given towards augmentation of natural recharge of springs by applying both traditional and modern techniques. Some of these techniques have been employed for many years, ranging from simple check bunds in gullies to complex diversion and infiltration structures as well as injection wells; these efforts have made fewer impacts on ground. Therefore, innovative efforts are needed for restoration of spring-sheds for ensuring water security and ecosystem sustainability, particularly in the Himalayan region. This calls for effective integration of science-based approaches with the customary bio-engineering interventions, and building synergy amongst diverse stakeholders, including community and community-based organizations for addressing the water sacrcity. Realizing this, a systematic, integrated and collaborative approach 'Spring-Shed management (SSM)' was tested at a pilot site in Gorang valley (Uttarakhand) that helped in augmenting spring discharge significantly and restoration of spring-shed. The article also presents some good example of springshed restoration experiments in the mid-hills of Uttarakhand and Sikkim from the published literature to depict efficacy of the echo-hydrological approaches for spring augmentation.

MATERIAL AND METHODS

Study Site

The SSM approach was applied at a pilot scale in Gorang valley, Chandak-Aulaghat Watershed (CAW), in KSL part of India. The Gorang valley, between 80°09.00' to 80°11.00'E long. and 29°36.00' to 29°37.00'N lat., has gentle sloping hills at its periphery and forms vast undulating plain composed of unconsolidated debris at its centre. Total population of the Gorang valley, in 17 villages/ toks, is 4756 (806 households) with an average household size of six. Additionally, results from other studies in Uttarakhand and Sikkim are also presented as an example to discuss the effectiveness of the approach for spring shed restoration.

Spring-Shed Management (SSM)

The Spring-Shed Management (SSM) approach refers to a systematic practice of identifying springs and their recharge zones by characterizing them based on their types, discharge trends, seasonality, and structural control. The approach broadly considers two major aspects, (i) using knowledge of hydrogeology for understanding dynamics of springs, and (ii) adopting participatory approach for implementation and management. This approach helps in identifying the nature of underlying rocks and their behavior such as permeability, porosity, and structural aspects (i.e. strike and dip) so as to increase the understanding about types of springs and the aquifers feeding them. Moreover, the approach also considers the groundwater hydrodynamics, which helps identifying the recharge area and forms the basis for laying out the precise interventions required for the preparation and implementation of SSM plans. The eight-step methodology of SSM, devised under Kailash Sacred Landscape Conservation and Development Initiative (ICIMOD 2016) through expert consultation, is mentioned in Box 1.

Box 1.
Eight Step Approach of SSM

i. Comprehensive mapping of springs and Spring-Sheds
ii. Setting up a data monitoring systems
iii. Understanding social and governance aspect
iv. Hydro-geological mapping
v. Creating conceptual hydro-geological layout of spring shed
vi. Classification of spring types, aquifers and recharge areas
vii. Developing spring-shed management protocols for implementation
viii. Monitoring the impacts of spring revival

Further, to study water balance, rain gauges were installed at four different locations covering different elevation range and aspects of the valley (Fig. 1) in collaboration with the local partner and identified resource persons from the village community.

Fig. 1. (a) Automatic raingauge installed within study area, (b) Hands-on training of resource person from community, (c) Radar based water level sensor installed in the study area, (d) Stream discharge measurement using flow probe

RESULTS AND DISCUSSION

Based on extensive surveys and community consultations 53 springs (27 Naula and 26 Dhara) were georeferenced and mapped in the study area. Major focus of the surveys was: (i) locating all the natural springs following interaction with villagers; (ii) georeferencing each spring with the help of hand held GPS, and (iii) documenting the status/nature (seasonal/ perennial) of each spring. Most of the springs were located within the elevation range of 1428-1826amsl whose discharge greatly decline during lean season. Out of the mapped springs, 18 springs with high dependency (S-D ratio <1) were selected for long term monitoring and continuous observations on spring discharge were taken on fortnightly basis. Study revealed that spring water in Gorang Valley is mostly consumed for domestic purpose (49%), followed by livestock sector (39%) and drinking (12%) and it is mostly collected by the women (78%).

The hydro geological investigation of the study area showed that the dominating rock types in the valley are dolomitic limestone, talc, calc-silicate, magnesite, slate, quartzite and metavolcanics that correspond to the Gangolihat Dolomite, Sor Slate and Berinag formations. The rocks were highly sheared, shattered, weathered and fractured corresponding to the formation of innumerable planes of secondary porosity both in quartzite-metavolcanics and calc-silicate/dolomitic limestone. The entire valley is covered by quaternary debris, rock falls, landslide slope wash material that corresponds to both porosity and permeability. The secondary porosity seems to exceed the primary porosity in the valley. The geological mapping showed that the joint planes were mostly dipping towards the valley slope indicating a dominant control of secondary porosity in the transport of ground water and formation of spring in the valley. The results indicates that the prevailing structural aspects (i.e. strike and dip) making (i) a pathway for groundwater movement towards the valley, and (ii) favorable condition for spring recharge in the area.

In Digtoli and Nakina villages of the valley, 5 springs (namely; Shivalaya, Naunipani, Panigair, Padpani and Bajni) were identified for implementation of SSM. Hydro-geological analysis suggested that the majority of locally confined aquifers were controlled by fractures. Most of the springs occur at the intersection of aquifer with topography as depressions or fractures at the escarpment slope. It was found that the dominant rock types, quartzite, dolomitic limestone, slate and phyllite showed varying degree of deformation.

Further, the strike of the rocks was N 33° (NW-SE) dipping towards valley (N60° -NE) at angles varying from 9° to 65° from the horizontal. The ground water infiltrate through fractured quartzite, slate and phyllite. At places, where unconsolidated debris is present, groundwater movement is also controlled by the topography. Hence, recharge zone for the individual spring is controlled by local geology and topography. Based on the hydrogeology of the study area, different kind of recharge structures were recommended as per varying slopes (Table 1).

Table 1. Recommended design of the trenches on the sloping lands

Slope	Size			Type
Degrees	Length (m)	Width (m)	Depth (m)	
less than 20	5.0	2.0	1.0	Ponds
20-30	2.0	1.0	0.6	Trenches
30-40	2.0	0.6	0.6	Trenches, Check walls
40-50	2.0	0.6	0.45	Trenches, Check walls

Based on the primary understating of hydrogeology, plans for intervention and implementation of SSM were prepared in consultation with the community and various line departments. Community engagement in implementation of SSM was ensured from the beginning for which several meetings, training and field workshops were organized. Following the consultation with the stakeholders, an effective convergence with various government departments and the community based organizations (CBOs) was achieved. Based on hydro-geological mapping, interventions for implementation of SSM at pilot site (i.e. in Digtoli and Nakina villages) of the valley were made (Fig. 2).

Fig. 2. Photographs representing interventions in Digtoli and Nakina villages of Gorang valley

After implementation of the SSM based spring recharge activities in 2015, continuous monitoring of discharge of identified springs was carried out. For the identified springs, the discharge data for pre-implementation period in 2015 and post implementation period 2016-17 was analyzed and compared. The preliminary analyses indicated that post intervention the discharge of selected springs increased by 16-24% during different seasons. During the monsoon season (June-September) discharge of the selected spring increased by 24% while during post monsoon season (October-November) it was increased by 20% from 2015. Similarly, 19% increase in winter season (December-February) discharge of selected springs in the valley was observed. During the pre-monsoon season (March-May), which coincides with the summer season having highest water scarcity, the discharge was found to be increased by 16% (Fig. 3).

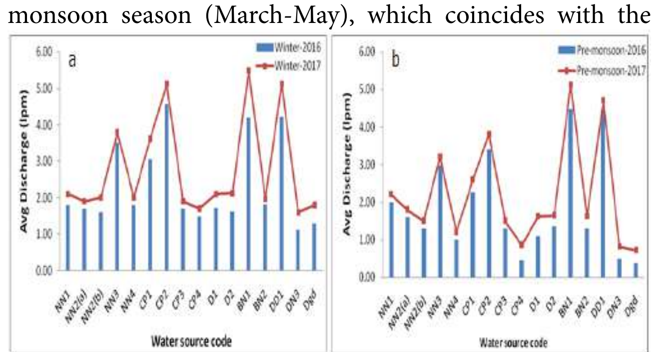

Fig. 3. Change in discharge pattern for winter and pre-monsoon season of selected spring after implementation of SSM

The effectiveness of the eco-technological approaches for artificial recharge of aquifer was also presented by Negi and Joshi (2002) in their study conducted in Garhwal region of Uttarakhand with a pioneering concept of "spring sanctuary development". In their study, the recharge zone of a spring, about 18.5 ha in size, was treated with engineering, vegetative, and social measures, which resulted in doubling of spring discharge during the dry season, from 1055 L/d in 1995 to 2153 L/d in 2000. During the hydrological year 1994–1995 annual discharge amounted to 7.0% of the rainfall which increased to 12.5% in the 1999–2000 hydrological year.

Likewise, in Sikkim, Tambe *et al*., (2012) applied the spring shed development approach to revive 5 springs in the South and West districts of the State using rainwater harvesting and geohydrology techniques. These springs were undertaken by the Rural Management and Development Department (RMDD), Government of Sikkim under its Dhara Vikas program for ground level implementation. The results from this initiative showed that the artificial recharge activity resulted in annual groundwater recharge of 900 million cub. litres. Further 5 lakes, namely, Doling, Deythang, Nagi, Karthok, and Datum were restored under this initiative. The action research on SSM yielded encouraging results with the lean period discharge increasing significantly from 4.4 to 14.4 L/min in 2010-2011 (Table 2).

Table 2. Impact of spring shed development on discharge of selected springs in Sikkim.

		Artificial Recharge taken up		Lean Period rainfall (cm)		Lean period spring discharge(l/m)	
Spring Name	Elevation(m)	Area (ha)	Volume (m^3)	Mar-May (2010)	Mar-May (2011)	Mar-May (2010)	Mar-May (2011)
Malagiri Dhara	975	13	841	15.1	11.3	7	20
Aitbarey Dhara	1600	5	454	41.7	35.3	3	11
Dokung Dhara	1200	7	349	41.7	35.3	4	17
Nunthaley Dhara	1600	5	152	41.7	35.3	3	11
Kharkharey Dhara	1560	5	222	41.7	35.3	2	8

Source: Tambe et al., (2012)

CONCLUSION

The effective augmentation of spring recharge and restoration of spring shed necessitates a good understanding of hydrogeology and participatory approach. For this purpose, a scientifically validated and integrated approach is required to identify the catchment area of a spring or ‘Springshed’. Once the springshed is identified, the goals of springshed restoration are similar to those of watershed management which include (i) reduce soil erosion, increase vegetation cover and soil organic matter, (ii) increase natural infiltration of water into the soil and recharge of the aquifer, (iii) protect the area to allow ecological restoration and prevent pollution of the groundwater and surface runoff by maintaining cleanliness in the catchment area, and (iv) augment natural infiltration and recharge through best practices. One of the grave impacts of climate change is observed across most of the middle Himalayan region in the form of significant decrease in the temporal spread of rainfall, increase in erratic rainfall events, and a noticeable decline in winter rainfall. These changes have resulted in drying of springs, which together with the increasing demand of water supply has resulted into acute water shortage in many villages, particularly during the lean season, and thus has raised a great concern for the sustainability of the resource and the livelihoods in Himalaya. Most often reduced rainfall, its uneven spread and reduced infiltration are considered as the main factors for the decline in spring discharge. However, the spring discharge is mainly governed by an aquifer, which stores and discharges the groundwater to these springs. Therefore, without a proper understanding of aquifers, any study of springshed restoration remains incomplete. Study of springs, with a strong hydro geological context is especially relevant to the conservation, protection and land-treatment measures in order to adapt to various perturbations imposed by the overarching climate change. The present study describes the efficacy of integrated and participatory Spring-Shed Management (SSM) approach for augmenting the spring recharge in midhills of the Himalayan region. The pilot level implementation of the SSM showed that SSM approach, if applied in an integrated and participatory manner, could effectively restore the springshed and help in rejuvenating the drying springs leading to sustainable water resource management and adaptation to climate change.

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SPRING ECOSYSTEM MAPPING FOR ITS RESTORATION AND MANAGEMENT USING GIS BASED ANALYTICAL HIERARCHICAL PROCESS (AHP) TECHNIQUE THROUGH MULTI-CRITERIA EVALUATION

Ashutosh Tiwari*, Akshayi AS and Kireet Kumar

Govind Ballabh Pant National Institute of Himalayan Environment (GBP-NIHE), Kosi-Katarmal, Almora, Uttarakhand, India

***Correspondence:** ashus_rhythm@yahoo.com

ABSTRACT

In Indian Himalayas, large population depends on springs for their domestic and agricultural water demands. As per the recent report of NITI Aayog, approximately 50% of the mountain springs in the Indian Himalayan region (IHR), are drying up and about 60 percent of the local people depend on springs for meeting their water requirements (NITI Aayog 2018). Spring water plays a vital role in the ecosystem conditioning of the region and offers variety of ecosystem services. However, springs are getting deteriorated and vulnerable due to a lack of proper assessment and management. Not only humans, spring water plays a vital role in the ecosystem conditioning of the region and offers variety of ecosystem services. However, to assess the role of spring water on the ecosystem, it is important to understand the extent and conditions of its linked biotic and abiotic parameters. For the protection and restoration of the springs ecosystem, it is essential to initially inventorize the distribution of springs cluster, derive its boundary and assess the health of the ecosystem. The spring ecosystem inventory protocol define the mechanism to collect the in-situ spring distribution data and gives information regarding the springs ecosystem extent based on multi-criteria evaluation after collecting the baseline data such as elevation profile, micro watershed, LULC, geology, etc. Once the spring ecosystem boundary is obtained, the health indicators can be analysed for adopting measures towards ecosystem restoration. This study uses space based inputs over the Geographical Information Systems (GIS) platform to suggest the mechanism for deriving the approximate springs ecosystem boundary suing Multi-criteria evaluation (MCE) approach and further optimizing it using the Analytical Hierarchy Process (AHP) technique.

Keywords: Spring, IHR, Springs ecosystem, Ecosystem boundary, Ecosystem restoration, MCE, AHP

INTRODUCTION

Springs are known to be a valuable resource of fresh water that plays a vital role in the survival of mid and high region inhabitant communities of IHR. People of this region are completely depending upon springs for their households, domestic, and even irrigation demands. Approximately 50% of the population in Kumaon Himalaya are dependent on spring water for their daily water requirements (Singh and Rawat 1985). Due to anthropogenic activity, changing rainfall patterns, and lack of proper monitoring and conservation, the discharge of the spring water is declining and even permanent springs are becoming seasonal (Meenu Rani *et al*., 2018). For mountain ecosystem accounting, the functioning of the springs ecosystem services plays a crucial role in ecological balancing. The assessment and management of the springs ecosystem is essential in maintaining healthy springs for ensuring water security in the Indian Himalayan Region. These effective management practices are important for spring ecosystem restoration. Spring clusters are entirely considered as an ecosystem in which the rainwater after series of surface and subsurface interactions reaches the aquifer as groundwater and again rushes out at the surface of the Earth either at the land water interface or at the land atmosphere interface (Stevens *et al*., 2016). For spring revival, the appropriate unit is the springshed which is the unit of land from where the spring aquifer is recharged and then emerges at the discharge point, the spring. Unlike watersheds concepts, for the springshed it is very important to consider underlying geology, its structural characteristics and slope of such subsurface lithological formations (Gupta A and Kulkarni H 2018). The term springs ecosystem brings the concept of biological as well as physical factors to the readers. Conducting thorough inventory and monitoring on springs, and developing specific restoration goals are the strategies for implementing effective spring ecosystem restoration (Giardina M 2016; Meenu Rani *et al*., 2018). Further, Minnesota Spring Inventory guidelines also emphasize on creating the spring inventory of spatial distribution and also analysing its groundwater condition which may be subsequently used for restoration of springs towards the sustainability of ecological beings

This study elucidates the approach for approximating the spring ecosystem boundary and further optimizing the potential recharge zones effectively. The present study deals with the development of spring inventory protocol for identification of spring ecosystem through scientifically deriving the springs ecosystem boundary. The protocols will help to advance the spring's ecosystem management and ecological-restoration. The study gives an approach for delineation of springs ecosystem boundary by the techniques of approximations and optimizations using remote sensing and GIS on the basis of Physical and biological parameters such as topography (elevation and slope), Hydrological parameters (micro-watershed/sub-watershed and drainage density), physical characteristics (surface and sub-surface characteristics such as Land Use and Land Cover (LULC), soil, geomorphology, lithology and lineaments. The springs ecosystem boundary delineation helps in focusing on much smaller region for effective springs ecosystem restoration and management. Elevation vector datasets and micro-watersheds/sub watersheds boundary are used in the initial stages for approximately deriving the potential recharge zone for given spring clusters. The obtained potential recharge zone is further optimized (reduced) using the multi-criteria analysis following the weight based method in which this potential zone is categorized among the five regions of recharge potential capabilities which are: Very high, high, medium, low and very low. Multi-criteria approach is generally adopted over the GIS platform by utilizing geospatial layers for the delineation of potential recharge zones in the rocky aquifers in the mountain regions and has also been effectively applied in similar type of study in central Nepal (Pathak D and Shreshta SR 2016). The Analytical Hierarchical Process-based modelling has been done on suitable GIS platforms. The final ecosystem boundary for the cluster of springs is demarcated through the polygons of medium to very high recharge zones.

METHODOLOGY

Study area

The present study is based on the clusters of springs in the watersheds of the Lohaghat block of Champawat district. About 22 springs are taken under this cluster which lies in the Grampanchayat of Maandhunga, Bardarbunga, Nakotkholiya, Binda Tiwari, Dungri, and Gureli. Jakhjindi and Tunkandey. One of the springs of Maandhunga at the elevation of 1800m above MSL is the spring of the highest elevation in the entire cluster. The spring of the lowest elevation in the cluster is situated in the Jakhjindi panchayat at an elevation of 1169 m above MSL. The study area map is depicted in Fig. 1.

The springs lie in the Gumalikhet formation of the Almora group whose lithology comprises of Carbonaceous, phyllite, quartzite, and schist of Proterozoic age. The major lithology of the larger optimized area comprises Leucocratic granite, granodiorite, garnetiferous mica, chlorite schist, biotite schist, and quartzite. The land cover of the area is densely occupied by vegetation cover followed by barren land, built ups, and water bodies. The surface thickness is covered by excessively and well-drained loamy soils ranging from shallow to moderate depth.

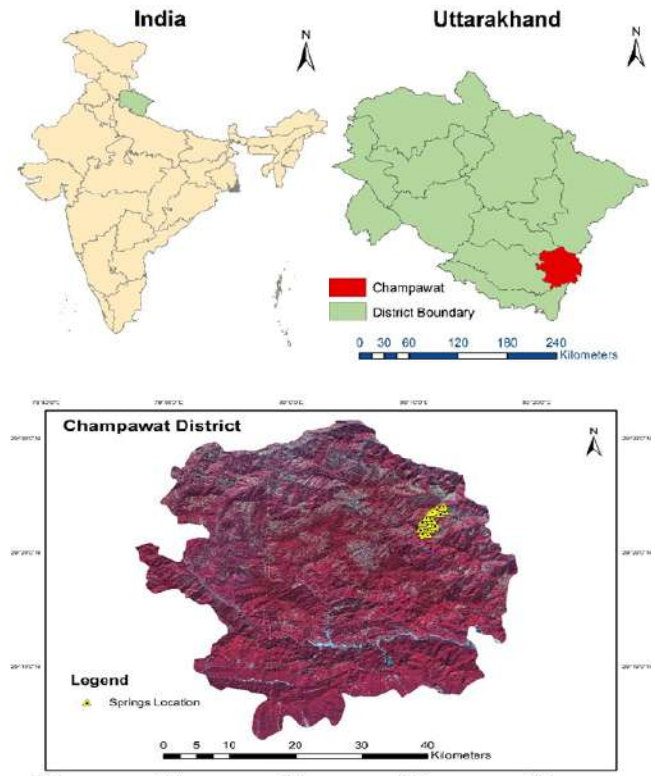

Fig. 1. Study area map

Datasets and Software Packages Used

The study is carried out using the number of datasets and tools to process the data which is described here. ALOS PALSAR DEM of 12.5m resolution is used for the extraction of elevation vector polygon, subwatersheds, and micro watersheds using Arc hydro tool in ArcGIS environment. It requires Digital Elevation Model (DEM) as an input to delineate micro and subwatersheds through flow direction, flow accumulation, stream definition, and stream segmentation analysis. The Sentinel 2A Multi-Spectral Image of 10m resolution is used under standard False Colour Composite (FCC) after basic image processing and enhancements in ERDAS Imagine software. This sentinel image is used for deriving the LULC map of the area. The LULC is derived in the platform of ERDAS Imagine using unsupervised classification with an accuracy of 86 %. The Geology and Geomorphology maps are updated using the sentinel MSI processed and enhanced in different band combinations. The lithology, geomorphology, and soil map is downloaded from web portal 'GSI Bhukosh' at a scale of 1: 50,000. The shapefiles are clipped within the required boundary and dissolved using the available tools in the Arc toolbox. The lineament map is prepared from the hill shade image extracted from DEM at different azimuth and range values. This is further validated with the topographic profile obtained from 3D analyst tools of Arc GIS

Spring Ecosystem Boundary Extraction

A fundamental aspect of effective management for the spring ecosystem lies in understanding the spring distribution that is achieved by maintaining an accurate and thorough inventory and assessment of springs under a management agency's given jurisdiction. (Stevens and Meretsky 2008). To delineate the springs ecosystem boundary, the techniques of approximation and optimization have been applied. Initially the approximate spring ecosystem boundary is extracted using topographic and hydrologic parameters. For deriving this first cut-out boundary (approximate boundary), the minimum elevation spring is identified from the cluster. Now the DEM data is used to identify the higher elevation region than the minimum spring elevation point. The cluster of DEM grids is dissolved to form the confined polygons only the connected polygon with the given spring cluster is considered for further study.

There can be two scenarios. In first case, the higher elevation region gets confined to a single polygon connected with the spring point thus giving the potential recharge zone directly. In another case when the higher elevation region does not get confined, in such cases the three neighbouring micro-watersheds have been used for the intersection with higher elevation region (polygon feature). This restricts the size of potential recharge zone. For this study, second scenario has been applied where the DEM polygon with higher value than the minimum spring elevation of 1169m has been taken into consideration. This unconfined polygon was restricted using intersection with DEM-derived neighbouring micro-watersheds of spring cluster. This boundary of the potential recharge zone gives the approximated springs ecosystem boundary. The details for delineation of springs ecosystem boundary used in this study has been depicted using the flowchart as shown in (Fig. 2).

For effective assessment and restoration, complex interactions of surface and subsurface parameters related to spring water should be brought into consideration. The surface soil cover and topography, geomorphic features, land covers, subsurface lithological and structural environments are important dependent factors in the recharge of the aquifer, complex, and lengthy groundwater flow paths, and discharge at the spring point. Thus, within this boundary, the multi-criteria evaluation along with the AHP has been applied to further optimize the ecosystem boundary extent. Geomorphology has a direct indication of potential aquifers and infiltration of surface water (Thapa *et al.*, 2017). High weightage value is given to geomorphology followed by lithology and lineament. Finally, this approach categorizes the approximated boundary into five classes viz. very high, high, medium, low, and very low recharge potential zones. For multi-criteria evaluation seven thematic layers have been used that are: Geomorphology, lithology, lineament density, slope, LULC, drainage density and soil. The criteria weights of each geospatial layer are obtained from the normalized pairwise comparison matrix generated based on intensity value specified by considering the relative importance among the parameters (Thomas L Saaty 2008). The relative weights are thus assigned to each layer using Analytical Hierarchical Process (AHP) method where different classes are assigned based on their relative contribution towards the recharge of groundwater.The polygons involved in medium to very high potentiality are considered to obtain the final springs optimized ecosystem boundary.

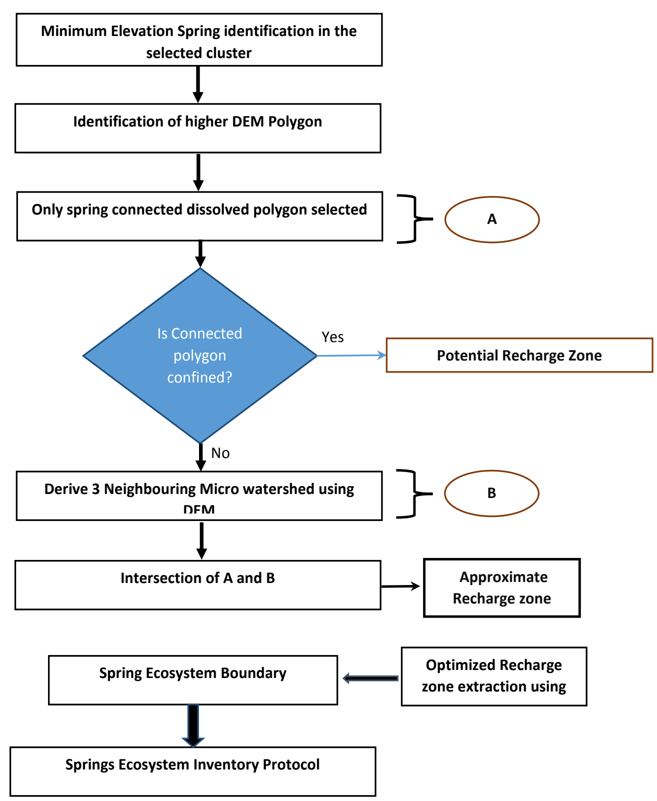

Fig. 2. Spring ecosystem boundary delineation methodology flowchart

RESULTS AND DISCUSSIONS

The spring ecosystem boundary is obtained by intersecting the higher elevation region with respect to minimum elevation spring point along with the neighbouring micro-watersheds. As shown in the Fig. 3., different polygons have been created but only the connected polygon with the spring cluster accounts for the recharge of the springs. Therefore, this single connected polygon has only been considered that holds the potential recharge zone area of the spring clusters and further gives the approximate springs ecosystem extent. This approximated spring ecosystem boundary has been used to derive and clip the seven thematic layers viz. geomorphology, lithology, lineament density, drainage density, LULC, soil, and slope as discussed earlier in the methodology for multi criteria evaluation. However, all of these seven layers may not contribute equally, for relative weight assignments to these layers, AHP has been used. Care was taken so as to keep the Consistency Ratio (CR) less than 0.1 (to ensure optimal relative weight assignments). The pair-wise square Matrix generated was calculated for its consistency, where a very good consistency was achieved with CR value to be 0.03, which is consistent.The region with high lineament density is having a high potential for recharging because these regions represent the zone of shear and fracture where the infiltration rates should be high. The high drainage density region has been again considered under very good groundwater potential region due to availability of more water. The derived slope map is divided into five classes with a five-degree interval and higher slope gradient contributes to lower recharge. The soil layer is considered to be of less influence because, in highly metamorphosed rock terrain, the soils formed by weathering activity would be unstable as it is denuded to low elevation regions due to highly varying slope gradient. Finally, within the approximated spring ecosystem boundary, the categorization of the region has been achieved based on their potential of recharge contribution to springs as shown in Fig. 3. The very high and high recharge potential zones can be furtherconsidered for implementing the water sanctuary concept towards the spring restoration through effective spring ecosystem management.

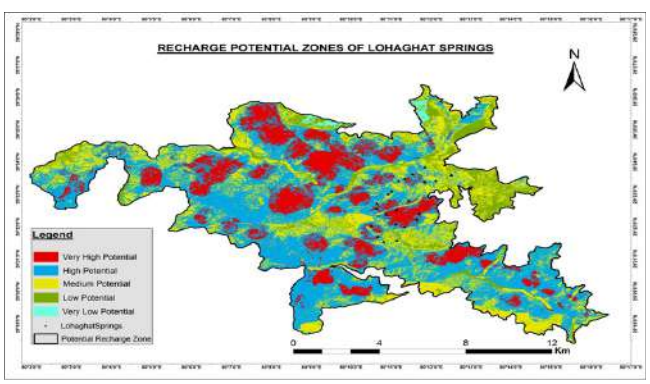

Fig. 3. Optimized springs ecosystem Boundary with groundwater recharge potentials

CONCLUSION

Ecosystem restoration and rehabilitation through springs ecosystem assessment and management involves investigation of springs and maintaining of proper records related to its inventory. Spring inventories are being fundamentally prepared using the information of its spatial distribution, its hydrology, Land use land cover, hydrogeology and other geophysical characteristics. Spring inventory is crucial for analysing the trends of temporal water availability in the region from springs in totality. Further, using the spatial distribution of spring clusters, the biotic and abiotic characteristics of its surrounding region may be extracted. However, it is essential to derive a boundary for effectively studying the spring ecosystem in context to its surface and ground water interaction with other ecosystem assets. Moreover, to derive this extent, it is important to delineate the recharge potential zone for the spring clusters. The GIS platform can be used suitably to derive the springs ecosystem boundary using the AHP technique and multi-criteria evaluation. Thehigher recharge potential zones demarcated within the springs ecosystem boundary can be readily used for implementing the springecosystem management program such as Jal Abhyaranya (water sanctuary) towards ecosystem restoration and springs sustainability in terms of its discharge and water quality.

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COVID-19 EFFECTS ON HIMALAYAN ENVIRONMENT AND LIVELIHOOD

Neha Dhapola

Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Correspondence: nehadhapola720@gmail.com

ABSTRACT

"Climate change is no longer a some-far-off problem; it is happening here; it is happening now." The Himalayan region is unique in floral and faunal richness and abundance in natural resources. Recent trends in climate change and Covid-19 have severely affected Himalayan biodiversity and significantly impacted lifestyles, livelihood, and the environment. People worldwide suffer the consequences of the climate emergency, food and water insecurity, and the COVID-19 pandemic. Covid-19 has some positive effects, but the negative impacts are much more severe and cannot be overlooked. Ecosystems are the most vulnerable to these challenges. Protecting them and sustainably managing their resources is an urgent liability. But just increasing the protection and sustainable management of our remaining natural landscapes and oceans will not be enough. Somebody must take the restoration measures for ecosystems. The UN declared the 17 goals for sustainable development. The 6th report of IPCC has severe results, and the situation has now become "It's now or never." If now steps are not taken then surely it will be going to cost our existence. By declaring the UN Decade on Ecosystem Restoration, governments have recognized the necessity to forestall, halt and reverse the degradation of ecosystems worldwide to learn each folks and nature. The 2021–2030 timeline underlines the urgency of the task. While not a robust 10-year drive for restoration, we are able to neither come through the climate targets of the Paris Agreement nor the Sustainable Development Goals. This paper can discuss the impact of stay-at-home conditions and global climate change on the atmosphere within the mountain range scheme and the way it affects native lives.

Keywords: Himalayan Biodiversity, Covid-19, Environment, Livelihood

INTRODUCTION

On the positive front, Covid-19's lockdown situation caused a substantial improvement in air and water quality due to the reduction in pollution and greenhouse gas emissions. The air pollution levels have reduced, water bodies have been cleaned (Gangetic dolphins are again seen at the Bay of Bengal), and the air quality index of the most polluted cities has improved. Nature has taken time to heal itself. The noise pollution level has also declined to a considerable level, and wildlife seems to retaliate. The pandemic condition facilitates the biodiversity to flourish and consequently benefitted Himalayan ecosystems. The breeding rate of wildlife species has increased due to less human interaction, which is a good sign of getting more birds and wildlife in the succeeding years (Montgomery 2020). However, there was a rise in poaching during the lockdown. The glaciers of the Himalayan region feed the most important rivers and nourish numerous perennial streams. That is why it is also called "Third-pole." It has a significant hydropower potential that fulfills the energy requirement of a large population. Many holy rivers and springs originate here and play essential roles in Indian culture and tradition (Bahukhandi 2020; Kanchan *et al.*, 2020). The most significant preventive step during the Covid-19 Pandemic is to control coronavirus transmission by imposing 'lockdown' over the region. This lockdown has been highly helpful in purifying the Himalayan environment. The ambient air quality and noise level were found under the permissible limit of the National Ambient Air Quality Standard. The water quality of the Himalayan region was improved during the lockdown and was found under the allowable limit of BIS of drinking water quality.

AFFECT ON LIVES OF PEOPLE DURING COVID-19

Negative impacts and way forward

One of the most stressful impacts of covid-19 on livelihoods is unemployment. Many children lost their guardians or caretaker. Many families lost their breadwinners. Education is getting hampered schools were closed for more than 503 days. Most of the population residing in villages cannot use internet facilities due to poor network penetration in those areas. Industries were shut, the prices of goods hiked. The economy was also affected severely, and the GDP of the is also decreased. The negative impacts on the environment cannot be neglected. The increase in medical waste, use of medicines, and syringes have been increased, so the problem of its disposal also creates a severe problem. Haphazard disposal of bio-medical waste is detrimental to human and environmental health. Municipal Solid waste is also not getting disposed of because of the lockdown, garbage collecting facilities are not available, leading to poor sanitation, the burden of wastes continuously endangering the environment. The recycling process is also reduced due to the pandemics. Excessive use of sanitization caused important bacterias present in the atmosphere to die (Rume *et al*., 2020).

The objective should be to find suitable ways to achieve long-term environmental benefits. Such as proper waste disposal methods should be broadcasted through media. Awareness among the society should be the primary objective. Plastic use should be minimized. Adequate implementation of the proposed strategies might be helpful for global environmental sustainability.

Positive impacts and way forward

A large number of the Himalayan population is working in urban areas. During the lockdown, there was a trend of reverse migration. People were more tend to come to the hill. Abandoned villages getting flourished with reverse migration. Cultural enrichment is also facilitated due to the increase in population. Forgotten festivals and folk songs and dances are again in trend as people find ways to entertain themselves. Most of the labor population lost their job and now has to rethink ways to earn. There are various options of livelihood during Covid-19, are listed below:

1. Increase trend of organic farming, 2. Gardening, 3. Dairy 4. Women self-help groups (a. Masks, b. Tailoring jobs, c. Achaar, Madua biscuits, Namkeen, d. Home décor items, e. Dalia and "ringaal" items, f. Carpets, g. Alpana/ Aipan designs, h. Home-made Rakhi, i. Crafts), 5. Small skills business (a. Bakery, b. Restaurants) 6. Using the internet and social media platform (a. E-tourism, b. Makeup tutorials, c. Local dishes cooking tutorials, d. Vlogging, e. E- tuitions), 7. Apiculture (E-portal Madhu kranti)

Ancient herbs' uses have increased as people are inculcating ayurvedic ways of living. The inclination of the population towards Ayurveda and yoga has given a boost to the Himalayan herbs economy. The Himalayan region has an abundance of herbal medicinal plants such as "Giloy," "Tej Paat," and "Tulsi" has known worldwide. Thinking of people has been changed that they can earn by living here and producing employment. Part of the world has been mobilized to their native places, which leads to exchanging ideas, technologies, and culture. Health and hygiene consciousness has been increased. Recently, the Hon'ble PM of India has emphasized the need for the country to achieve self-sustainability through the Aatma Nirbhar Bharat Abhiyaan and his vision of 'vocal for local' to promote local-made products. Eg. Pahadi pisi noon, local cuisine restaurants became trendy. Socialization of people, Life skills development of people has enhanced.

Vermicomposting can also be used for alternative livelihood generation in this region. Vermicomposting is a simple technique in which biodegradable waste, i.e., agricultural and vegetable residues, weeds, excreta of animals, etc., are converted into organic manure with the help of earth worms.

Mushroom cultivation can be considered as a good source of employment for landless farmers and unemployed people. It is a low-cost business and is regarded as the best food for diabetic and heart patients.

Various cost-effective technologies can be used as an alternative source of income. Such as water harvesting tank technology. It is easy and cost-effective. Water harvesting tanks can store rainwater or unused spring or wastewater for irrigation and another purpose during the lean period. This technique is of great value for areas with scarce water for livestock and little irrigation needs. Pisciculture can also be enhanced.

Poultry Farming is also an option, and the government is also enhancing by providing chickens. This article presents how the Covid-19 affects the Himalayan environment and livelihood.

CONCLUSION

Although there are several pros and cons of lock during the pandemic, we have to think constantly about the future to contribute to saving, restoring, and preserving our environment and biodiversity. The Himalayan ecosystem is abundant in its biodiversity. If conditions are favorable, the species will flourish, which will benefit humankind in the long term. The above article presents many ways to approach sustainable practices. The trend of harmony among cultural, social, and ecological diversity is needed to maintain.

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INTEGRATED FARMING SYSTEM: AN AID FOR DOUBLING FARMERS INCOME BY 2022

Dhiraj Bhattacharjee*[1] and Archita Ojah[2]

[1]Department of Horticulture, College of Agriculture Assam Agricultural University, Assam, India

[2]Department of Agronomy, College of Agriculture, Assam Agricultural University, Assam, India

***Correspondence:** dhirajbhattacharjee99@gmail.com

ABSTRACT

The present scenario in agriculture is subjected to high degree of uncertainty and fluctuations of income from the crop enterprises. With the aim of doubling farmer's income by 2022, crop enterprises alone don't have the capacity to uplift income and employment of the farmers. So integration of various enterprises is necessary for supplying steady income and prevention of risk of failure of one enterprise. Various agricultural enterprise viz, crop, animal husbandry, fishery, forestry, apiculture, mushroom etc have great potentialities for increasing agricultural economy. Integrated Farming system was introduced by Keller et al 1986 for maximum production in cropping pattern and takes optimum utilization of resources. The main objectives of IFS are:

• Maximum yield from all the components or enterprises to provide stable income.

• To achieve agro ecological equilibrium and control weeds, disease and insect population.

• To increase the use of natural resources efficiency & reduce chemical fertilizers application.

IFS model utilizes farm wastes and utilizes one waste for the betterment of the other enterprise. The manure of livestock contains a substantial amount of nutrients and it can be applied in the pond for growth of phytoplankton's and zooplanktons which indirectly helps in development of fish enterprise, similarly crop residues or stubbles from crop enterprise can be used as feed in diary enterprise & also in Mushroom production. In North East India there are different IFS models applicable particularly due to the cultivation and natural habitat viz, Fish cum Pig farming, Fish cum Duck Farming, Fish cum Cattle, Fish cum Chicken etc. Thus we can see that IFS model in general not only uplift the economy of the farming community but also helps in waste recycling and helps the farmers to avoid risk from the a single enterprise. Inclusion of different scientific techniques in IFS system like precision farming, Nutrient management, Pest management etc will not only improve resource use efficiency but also helps in sustainability of a small and marginal holder family farming and helps in mitigate negative impact through proper recycling of nutrients. Thus IFS model is a good scope for the government for doubling farmer's income by 2022.

Keywords: Animal husbandry, Apiculture, Forestry, Mushroom, Economy

INTRODUCTION

With increase in population in the country, decreasing GDP contribution from agricultural sector and low per capita available food crops, there is a huge role of the farming community to increase the productivity to meet the demands of the growing population and this can only be achieved by adopting new scientific practices for increasing production potentials rather than sticking to old or primitive ones. One of the ways of improving the productivity of a land is Integrated Farming System. Integrated farming system is defined as the integrated set of elements, components and activities that farmer perform in their farms under their resources and circumstances to maximize the productivity and net farm income on a sustainable basis (Singh and Ratan 2009).

Integrated Farming system was introduced by Keller *et al.,* 1986 for maximum production in cropping pattern and takes optimum utilization of resources. Integrated Farming System is a whole farm management system which aims to deliver more sustainable agriculture (EAOS). The main objectives of IFS are:

1. Maximum yield from all the components or enterprises to provide stable income.

2. To achieve agro ecological equilibrium and control weeds, disease and insect population.

3. To increase the use of natural resources efficiency & reduce chemical fertilizers application.

IFS is based on “no waste, if wastes then only resource” concept. The different components of IFS are:

A. Field-Crop-Vegetable-Fruit-Poultry-Livestock-Duckery-Piggery-Aquaculture-Agroforestry-Apiculture-Mushroom-Biogas.

The different elements of IFS are:
B. Watershed-Farm pond-Bio pesticides-Bio fertilisers-Biogas-Solar energy-Compost making-Green manuring-Rainwater harvesting.

Farming systems varies with the size of the farm holding and topography of the land. Some of the famous Integrated farming system observed in Northeast India are; Paddy cum Fish, Fish cum Poultry, Fish cum Piggery, Crop-livestock-Fish-Piggery-Silviculture etc. Integrated Farming system enterprises are interlinked with each other by the following ways;

In case of crop-livestock Farming system, the residues of one enterprise are utilized in the livestock enterprise and their byproducts of livestock enterprises as feed can be used in the crop enterprise as manure & biopesticide and thus making it interlinked.

METHODS

A field survey was conducted in the villages and seen that although Integrated farming systems provides a judicious yield and a steady farm income yet it is not widely popular in certain part of the country. Due to lack of proper extension services this practice is not widely used and for proper implementation certain measure must be taken by the extension officials in those regions viz,

1. Focus Group Discussions(FGD): It is a popular method where group is formed in the villages in a particular district for transfer of technology by the extension officials.

2. Transect Walk: To understand the existing farming & non farming practices in specific villages.

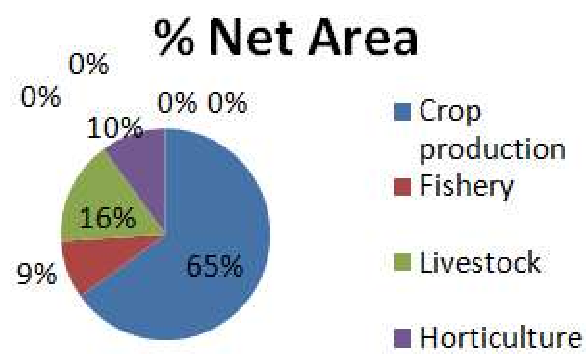
3. Market Observation: To access the opportunity for upliftment of poor rural producers this method is necessary.

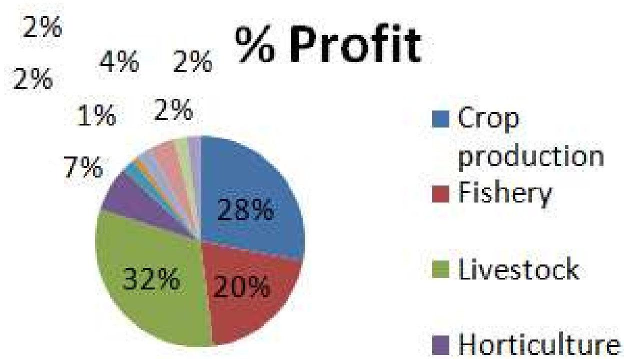
4. House hold level Data collection: To understand the possibilities of doubling farmer’s income information were collected by the extension officials.

5. Workshops: Conducting various workshops regarding new

Enterprises’	Area	Yield
Horticulture	10%	7%
Poultry	0%	4%
Vermicompost	0%	2%
Apiary	0%	2%
Biogas	0%	1%
Liquid manure	0%	2%

Source: Assam Agricultural University 2018





technology and methods helps in technology transfer in the rural environment.

FINDINGS

Integrated Farming system can be utilized effectively in the Farmers field as it provides innovation in farming through judicial use of locally available resources, eco-friendly and self sustainable farming practices.

As per research done by different State Agricultural Universities in different parts of the country following observations are seen:

Land distribution under different enterprises (Ref. AAU Jorhat)	Area (sq.m)
Animal shed, Store house, Apiary, VM unit, Threshing floor and common uses.	1050
Area under cereals, pulses, oilseed, fodder to meet house hold requirement	3846
Rice +Vegetable	1450
Fruit and Fodder Crops	950
Fishery	920
Raised and sunken bed	1200
Seed Bed/ Nursery	500
Passage, Drain	84
Biogas plant	2
Vermicompost	2.26
Liquid manure tank (3 Chambered)	2.34
Green grass	354

Source: Assam Agricultural University

yields 20% of the farm income. So techniques like composite fish culture are required where depth of the pond can be used for rearing different fishes.

4. In case of small enterprises like,

5. In case of the above enterprises small area is required but they provide with a steady income and are interlinked with each other for e.g.: If banana plantation is grown in horticultural land then the biomass can be easily used in the vermi-compost unit. Similarly if multistoried cropping is done with Arecanut-Coconut-Banana then apiary provides a good scope for honey production.

DISCUSSION

Integrated farming system stabilizes the farm income and increase the farm yield by utilizing the resources of one enterprise in another and thus all the three critical aspects of sustainability viz economic, environment and social are maintained. Moreover in single piece of land diversified cropping may reduce the risk in the farming and thus no economic decline is seen.

The economics of IFS was calculated by some resource persons of different states and found out to be: For an area of 0.809ha.

Farming systems	Only Rice	Rice-wheat	Vegetable	Fishery	Duck-ery	Cattle	Net Income
Rice	32050						32050
Rice- Wheat		46122				42290	46122
Rice-Wheat-Dairy		43815				42290	86105
Rice-Wheat-Dairy-Fish		38050		22500		42290	102840
Rice-Wheat-Fish-Duckery		38050		22500	18000		144165
Rice-Wheat-Dairy-Fish-Duckery		38050			18000	42290	134130
Rice-Wheat-Vegetable-Dairy		32285	53790	22500		42290	128365
Rice-Wheat-Vegetable-Dairy-Fishery		32285	53790	22500		42290	150865

(Sanjeev kumar *et al.*, 2012); (Birbal Sahu *et al.*, 2017)

1. In case of crop enterprise (per ha) large area is required which covers nearly 65% but it results in yield of just 28% income. So a high value cash crop which is popular as per demand and price should be grown apart from growing crops for household consumption.

2. In case of Livestock an area of 16% is required which yields 32% of the total farm income. So a good breed of livestock is suggested for high return in the farm land.

3. In case of Fishery an area of just 9% is required which

IFS model utilizes one enterprise waste for the betterment of the other enterprise. The manure of livestock contains a substantial amount of nutrients and it can be applied in the pond for growth of phytoplankton's and zooplanktons which indirectly helps in development of fish enterprise, similarly crop residues or stubbles from crop enterprise can be used as feed in diary enterprise & also in Mushroom production.

In North East India there are different IFS models applicable particularly due to the cultivation and natural habitat viz, Fish cum Pig farming, Fish cum Duck Farming, Fish cum

Cattle, Fish cum Chicken etc. As the terrain is undulating in the region so a specific set of goals and objectives are required for carrying out IFS in this region which are:

1. Evaluation of the already available resources and skills in the farmer's field where IFS should be implemented.

2. Study on the constraints, problems of the farming practices (especially in areas where certain enterprises are not accepted as by norms or traditions).

3. Roles of the enterprise with the supply and demand in the market for easy returns.

Thus we can see that IFS model in general not only uplift the economy of the farming community but also helps in waste recycling and helps the farmers to avoid risk from the a single enterprise. Inclusion of different scientific techniques in IFS system like precision farming, Nutrient management, Pest management etc will not only improve resource use efficiency but also helps in sustainability of a small and marginal holder family farming and helps in mitigate negative impact through proper recycling of nutrients. Thus IFS model is a good scope for the government for doubling farmer's income by 2022. Assam Agricultural University: Land distribution under different enterprises(Ref. AAU Jorhat).

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ROLE OF PHYTOSOCIOLOGICAL TRAIT VARIABILITY IN THE DIFFERENTIAL INVASION SUCCESS OF AMARANTHS IN KASHMIR HIMALAYA, INDIA

Rezwana Assad*, Zafar Ahmad Reshi and Irfan Rashid

Department of Botany, University of Kashmir, Srinagar, Jammu and Kashmir, India

***Correspondence:** rezumir@gmail.com

ABSTRACT

Biological invasions, particularly in the hotspots of biodiversity, being a foremost threat to biodiversity and ecosystem functioning, requires immediate attention. Several alien plant species have been introduced into Kashmir Himalayan biodiversity hotspot from different regions of the world. Subsequently only some of these have been able to inhabit and become invasive. The trait comparisons of invasive with less/non-invasive congeners help in understanding the role of various traits in invasion success. In current study, we investigated the differences in phytosociological traits of three alien plant congeners (*Amaranthus blitum* Linn., *A. caudatus* Linn. and *A. spinosus* Linn.), which differ in their invasion status, and attempted to relate the trait differences to their differential invasion potential in Kashmir Himalaya. Comparison of phytosociological trait variability not only advances our understanding of the factors that promote alien plant invasion but, also equip stakeholders with crucial management tools. In this study, the traits that contribute to the spread of Amaranths in Kashmir Himalaya have been identified for their better management and prospective restoration of degraded ecosystems of Kashmir Himalaya.

Keywords: *Amaranthus*, Invasive, Kashmir Himalaya, Phytosociology, Restoration, Trait

INTRODUCTION

In the present globalized world, invasive alien species (IAS) attract a lot of attention because of the harmful ecological and economic impacts they inflict upon the ecosystems in non-native biogeographical regions (Senator and Rozenberg 2017), and are recognised as the second greatest threat to biodiversity next to habitat loss (Rai and Singh 2020). The current spate of species invasions, mediated mainly by anthropogenic activities, is altering world's biota at an unprecedented scale (Mack *et al*., 2000). Thus ecological restoration of ecosystems degraded by IAS assumes utmost importance (Holmes *et al*., 2020). Even the on-going United Nations Decade on Ecosystem Restoration (2021-2030) have brought ecosystem restoration onto the centre stage of global discussion about ways to combat climate change, prevent biodiversity loss and improve human livelihood (UN Decade on Ecosystem Restoration 2021).

Biological invasions, particularly in the hotspots of biodiversity, being a foremost threat to biodiversity and ecosystem functioning, requires immediate attention. Kashmir Himalaya is renowned as one of the major biodiversity hotspots which harbor rich repositories of biodiversity. Several alien plant species have been introduced into this hotspot from different regions of the world; subsequently, only some of these have been able to colonize, become dominant and turn invasive. Plants that become superabundant only in the introduced range must be 'doing something different' in recipient communities that enables them to attain such dominance. The question whether it is possible to determine a set of traits that predispose a species to be invasive has been a central theme of invasion ecology since its emergence as a major discipline (van Kleunen *et al*., 2015). In this regard, the trait comparisons of invasive with less/non-invasive congeners help in understanding the role of various traits in invasion success (Assad *et al*., 2021). These trait-based screening protocols are valuable weapons in the battle against biological invasions (Bradley *et al*., 2010).

The members of genus *Amaranthus* are commonly called as '*Amaranths*' (Assad *et al*., 2017). In Kashmir Himalaya, six species of this genus are found viz., *Amaranthus blitum* Linn., *A. caudatus* Linn., *A. graecizans* Linn., *A. hybridus* Linn., *A. hypochondriacus* Linn., and *A. spinosus* Linn. In the present study were three alien congeners viz., *Amaranthus blitum* Linn., *A. caudatus* Linn., and *A. spinosus* Linn were selected (Fig. 1). While *A. caudatus* is highly invasive and grows throughout the Kashmir Himalaya, *A. blitum* is non-invasive and *A. spinosus* is also widespread but, not as invasive as *A. caudatus*. We investigated the differences in phytosociological traits of these three species and attempted to relate the trait differences to their differential invasion potential and prospective ecological restoration practices in Kashmir Himalaya.

MATERIALS AND METHODS

The present study was carried out in the Kashmir Himalaya which extends between coordinates of 32° 20' to 34° 50' North latitude and 73° 55' to 75° 35' East longitude. During the present study seven important sites of Kashmir Himalaya were surveyed for assessing the distribution, frequency, density and abundance of *Amaranthus blitum, A. caudatus* and *A. spinosus*. The selected sites were demarcated on the basis of location, availability of particular species, habitat type and accessibility. Table 1 shows the geographic coordinates of study sites selected for the present study and their locations are given in Fig. 1.

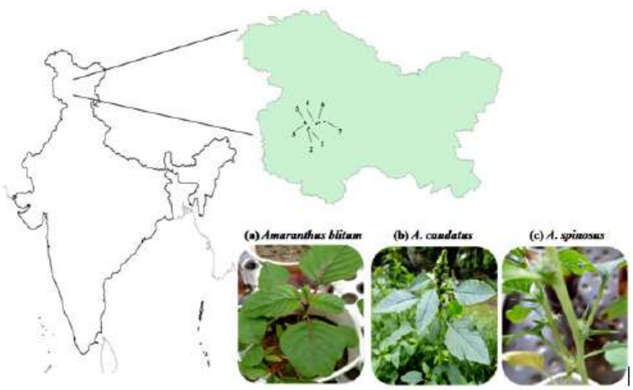

Fig. 1. Map showing studied sites and studied species in Kashmir Himalaya, India

The phytosociological studies were conducted at 7 selected sites (Table 1) in Kashmir Himalaya. At each site, within a vegetation plot, 10 relevés (1m^2 quadrats) were randomly laid in invaded plots of *Amaranthus* species (total of 70 quadrats) at the peak of growing season. Data on various phytosociological parameters like species composition, abundance, density, frequency and IVI of each species were noted down in *Amaranthus* invaded plots by using random sampling technique with quadrat (of 1m^2) as sampling units. Following formulae were used to calculate abundance, density, frequency and IVI:

Table 1. Geo-coordinates of the study sites selected for the present study

S.No.	Sites	Latitude (N)	Longitude (E)	Altitude (amsl)
1.	Shalimar Srinagar	34° 08'36"	74° 51' 44"	1604
2.	Rainawari Srinagar	34° 06' 16"	74° 49' 19"	1615
3.	Lar Ganderbal	34° 15'16"	74° 45' 2"	1640
4.	Haaknar Ganderbal	34° 14' 54"	75° 04' 7"	2082
5.	Waliwar Ganderbal	34° 17' 16"	74° 44' 22"	2120
6.	Kulan Ganderbal	34° 16' 11"	75° 09' 17"	2223
7.	Sonamarg Ganderbal	34° 17' 58"	75° 18' 3"	2700

$$\text{Abundance (ind. m}^{-2}\text{)} = \frac{\text{Total number of individuals of a species in all the quadrats}}{\text{Total number of quadrats in which species occurred}}$$

$$\text{Density (ind. m}^{-2}\text{)} = \frac{\text{Total number of individuals of a species in all the quadrats}}{\text{Total number of quadrats studied}}$$

$$\text{Frequency (\%)} = \frac{\text{Total number of quadrats in which a species occurred}}{\text{Total number of quadrats laid}} \times 100$$

$$\text{IVI (\%)} = \text{Relative Abundance} + \text{Relative Density} + \text{Relative Frequency}$$

$$\text{Relative Abundance} = \frac{\text{Abundance of a species}}{\text{Total abundance of all species}} \times 100$$

$$\text{Relative Density} = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$$

$$\text{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

Principal component analysis (PCA) was executed by loading abundance data of each species in PAST (Paleontological Statistics) software (Version 3.25).

RESULTS AND DISCUSSION

Phytosociological studies revealed that *Amaranthus blitum*, *A. caudatus* and *A. spinosus* vary in distribution across the study sites located in the Kashmir Himalaya. Out of the 7 sites sampled, *A. caudatus* was found at all the 7 sites while as *A. blitum* and *A. spinosus* were found only at 2 and 3 sites, respectively. Both *A. blitum* and *A. spinosus* were not present at higher altitude sites. *A. caudatus* was seen growing in highly disturbed regions (ruderal habitats); while as *A. blitum* and *A. spinosus* were found in regions which were comparatively lesser disturbed (like orchards, graveyards). In comparison to other two *Amaranthus* species, *A. caudatus* was more widespread in occurrence as well as in abundance in Kashmir Himalaya (Tables 2, 3 and 4). Although *A. spinosus* formed dense populations on disturbed or xeric sites, it is still an infrequent species in Kashmir Himalaya. Abundance of invasive plants correlates with their impact. For example, in agricultural systems, managers are concerned about invasive plants that are or are likely to become abundant and damaging to crops, while as the invasive plants that establish, but maintain low densities are of minimal concern (McDonald *et al.*, 2009). Further, it was observed that more number of species was associated with *A. caudatus* in comparison to the rest of the two species. Field studies revealed that 17 plant

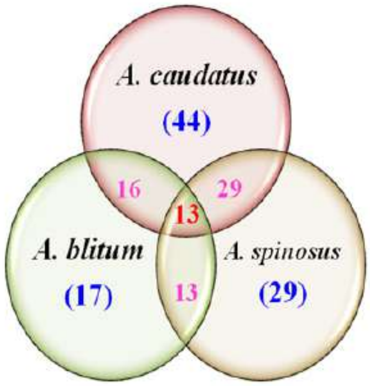

Fig. 2. Venn diagram showing the number of taxa associated and common among *Amaranthus blitum, A. caudatus* and *A. spinosus*

species were growing in association with *A. blitum*. In *A. caudatus* invaded plots, a total of 44 species were recorded while as a total of 29 species were found associated with *A. spinosus*. Number of common species found in association with *A. blitum*, *A. caudatus* and *A. spinosus* is 13. After further analysis of the data, 16 plant species were found common between *A. blitum* and *A. caudatus*, 13 species between *A. blitum* and *A. spinosus* and 29 species between *A. caudatus* and *A. spinosus* invaded sites (Fig. 2). *A. blitum* was never found in association with *A. spinosus*. However, *A. caudatus* was found to be associated with both *A. blitum* as well as with *A. spinosus*, pointing towards the broader niche of *A. caudatus*.

Principle component analysis (PCA) separated the three study species (Fig. 3), there by indicating that there is a marked difference in the association pattern of these species. PCA also revealed more difference between *A. blitum* and *A. spinosus* than the difference of the either species with *A. caudatus*.

Table 2. Phytosociology of sites invaded by *A. blitum*

S.No	Name of species	Abundance (Mean ± SD)	Density (Mean ± SD)	Frequency (Mean ± SD)	IVI (Mean ± SD)
1	*Amaranthus blitum* L.	4.13 ± 1.66	4.13 ± 1.66	100 ± 0	24.68 ±2.82
2	*Amaranthus caudatus* L.	6.50 ± 2.55	2.20 ± 0.42	35 ± 7.07	12.25 ± 0.90
3	*Bothriochloa ischaemum* Keng	12.69 ± 6.60	7.45 ± 5.54	52.50 ± 22.17	25.53 ± 11.96
4	*Conyza canadensis* Cronquist	2.50 ± 1.32	0.37 ± 0.06	16.67 ± 5.77	5.05 ± 1.00
5	*Cynodon dactylon* Pers.	39.75 ± 19.52	39.03 ± 20.78	95 ± 10	92.02 ± 41.67
6	*Daucus carota* L.	11.50 ± 0	6.90 ± 0	60 ± 0	25.72 ± 0
7	*Galinsoga parviflora* Cav.	6.525 ± 2.59	3.70 ± 1.90	55 ± 10	18.03 ± 4.33
8	*Geranium nepalense* Sweet	19.60 ± 0	5.90 ± 0	30 ± 0	20.37 ± 0
9	*Lactuca dissecta* D.Don	3.40 ± 0	1.70 ± 0	50 ± 0	12.54 ± 0
10	*Nepeta cataria* L.	12 ± 0	2.40 ± 0	20 ± 0	11.62 ± 0
11	*Oxalis corniculata* L.	27.37 ± 27.84	17.73 ± 25.87	43.33 ± 32.15	39.78 ± 40.94
12	*Plantago major* L.	1.60 ± 0	0.50 ± 0	30 ± 0	7.08 ± 0
13	*Polygonum heterophyllum* Lindman	17.15 ± 3.46	11.05 ± 1.06	65 ± 7.07	39.56 ± 8.80
14	*Portulaca oleracea* L.	6.60 ± 0	2.00 ± 0	30 ± 0	10.32 ± 0
15	*Rumex dentatus* L.	1.30 ± 0	0.40 ± 0	30 ± 0	7.27 ± 0
16	*Setaria viridis* P.Beauv.	12.15 ± 4.36	3.83 ± 2.46	32.50 ± 17.08	19.19 ± 9.25
17	*Trifolium repens* L.	12.45 ± 2.97	7.90 ± 3.06	62.50 ± 15	28.88 ± 8.43
18	*Urtica dioica* L.	5.10 ± 2.69	1.40 ± 0.79	33.33 ± 20.82	11.14 ± 5.13

Table 3. Phytosociology of sites invaded by *A. caudatus*

S.No	Name of species	Abundance (Mean ± SD)	Density (Mean ± SD)	Frequency (Mean ± SD)	IVI (Mean ± SD)
1	*Amaranthus caudatus* L.	20.20 ± 6.92	20.20 ± 6.92	100 ± 0	38.03 ± 8.26
2	*Amaranthus spinosus* L.	4 ± 0	2.00 ± 0	50 ± 0	11.40 ± 0
3	*Anthemis cotula* L.	4 ± 0	0.40 ± 0	10 ± 0	3.43 ± 0
4	*Arctium lappa* L.	4 ± 0	0.80 ± 0	20 ± 0	6.72 ± 0
5	*Artemisia tournefortiana* Reichb.	4 ± 0	0.80 ± 0	20 ± 0	6.01 ± 0

6	*Asparagus filicinus* Ham.	4 ± 0	0.40 ± 0	10 ± 0	2.33 ± 0
7	*Bothriochloa ischaemum* Keng	33.35 ± 25.84	8.80 ± 4.65	30 ± 14.14	22.39 ± 6.98
8	*Cannabis sativa* L.	4 ± 0	1.00 ± 0.28	25 ± 7.07	6.93 ± 0.30
9	*Chenopodium album* L.	10.86 ± 3.19	3.76 ± 3.03	38 ± 30.33	13.08 ± 7.03
10	*Cirsium arvense* Scop.	4 ± 0	0.40 ± 0	10 ± 0	3.54 ± 1.71
11	*Clinopodium vulgare* L.	4 ± 0	0.40 ± 0	10 ± 0	3.43 ± 0
12	*Convolvulus arvensis* L.	7.80 ± 3.02	3.70 ± 2.74	47.50 ± 26.30	12.96 ± 6.68
13	*Conyza canadensis* Cronquist	6.50 ± 3	0.90 ± 0.76	12.50 ± 5	4.63 ± 2.02
14	*Cynodon dactylon* Pers.	52.31 ± 35.68	51.63± 35.97	98.33 ± 4.08	70.48 ± 28.02
15	*Datura stramonium* L.	5.60 ± 0	2.80 ± 0	50 ± 0	13.19 ± 0
16	*Daucus carota* L.	19.55 ± 3.46	8.20 ± 5.37	45 ± 35.36	20.59 ± 16.65
17	*Echinocloa cruss-galii* P. Beauv.	5 ± 1.41	1.00 ± 0.28	20 ± 0	5.13 ± 1.63
18	*Euphorbia helioscopia* L.	14 ± 14.14	2.60 ± 3.11	15 ± 7.07	6.25 ± 4.40
19	*Galinsoga parviflora* Cav.	9.90 ± 4.15	4.90 ± 3.15	46.67 ± 11.55	13.81 ± 4.48
20	*Geranium nepalense* Sweet	6 ± 0	1.20 ± 0	20 ± 0	6.28 ± 0
21	*Lactuca dissecta* D.Don	16 ± 16.97	3.00 ± 3.68	15 ± 7.07	6.97 ± 4.90
22	*Lactuca serriola* L.	6 ± 2.83	0.60 ± 0.28	10 ± 0	4.07 ± 0.90
23	*Lycopersicon esculentum* Mill.	4 ± 0	0.40 ± 0	10 ± 0	3.43 ± 0
24	*Malva neglecta* Wall.	4.66 ± 1.15	0.93 ± 0.23	20 ± 0	6.68 ± 1.79
25	*Marrubium vulgare* L.	8 ± 0	2.40 ± 0	30 ± 0	11.45 ± 0
26	*Nepeta cataria* L.	5.33 ± 2.31	0.67 ± 0.23	13.33 ± 5.77	4.12 ± 1.63
27	*Oenothera rosea* Ait.	4 ± 0	0.40 ± 0	10 ± 0	2.33 ± 0
28	*Oxalis corniculata* L.	93.60 ± 0	46.80 ± 0	50 ± 0	45.67 ± 0
29	*Plantago lanceolata* L.	3.50 ± 1	0.65 ± 0.44	17.50 ± 9.57	4.29 ± 2.08
30	*Plantago major* L.	7.25 ± 4.43	1.15 ± 0.62	17.50 ± 5	5.95 ± 1.02
31	*Polygonum heterophyllum* Lindman	29.98 ± 18.95	9.04 ± 6.23	36 ± 31.30	21.39 ± 7.58
32	*Polygonum lapathifolium* L.	24 ± 0	12.00 ± 0	50 ± 0	26.70 ± 0
33	*Rubus ulmifolius* Schott.	4 ± 0	0.40 ± 0	10 ± 0	2.33 ± 0
34	*Rumex dentatus* L.	6.33 ± 3.20	1.27 ± 0.59	23.33 ± 12.11	6.98 ± 3.35
35	*Sambucus wightiana* Wall. ex Wight & Arn.	4 ± 0	2.00 ± 0	50 ± 0	12.62 ± 0
36	*Setaria viridis* P.Beauv.	19.38 ± 5.69	11.84 ± 3.08	62 ± 10.95	25.17 ± 5.07
37	*Sisymbrium loeselii* L.	8 ± 4.32	1.80 ± 1.06	22.50 ± 12.58	6.81 ± 2.79
38	*Solanum nigrum* L.	4.73 ± 1.10	1.70 ± 1.3	33.33 ± 20.82	7.90 ± 4.89
39	*Sonchus asper* Hill	4 ± 0	0.80 ± 0	20 ± 0	4.94 ± 0
40	*Sorghum halepense* Pers.	21 ± 0	8.40 ± 0	40 ± 0	13.42 ± 0
41	*Stipa sibirica* (L.) Lam.	8 ± 0	2.40 ± 0	30 ± 0	13.27 ± 0
42	*Taraxacum officinale* Weber	5.32 ± 2.12	0.85 ± 0.34	17.50 ± 9.57	6.14 ± 2.09
43	*Trifolium repens* L.	21.34 ± 12.18	11.90 ± 7.60	52 ± 14.83	23.93 ± 8.36
44	*Urtica dioica* L.	6.80 ± 5.22	1.04 ± 0.46	18 ± 8.37	5.98 ± 2.12
45	*Xanthium spinosum* L.	4 ± 0	0.53 ± 0.23	13.33 ± 5.77	4.19 ± 1.58

Table 4. Phytosociology of sites invaded by *A. spinosus*

S. No	Name of species	Abundance (Mean ± SD)	Density (Mean ± SD)	Frequency (Mean ± SD)	IVI (Mean ± SD)
1	*Amaranthus caudatus* L.	7.30 ± 0.99	5.60 ± 2.26	75 ± 21.21	20.91 ± 0.80
2	*Amaranthus spinosus* L.	4.13 ± 1.56	4.13 ± 1.56	100 ± 0	21.80 ± 3.91
3	*Anthemis cotula* L.	4 ± 0	0.40 ± 0	10 ± 0	3.79 ± 0
4	*Artemisia tournefortiana* Reichb.	4.85 ± 1.20	2.80 ± 3.39	50 ± 56.57	11.80 ± 8.87
5	*Bothriochloa ischaemum* Keng	13.70 ± 6.65	6.85 ± 3.32	50 ± 0	22.95 ± 1.05
6	*Cannabis sativa* L.	5 ± 1.41	1.60 ± 1.13	30 ± 14.14	9.39 ± 2.40
7	*Chenopodium album* L.	8 ± 0	3.20 ± 0	40 ± 0	18.29 ± 0
8	*Cirsium arvense* Scop.	4 ± 0	0.60 ± 0.28	15 ± 7.07	5.62 ± 0.13
9	*Convolvulus arvensis* L.	4.47 ± 2.44	1.63 ± 0.64	40 ± 10	10.78 ± 2.63
10	*Conyza canadensis* Cronquist	3.17 ± 1.44	0.63 ± 0.29	20 ± 0	5.86 ± 1.59
11	*Cynodon dactylon* Pers.	66.40 ± 39.49	65.05 ± 41.71	90 ± 17.32	109.23 ± 40.69
12	*Datura stramonium* L.	4.20 ± 0.35	2 ± 0.80	46.67 ± 15.28	11.90 ± 5.50
13	*Daucus carota* L.	13.80 ± 0.92	3.47 ± 2.66	33.33 ± 15.28	18.35 ± 9.76
14	*Galinsoga parviflora* Cav.	7 ± 0	4.20 ± 0	60 ± 0	21.32 ± 0
15	*Geranium nepalense* Sweet	4 ± 0	0.80 ± 0	20 ± 0	5.71 ± 0
16	*Malva neglecta* Wall.	3.20 ± 1.39	0.83 ± 0.35	26.67 ± 5.77	6.48 ± 1.33
17	*Marrubium vulgare* L.	5 ± 1.41	1 ± 0.28	20 ± 0	7.57 ± 3.59
18	*Oxalis corniculata* L.	21.30 ± 0	6.40 ± 0	30 ± 0	19.73 ± 0
19	*Plantago lanceolata* L.	2.27 ± 1.50	0.37 ± 0.06	20 ± 10	4.81 ± 1.45
20	*Polygonum heterophyllum* Lindman	18.73 ± 8.99	11.63 ± 4.96	63.33 ± 5.77	34.71 ± 5.31
21	*Rubus ulmifolius* Schott.	4 ± 0	0.80 ± 0	20 ± 0	5.71 ± 0
22	*Rumex dentatus* L.	3.43 ± 1.91	1.20 ± 0.80	33.33 ± 5.77	8.84 ± 4.10
23	*Sisymbrium loeselii* L.	3.90 ± 0.14	1.95 ± 1.06	50 ± 28.28	12.19 ± 7.86
24	*Solanum nigrum* L.	4 ± 0	0.40 ± 0	10 ± 0	5.53 ± 0
25	*Taraxacum officinale* Weber	3.25 ± 1.06	0.65 ± 0.21	20 ± 0	5.58 ± 0.77
26	*Trifolium repens* L.	24 ± 0	9.60 ± 0	40 ± 0	25.02 ± 0
27	*Urtica dioica* L.	5.08 ± 0.65	1.85 ± 0.50	37.50 ± 12.58	11.21 ± 3.97
28	*Xanthium spinosum* L.	2.50 ± 2.12	0.45 ± 0.49	15 ± 7.07	4.08 ± 2.31
29	*Xanthium strumarium* L.	3.67 ± 0.58	1.03 ± 0.67	26.67 ± 15.28	6.79 ± 2.00

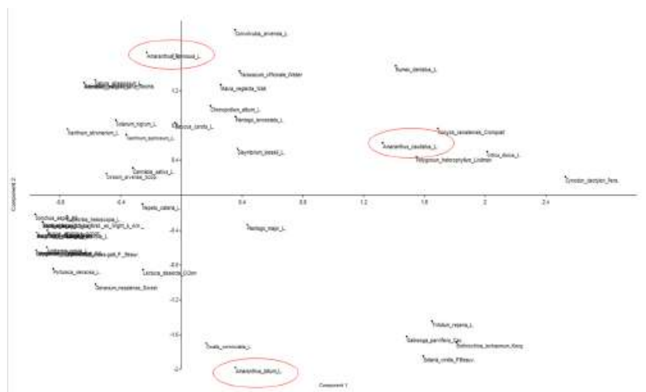

Fig. 3. PCA of *Amaranthus blitum, A. caudatus* and *A. spinosus* based on abundance data

CONCLUSION

Phytosociological studies revealed that A. caudatus is a highly established alien invasive plant species in Kashmir Himalaya. The traits that contribute to the differential spread of Amaranths in Kashmir Himalaya have been identified in current study, which can be further employed for devising long term management strategies of these aggressive species for prospective restoration of degraded ecosystems of Kashmir Himalaya.

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METAL POLLUTION THREATS TO RIVER GANGA IN UTTARAKHAND: AN URGENT NEED FOR ECOLOGICAL RESTORATION

D. M. Tripathi*[1], Kamini Lakhera[2] and Shruti Saxena[2]

[1]Department of Zoology, Pt. L.M.S. Campus Rishikesh, Sri Dev Suman Uttarakhand Vishwavidyalaya, Badshahithal, Tehri Garhwal, Uttarakhand, India

[2]Department of Zoology, Sri Guru Ram Rai University, Dehradun, Uttarakhand, India

***Correspondence:** dmtripathi31@gmail.com

ABSTRACT

Ganga is the most significant river for Indians because of providing life, sustainability to the environment and ecology. The man made interventions have drastically altered the healthy environment mainly from the last four to five decades. Recent developments in human civilization raised serious questions on the safety of water for drinking and other purposes. Metallic pollution caused toxic effects on the health of river Ganga has attracted ample focus specially in the metropolitan cities of India and in its downward journey i.e. from Haridwar to the bay of Bengal. The anthropogenic activities, including direct discharge of industrial wastes, agricultural run of etc., along the river bank of Ganga are held responsible for consistent down gradation of its water quality. Such actions result in the increase of domestic, industrial and agricultural wastes in Ganga. Eventually, these wastes containing health hazardous chemicals like salts of chromium, copper, cadmium, arsenic, mercury and lead pose severe ill effects on animals including the human health and disrupt its hydroecology.

The processes of bioaccumulation and biomagnifications start immediately after reaching the metallic pollutants through river to the biotic community. These heavy metals do not degrade readily and thus accumulate in the body of animals including human beings. Further, these accumulations cause serious side toxic effects to the biotic community exceeding the tolerance limit. Contamination of Ganga water by heavy metals is considered as serious threat to human health and life which may well be envisaged from various diseases, being caused to human beings, including developmental retardation, kidney damage, various cancers and even death in instances of very high exposure. The present research review article is endeavored to comprehend the research findings of various groups in this direction. Considering all the different types of toxicants, heavy metals rank the top position because of their toxic, bioaccumulation and non degradable nature. Heavy metals like Lead (Pb), Copper (Cu), Cadmium (Cd), Chromium (Cr), Zinc (Zn), Nickel (Ni) and Arsenic (As) pose adverse effects on human health and metabolism. Heavy metals, after being accumulated in our body, cause damage to the central nervous system, lungs, kidneys, liver, endocrine glands, bones etc. Some heavy metals like copper, cadmium, lead and chromium are the main pollutants of river Ganga affecting adversely the aquatic life, hydroecology and the human health. Through this research article, we have tried to depict the serious picture of metal pollution in the river Ganga, its sources, present status, effects on animals' body and health including human beings. The strategic ways to mitigate this crisis through ecological restoration have been suggested.

Keywords: Aquatic Ecosystem, Metallic Pollution, Ganga in upper Himalayan region, Biotic communities, Human Health

INTRODUCTION

Rapidly increasing population, rising standards of living, intensified industrialization and urbanization etc. have exposed the water resources including the rivers, to various forms of alterations and degradation. At several places, Ganga water like several other rivers, is found unfit even for bathing purpose. Ganga is the largest fresh water ecosystem in India with acclaimed cultural, economic and environmental values. River Ganga fulfills the needs of approximately 450 million people with aound 550 individuals per square kilometer (Behera *et al.*, 2011). Further, Ganga water is being utilized for fish farming, aquaculture, irrigation and domestic purposes and its basin is suitable for growing the vegetables and cereals. These activities are immensely significant and indispensable for the nutritional requirement and improving the economic status of millions of households. direct discharge of industrial wastes, agricultural run of etc., along the river bank of Ganga are held responsible for consistent down gradation of its water quality. Such actions result in the increase of domestic, industrial and agricultural wastes in Ganga. Eventually, these wastes containing health hazardous chemicals like salts of chromium, copper, cadmium, arsenic, mercury and lead pose severe ill effects on animals including the human health. The pollutants containing heavy metals get accumulated in the river basin, water column and organisms such as plants and the animals (Gupta *et al.*, 2017). The heavy metals are not decomposed by natural processes.

Sources of metallic pollution

A consistent increase in hazardous domestic and industrial wastes and effluents is noticed as commonly occurring phenomenon due to over growing human population, rapid industrialization, urbanization and more and more uses of chemicals and fertilizers for enhanced production. The weathering of soil and rocks, volcanic eruptions and various human activities related to the mining, tanning, processing, use of metals or substances containing metal contaminants are prominent sources of metals into the aquatic system (Prasad and Ruapanwar1990). Besides, the ever increasing human population on the either sides of the river banks, poor sanitation practices by local habitants, untreated domestic

wastewater and industrial effluents, agricultural runoff, dead body dumping and cattle washing, undetected and untreated pesticide residues etc. mount serious toxic threats to the river system. Further, religious activities and immersion of idols and the biggest assemblage of people during Kumbh/ Mahakumbh adversely affect the water quality of Ganga. Kavar yatra of about several millions people in one month only drastically affect the health and quality of river Ganga.

The man made activities like fossil fuel combustion, mining, battery manufacturing, metal product like solder and pipes for water supply, X-ray shielding devices, leaded gasoline, glass containers of food and beverages immensely increase lead concentration in the environment (Singh *et al.*, 2003; Dutta *et al.*, 2005). Generally industries adding heavy metals in river water are metal industries, paints, pigment, varnishes, pulp and paper, tannery, distillery, rayon, cotton textiles, rubber, thermal power plant, steel plant, galvanization of iron products and mining industries as well as unsystematic use of heavy metal containing pesticides and fertilizer in agricultural fields (Suthar *et al.*, 2009; Sindern *et al.*, 2016). These heavy metals pose the accumulative effects at the low level in drinking water and ground water (Prabha and Selvapathy 1997; Paul 2017). The usual practice of draining out the industrial wastes as effluents and untreated domestic sewage in the aquatic ecosystem is consistently going on which leads in the increase of heavy metals' concentration in river system (Wang *et al.*, 2011; Capangpangan *et al.*, 2016).

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Overview of metal pollution in Uttarakhand

Heavy metals are the pollutants responsible for causing several diseases in animals and the human beings (Gupta *et al.*, 2009; Kumar *et al.*, 2009). River Ganga has been extensively studied in relation to pollution of all types including metals, pesticides, domestic wastes and industrial effluents etc. mainly in the plains of India (Kar *et al.*, 2008; Singh *et* *al*., 2003; Dutta *et al*., 2005; Nath and Banerrjee 2006), however, very limited research studies have been performed in Himalayan state of Uttarakhand. Ganga river water quality and heavy metal concentration at different Ghats of Haridwar have been assessed (Sharma *et al*., 2012). Singh *et al*., (2012) determined the distribution of heavy metals like Zn, Cd, Cu, and Pb in river Ganga water from Rishikesh to Allahabad. Further, he found metallic concentrations at same locations exceeding the standard limits owing to the increased anthropogenic activities. The effect of heavy metals like Co, Cd, Zn, Cr, Ni and Fe on Ganga water quality at Rishikesh and their tributaries including Tons and Asan in Uttarakhand were studied by Ishaq and Khan (2013). Goswami and Sanjay (2014) The river Ganga was further investigated for the concentration of heavy metals such as cadmium, copper, lead and zinc ions from Rishikesh to Allahabad and the findings suggested that the contaminations of water and soil sediment at Narora Barrage and Jajmau Kanpur were alarming because of drainages from tannery industries. The concentrations of Nickel, Copper, Zinc and Lead were analyzed in the water of Ganga with the aim of assessing its water quality and suitability at Rishikesh (Haritash *et al*., 2016). Very recently, we have reviewed the impact of pollution on the heath of river Ganga in Himalayan region of Uttarakhand (Tripathi and Lakhera 2019).

Toxic effects of heavy metals on aquatic animals and human health

The harmful effects of heavy metals are known as the biotoxic effects on body after taking above the bio recommended limits. the following have been reported as general signs associated with The general signs of toxicity associated with cadmium, lead, arsenic, mercury, zinc and copper are known to cause gastrointestinal (GI) disorders, diarrhoea, stomatitis, tremor, hemoglobinuria causing a rust red colour to stool, ataxia, paralysis, vomiting and convulsion, depression and pneumonia upon inhalation of its volatile vapors and fumes (Mc Cluggage 1991). Heavy metal lead is a known human carcinogen. The accumulation takes place in bones and the teeth having biological half-life of 20-30 years. From bones and the teeth, it is released into the bloodstream and binds with erythrocyte. Lead in blood has about one month's half life and is removed through urine (Kar *et al*., 2008). Greater toxicity of lead causes anemia (Gupta *et al*., 2009; Kumar *et al*., 2009). Pregnant women and young children are more predisposed to lead toxicity due to iron deficiency (Pandey *et al*., 2009). Similarly, lead gets accumulated in fish gill, liver and kidneys and also in digestive tract (Castro *et al* ., 2008). The accumulation of lead in fish body causes disorders in different fish species (Nath and Banerrjee 2006). Our researches on heavy metal exposures to fish have demonstrated immense harmful effects on the immune system, skin, gill and resistance power to several diseases (Khangarot *et al*., 1999, Khangarot and Tripahi 1990, 1991, 1992). Further, I have conducted detailed research studies in the form of Doctoral Thesis on heavy metals' caused alterations in the immune system of a fresh water fish (Thripathi 1993).

The greater lead toxicity in aquatic system causes generative damages and variation in blood and nerve cells in fish and other the aquatic animals (Beg and Ali 2008, Bhattacharya *et al*., 2008). High dose of chromium compounds in human beings may lead to lung cancer (Jordao *et al*., 2002). The chromium (VI) contaminated air breathing may cause nose irritations and nosebleed (Karadede 2004). Chromium poses toxicological effects on hematological, histological, morphological parameters in fish including growth inhibition, reactive oxygen species (ROS) production and loss of immune function (Rai *et al*., 2010). The depletion in the level of lipid, protein and liver glycogen in fish has been recorded in chromium contaminated water (Saxena and Tripathi 2007). Similarly, Cadmium is known for mounting carcinogenic, embryotoxic, teratogenic and mutagenic effects and may lead to hyperglycemia, reduced immunopotency and anemia (Rehman and Sohail 2010). Further, Cd damages and deforms kidney, liver and bone (Abbas 2008). The cadmium alters the histology of kidney in Cirrhinus mrigala (Dhevakrishnan and Zaman 2012). In Channa punctatus, it shows shrinking effects on kidney tissues (Kumari *et al*.,1989). The exposure of cadmium chloride resulted in full damage of proximal tubules of kidney (Dubale and Saha 1981). The chronic exposure of copper causes irritation in mouth, eyes and nose and also triggers headache, vomiting and diarrhoea. Further, copper is known to cause cirrhosis in children in India after quick accumulation in the liver (Tanner 1998). The morphological and histological changes, in the form of external lesions in tissues resulting to necrosis of liver and other cells, are evident following higher exposure of copper to fish like *Carassius auratus, Cyprinus carpio* and *Corydoras paleatus* (Cavas 2005). The long term toxic effects of copper can have effects on the growth, immunity, fertility, life span. Further, it also changes the physical appearance and natural behavior of aquatic organisms (Yacoub and Gad 2012).

Remedial measures for ecological restoration of Ganga

The foregoing deliberations on metallic pollution in river Ganga and its tributaries in Himalayan state of Uttarakhand are eye opening and alarming for human beings. It compels us to undertake effective measures and strategies for mitigating this crisis. The scientists and all other stake holders have now accepted it as a challenge keeping in mind the dangers for the environment, Ganga and the associated biotic communities including the human beings. The policies and laws have been enacted to control the drainage of effluents, untreated severs and wastes straightway to the water reservoirs including river Ganga. Recycling concept of wastewater containing heavy metals must be implemented not only for the good of environmental and health aspects but also as an effective measure to conserve and preserve the natural resources. The waste to wealth concept is also being executed for improving the prevailing status of Ganga. The public awareness programs and legal steps are urgent to be taken for minimizing the pollution problems. It is mandatory to identify and locate the sources of pollution so that these may effectively be checked and banned. Noteworthy to mention is the fact that the ever biggest Ganga Action Plan could not provide fruitful results because of targeting only the effects and not the causes of pollution. It is, henceforth, realized that Ganga Action Plan must be restarted with the input of present day approach. The National Ganga River Basin Project (NGRBP) is also endeavoring to clean up Ganga properly. Green belt and plantations are necessary to preserve and conserve this lifeline river of India for the good of the river directly and for all of us indirectly.

CONCLUSION

The research paper reviews the availability, sources and effects of heavy metals in river Ganga specially focusing at Himalayan state of Uttarakhand. These are extremely useful in day to day life like accumulators- lead, mercury- arch lamps and thermometers (Hg), utensils (Al) and various other products and hence can not be negated out rightly. However, their toxic effects with potential life threatening consequences can not be overlooked. A proper and safe handling and genuine occupational hygiene must be exercised in their use. Removal of heavy metals from natural water is a tedious, cumbersome and costly affair, hence these must be checked and stopped at the entry point. Heavy metals in water are accountable for many diseases to human beings. Besides, the aquatic animals living in Ganga are also adversely affected and suffer tremendously. It is high time to look this problem on top priority basis and put all efforts to restore the hydroecology of river Ganga for mitigation of metallic pollution.

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THE DANCING DANGER OF ANTHROPOGENIC INTERVENTIONS ON ANIMAL BIODIVERSITY OF HIMALAYA: AN URGENT CALL FOR ECOLOGICAL RESTORATION AND REVITALIZATION

DM Tripathi* and Manoj Singh

Post Graduate Department of Zoology, Pt. L.M.S. Campus, Rishikesh, SDSU Vishwavidyalaya, Badhshahithal, Tehri Garhwal, Uttarakhand, India

***Correspondence:** dmtripathi31@gmail.com

ABSTRACT

Himalaya- the abode of snow, is the youngest and the great mountain system of Asia. It is also the highest mountain in the world. Himalaya is among one of the 12 Biodiversity hot spots (region of extremely rich biodiversity) in the world. Extensively diversified nature of biological resources are being harbored including nearly 35,000 species of flora and fauna. It nourishes different categories of flora and fauna like some cosmopolitan, endemic and endangered ones. The prevailing varied climatic and geographical conditions, temperature, rainfall, seasonal, altitudinal, latitudinal, soil etc. enable Himalaya to be blessed with the richest floral and faunal diversity.The explosion in human population has fueled the ever growing needs for more and more food, clothing and shelter. These together force us to exploit immensely the available natural resources resulting ultimately in the increase of problems like pollution, global warming and climate change, glacier recession, cloud bursts, landslides etc. Further, these alterations evidently cause huge depletion in biodiversity and ecological wealth of Himalayan region. The ever increasing anthropogenic interventions mount serious threats to biodiversity in this region. Other than floral and faunal diversity, the microclimatic changes in this region also negatively affect the human health and livelihood. Himalayan biodiversity supports and flourishes millions of lives, henceforth, we must utilize sustainably the natural resources for our interest and the generations ahead. It is mandatory to adopt measures for restoring and revitalizing the disrupted ecological relations.

Keywords: Himalayan region, Biodiversity and wildlife, Anthropogenic interferences, Ecological restoration, Revitalization

INTRODUCTION

Himalaya is culturally rich heritage and precious gift of Nature for mankind. Besides, regulating climate, pollination, sustaining high levels of biodiversity and human wellbeing are aspects of immense significance for earth and the environment (Sharma and Sharma 2019). Himalaya offers enormous ecosystem services, like providing clean air, huge amount of fresh water, food, shelter, regulating climate, genetic resources, medicinal plants, sustaining high level of biodiversity and other benefits such as recreation, aesthetic enjoyment, spiritual values. The prosperous, wealthy and unique Himalayan biodiversity components and availability of wide range of healthcare bio-resources in this region, associated with their speedy depletion, are gaining global priority for protection and conservation (Khoshoo 1992; Dhar 1997). The unethical, illegal and limitless exploitational activities ofhuman beingsto biodiversity have caused serious losses and threats.Recently, it is being observed that ecosystem services are downgraded worldwide with faster speed and almost 60% of these services are still being degraded and unsustainably used (Sharma and Sharma 2019). Several anthropogenic interventions like detrimental and non planned exploitation activities amount to loss of various floral and faunal species. We, therefore, attempt to discuss, in this research paper, anthropogenic activities, importance of biodiversity focusing mainly the animal biodiversity, threats on sustenance and their possible solutions.

The prevailing scenario of Himalayan Biodiversity

Himalaya Himalaya in India contains two zones-1. Trans Himalaya and 2. Himalaya, representing nearly 3,95,485km^2. area (Chandra *et al*., 2018). Himalaya encompasses nearly 1500 glaciers and various kinds of ecosystems like river ecosystem, lake, most prominent forest – mountain and hill ecosystems in the world. Ecosystems offer a range of benefits to the people worldwide including provisioning, controlling, cultural and supporting services (Li *et al*., 2014b). It nurtures and sustains many perennial river systems like Ganga-Brahmaputra river system and Indus river system. These river systems are being consistently supplied water from ice water reserves (the Glaciers) of miraculous Himalaya. There are approximately 4,699 high altitude lakes in Indian Himalayan regions (Times of India 2013). The mountain ecosystem supports around 1/3rd of the global land biodiversity and ½ of the species wealth of global biodiversity hotspots including high levels of species endemism (Korner 2004; Chape *et al.*, 2008).

The vast variations in geographical, altitudinal, latitudinal, seasonal, climatic, rainfall and prevailing hard conditions in Himalaya bless this region with the bliss of Nature such as rare and prosperous biodiversity and the wildlife. Further, a great degree of endemism is unique feature offering this region an identity of biodiversity hotspot. Several group of workers (Namgail 2009; Habib *et al.*, 2015; Kumar *et al.*, 2017) reported the presence of prominent mammalian fauna inhabiting the trans Himalayan regions including snow leopard (*Panthera uncia*), Himalayan marmot (*Marmota himalayana*), Blue sheep (*Pseudois nayaur*), Tibetan woolly hare (*Lepus oiostolus*), Tibetan gazelle (*Procapra picticaudata*), Himalayan ibex (*Capra sibirica*), Tibetan argali (*Ovis* sps.), Tibetan antelope (P*antholopsh hodgsonii*), Ladakhurial (*Ovis vignei*),Tibetan wild ass (*Equus kiang*) and wild yak (*Bos grunniens*). The prominent vertebrates of India and its Himalayan region are listed in Table 1.

Table 1. Showing the prominent vertebrates of India and its Himalayan region

Faunal Group	No. of species in India	No. of species in Indian Hima-layan Region	% Popu-lation in Indian Hima-layan Region	No. of threatened species in Indian Himalayan Region
Fishes	3324	316	9.51	19
Amphibians	414	80	20.62	4
Reptiles	603	200	34.97	15
Aves	1340	940	70.00	52
Mammals	428	280	65.57	43

(Source: Chandra et al., 2018)

The faunal diversity in Central Himalaya is the highest with 14,183 species/subspecies followed by West Himalaya (12,022), North West Himalaya (8,731), East Himalaya (5,542), Ladakh Mountains (1,561), Tibetan Plateau (1,320) and Trans Himalaya-Sikkim (1,112). Regarding taxonomic richness, phylum Arthropoda with about 26,392 species/subspecies represents approximately 86.9% of the total diversity of Indian Himalaya including 24,933 species/subspecies of hexapods,1,075 species/ subspecies of arachnids, 277 species/subspecies of crustaceans, 52 species/subspecies of millipedes, and 51 species/subspecies of centipedes.

Serious threats to Himalayan biodiversity due to anthropogenic interventions

The anthropogenic interventions are referred to as the processes and actions, both natural or human caused, affecting adversely the status or sustainable use of any component of biological diversity. These factors interact to each other and enhance the consequences (Maikhuri *et al.*, 2017) which is depicted in Fig. 1.

Fig. 1. Showing various threats to Biodiversity

Population increase

Population explosion causes enormous necessities for resources and accordingly human starts pathetically exploiting the natural resources to satisfy their requirements. Ultimately, lots of other damages like deforestation, pollution, destruction of habitat etc. are caused. It is known that every component of ecosystem is interlinked/interdependent and hence, any harm/loss/damage at one stage causes damage to other stages also. Thus, increase in population results in collaterally damaging the environment. The over exploitation activities and pollution together bring changes in the microclimate of a particular area.

Industrialization

Rapid industrialization is a result of fulfilling the overgrowing demands of life sustaining materials/ products and luxurious desires. In today's world, human wants to explore beyond the Nature's limit and also desires the manufacturing of everything artificially. This invasive industrialization surely introduces luxury to human life and makes the daily life easy and joyful. Further, it is well known that science is both a boon and a curse for life, therefore, along with lots of blessings, it also causes pollution and exploitation of natural resources for raw materials. Industrialization and urbanization always walk side by side. The never ending urbanization heavily costs to depletion and loss of biodiversity. Yet, the increase in population is proportional to food and shelter requirements. These are all responsible for deforestation and providing land for agriculture to enhance agro-production for food and shelter requirements.

Deforestation

The population explosion escalated deforestation is one of the serious causes of loss of wildlife and biodiversity. In our country, the present scenario of deforestation is 13,000km^2 annually, which itself is sufficient to show the alarming and gloomy picture of future forests and the richness of our biological diversity fate. It has been anticipated that nearly 100 species every day would be diminishing due to deforestation-alone in coming years (Chandrakar 2012). Besides the above stated factors, the other ecological factors such as distribution range, degree of specialization, position of the organism in the food chain, reproductive rate, outbreaks of diseases etc. are found extremely responsible for biodiversity depletion, leading to extinction, of wildlife including the wild animals (Jayasankar 2015).

Destruction of habitat

Destruction of habitat is the ultimate fate of deforestation. The loss/cutting of even a single tree is accountable for making homeless to several insects, birds etc. The unplanned deforestation and sudden infrastructural developments, like national highways and other structures in remote locations and in deep forests, divide the forest into patches i.e., fragmentation of habitat. This habitat fragmentation is hazardous for ecosystem as it limits the animals' movement and resources availability, increases competition and predation.

Dam

With the construction of dams, huge area of forest land is wiped out or submersed. Dams resist the free flow of water (or rivers and water streams) and the life of high altitude fishes and other aquatic organisms, adapted to live in fast running shallow water, is thus negatively impacted. Studies have found dam building as the most substantial human impact on riverine ecosystems (Dynesius and Nilsson 1994). If all the dams are constructed as proposed, in 28 of 32 major river valleys, Indian Himalaya would be rated as one of the highest average dam densities in the world, approximately with one dam at every 32km of river channel (Grumbine and Pandit 2013). Over half of the dams would be in dense relatively undisturbed forests. Forest loss due to direct submergence and habitat degradation from dam building could lead to loss of 22 angiosperm and 7 vertebrate taxa by 2025 (Pandit and Grumbine 2012).

Pollution

ItIt is yet another factor of biodiversity loss. The normal and healthy composition of ecosystems are being disrupted and altered by introduction of the household wastes, toxic industrial wastes, chemicals like heavy metals, pesticides, hospital garbage, detergents etc. Toxic chemicals disrupt the food chain, food web thereby adversely affecting the ecosystems. Fatal consequences like acid rain, ozone depletion and global warming etc. are known to affect adversely both the plant and animal species threatening to their survival. Likewise, noise pollution is also considered as one of the significant causes of wildlife disturbance (Tripathi and Lakhera 2019).

Global warming

An increase in a greenhouse gas like carbon dioxide causes global warming. Recent changes in climate, particularly warmer winter temperatures have already had significant impacts on biodiversity and ecosystems. They have affected species distribution, population size, timing of reproduction and migration events, as well as the frequency of pest and disease outbreaks. The anticipatory estimations on warming in Indian region could be about 2.1 to 2.6^{0}C in the 2050s and 3.3 to 3.8^{0}C in the 2080s. These drastic changes may cause the extinction of several species (Maikhuri *et al.*, 2017).

Hunting and Poaching

Hunting of wildlife is completely banned in India after the enforcement of Wildlife Protection Act in 1972, but illegal and unethical killing/poaching is a serious problem and a serious challenge for wildlife lovers/well-wishers till date. Since the dawn of human civilization, man started hunting the wild animals to fulfill his requirements for food, cosmetics, pharmaceuticals, recreational purposes, perfumes etc. (Chandrakar 2012). Further, the hunting of rhino for horns, tigers for bones and skin, musk deer for musk with profound medicinal values, elephant for ivory, gharial and crocodile for their skin are the sole reasons for never ending activity of hunting and killing- the climax of brutality. Poaching of Indian tiger has gone up because of the increasing demand from pharmaceutical industries. It has accelerated the poaching of Indian tigers for fetching the consumption of about 100 tigers per year. For making huge money, smuggling of tiger bones and skins is a more profitable business (Tripathi and Lakhera 2019). The level of brutal killing may be envisaged by the fact that in 2010 only, 54.87 % of the 328 leopard deaths, throughout the country, were reported due to poaching. Poaching and illegal trade in animals are projected around 2 billion to 3 billion US dollars.

Exotic alien species

Invasive alien species are animals, plants, fungi and micro-organisms entered and established in the environment from outside of their natural habitat. They reproduce rapidly, cause tough competition to native species for food, water and space and precipitate as one of the prominent reasons for global biodiversity destruction. Species are frequently introduced deliberately through fish farming, pet trade, horticulture, bio-control or unintentionally through such means as land and water transportation, travel, and scientific research(United Nations decade on biodiversity 2020- Living in harmony with Nature).

Human and wildlife conflict

Wildlife killing happens as a human retaliatory response upon wandering of wild animals specially large mammals in human settlement zones. There are several factors responsible for this vintage human- wildlife conflict. This conflict causes loss to both sides. Human beings sustain life injuries/ fatal consequences and immense agricultural economic loss by attacks of wild elephants and other grazing animals' entering their agricultural land. The carnivores (the scavengers) like tigers, leopards, Jaguars etc. impose serious danger and loss to both human lives and livestock. The impact of such conflicts are huge including loss of lives, crops, livestock and property, however, wild animals do suffer big losses to their lives due to human retaliation.

Remedial measures for restoration and revitalization of ecological relations

Keeping in mind the foregoing facts, it becomes imperative to minimize the conflicting and fatal fighting between wild animals and the human beings. Biodiversity conservation is about saving life on earth in all its forms and keeping natural ecosystems functional and healthy. This incorporates the preservation, maintenance, sustainable use (conservation), recovery and enhancement of the components of biological diversity (Maikhuri *et al*., 2017). The pressing demand to declare wild life areas as protected/prohibited zones for frequent and common entry of people, for any purpose, appears quite logical and meaningful. Human interferences must be stopped immediately in wildlife habitats. Making Himalayan wildlife ecosystem more prosperous and rich, in terms of various components, deserves special attention. Stringent enforcement of various legal measures like wildlife protection act for prevention of hunting, poaching and smuggling of wild animals is an emergent need of the hour. Further, the provisions for strict punishment to culprits of wildlife including wild animals must be executed. In order to make wild animals safeguarded, there is a dire need to construct the flyovers on national corridors of wild animals including railway tracks, national/state highways etc. We should not ignore the crawling, slow jumping and moving animals while planning the effective measures for protecting the wild animals. Thus, construction of under pass on national/ state highways, railway tracks etc. is mandatory. Devising and enforcing the strategic measures to prevent forests from fire is in reality the most immediate need of the hour. Awareness programs, for ensuring public participation, must be launched at larger scale. Further, it is highly required to aware the people, make them feel about significance of wild animals and developing attitude of compassion. Curriculum must be designed accordingly so that the students at under graduate and post graduate levels may be made familiar with the techniques of protection of wild animals and the wildlife at large (Tripathi and Lakhera *et al*., 2019). The key to sustainable development is achieving a balance between the exploitation of natural resources for socioeconomic development and conserving ecosystem services that are critical to the wellbeing of everyone and livelihoods (Kremen 2005). There is no established plan for maintaining this balance, however, a deep realization of contribution from ecosystem services to the livelihoods and the related benefits and loses, arising out of developmental interventions, is extremely required.

CONCLUSION

The conservation of biodiversity encompasses the conservation of wild animals, plants and other life bearing entities including their support systems. By conserving, protecting and enriching this wonderful bliss of Nature, we are trying to ensure our own present peaceful and blissful and a better, healthier and congenial future for coming generations. Nature is the ultimate mother of all. It responsibly nourishes and flourishes every organism on earth. Therefore, it is our sacred and honest duty to live with love, peace and harmony to Nature. We must reduce to minimum the burden of our ill activities on Nature for its peaceful and successful sustenance to nurture the other organisms. Here, it is being endeavored to deliberate on the prevailing scenario of biodiversity in Himalayan region, its values, serious anthropogenic threats and anticipatory consequences on our survival.

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FUELWOOD DEPENDENCY AND CONSUMPTION PATTERN IN THE ASI GANGA SUB-BASIN, WESTERN HIMALAYA: NEED FOR ECO-RESTORATION OF WASTELANDS TO MEET THE FUELWOOD DEMAND

Khima Nand Balodi*[1,3,4], Suneet Naithani[1], Anil Kumar Mishra[2], Himani Singh[3,5], Amit Singh[1] and Mahesh Chandra[1,4]

[1]School of Environment and Natural Resources, Doon University, Dehradun, Uttarakhand, India

[2]National Centre for Good Governance, Govt. of India, Cozy Nooks, Charlevillae Road, Mussoorie, Uttarakhand, India

[3]Himalayan Institute for Sustainable Environment and Research, THDC Colony, Dehradun, Uttarakhand, India

[4]Institute for Rural Innovation, Development and Research, Himalayan Conservation Society,Barangal, Almora, Uttarakhand, India

[5]Deparment of Habitat Ecology, Wildlife Institute of India, Dehradun, Uttarakhand, India

ABSTRACT

Fuelwood consumption is a common socio-economic activity in low income communities throughout the world. The dependence of Himalayan communities is observed higher on natural resources including fuelwood for their survival. Lack of alternative energy options makes them over dependence on firewood and the consumption pattern varies with altitudes and resource availability. The present study was conducted in Asi Ganga Sub-basin of western Himalaya to understand pattern of fuelwood consumption among the different user groups. The consumption level was estimated much higher than previous studies in the region, however, varies with households, dhaba owner and migrated gujjars in sub-basin. The study also observed that utilization of various plant species is preferred by resident communities at different altitudes.

Keywords: Asi Ganga valley, Fuelwood, Gujjar, Western Himalaya

INTRODUCTION

The world's population has grown from 4.5 billion in 1980 to over 7.14 billion in 2013 and this has caused a corresponding rise in food and fuel consumption that straining the earth's natural resources. In developing countries, the pressure on natural resources is more acute because nearly 70% population are subsistence-based and live in rural communities. Rural households in the developing world rely heavily on solid biomass as a means for cooking and over 70% of energy use in countries of Indian sub-continent. The consumption of fuelwood is considered as most significant reasons behind forest loss in many countries (Singh and Singh 1992), and the estimates indicate that fuelwood accounts for over 54% of the total global harvest per annum (Bhatt and Sachan 2004; Singh *et al.*, 2010). The fuelwood demand in the country ranges from 96 to 157 million tons annually, including a rural demand of 80–128 million tones, thus raising the consumption level to 148 to 242kg per capita (Singh *et. al.*, 2010). However, the per capita annual consumption of dry wood in various parts of the Himalayas is reported to be much higher, ranging between 500 and 1200kg (Singh *et al.*, 2010). In North Eastern Himalayan region, 90% population use biomass as an important source of energy (Bhatt *et al.*, 2001, Bhatt and Sachan 2004).

In Garhwal Himalaya, about 77.4% of the total population is rural and the alternative sources of energy are not easily accessible hence making the population to totally depend on wood resources (Awasthi *et al.*, 2003; Bhatt *et al.*, 1994). The fuelwood resources and consumption in the Himalayan region vary with resource availability and quality (Samant *et al.*, 1996; Bhat and Sachan 2004; Singh *et al.*, 2010; Malik *et al.*, 2014). These studies have been made on the quality, availability, consumption and consequences of over exploitation on the Himalayan ecosystems. The continuous deterioration of forest resources due to over exploitation and poor implementation of existing environmental laws along with limited alternative sources, the local communities are observed to be threatened (Bhatt and Sachan, 2004).The fuelwood demand in the Himalayan region is expected to be increased manifold during this decade (Bhatt *et al.*, 2016). Therefore, the natural areas in the Himalayan landscape requires protection of native flora and as well as their restoration. Eco-restoration can be an efficient strategy in order to ensure ecological and socioeconomicbenefits such as maintaining the forest ecosystem services, household demand of fuelwood, fodder, medicines, grazing and other non-timber forest produces (Kuniyal *et al.*, 2021). Moreover, it considered important to maintain and enhance the biomass and carbon stock.

Therefore, the present study is an attempt to understand community dependency on fuelwood resources and utilization patterns of fuelwood, species preferred and the quantity harvested on annual basis by villagers, migrated gujjars and dhaba owners in the Asi Ganga Sub-basin. Also, to suggest some eco-restoration activities in degraded land to meet the fuelwood demand and to sustain the ecological functioning of the fragile ecosystem.

METHODOLOGY

Study Area profile

The study was conducted in Asi Ganga Sub-basin of Upper Bhagirathi basin in Uttarkashi district of Uttarakhand state of India (Fig.1).

Fig. 1. Map showing the location of the study area

The area falls under the bio-geographic province of western Himalayan region and Garhwal Himalaya sub-region. The sub-basin is extended over a small area about 195 square kilometers and partially constitute linkage between two prominent High Altitude National Parks of Uttarakhand state. The area ecologically and geologically very sensitive as it has a long history of natural disasters (Nand and Naithani 2018). The area was unexplored in terms of major ecological investigations especially on faunal diversity and assemblages. The world famous tourist destination named as Dodital (a high altitude lake) is situated in the area. About 83.5% of the total geographical area is covered with forests, sub-tropical zone between 1154-1800m supports dense and open forests with chir pine as the most dominant species. The warm temperate zone between 1800-2300m is characterised with *Pinus roxburgii*, *Quercus leucotricophora*, *Quercus floribunda, Rhododendron arboreum, Pyrus pashia, Pinus wallichiana, Alnus nepalensis, Buxus wallichiana, Lyonia ovalifolia, Celtris spp., Cedrus deodara* and *Juglans regia*. Most of the households are residing in the villages up to 2300 m and habitation above this altitude are temporary and purely for seasonal grazing related activities.Various species of fauna including birds (263 species), butterfly (112 species), mammals (36 species), amphibians and reptiles (13 species), fishes (4 species), moths (108 species), dragonflies, bees, beetles, etc are also recorded in the area (Balodi 2021 un published). Some important species of mammals recorded from the Asi Ganga Sub-basin include *Pseudois nayaur*, *Ursus arctos, Uncia uncia, Capra ibex, Hemitragus jemlahicus, Moschus chrysogaster, Ursus thibetanus, Panthera pardus* and species like macaque, Himalayan langur (*Semnopithecus schistaceus*), barking deer, goral, Himalayan serow, jackal, red fox, marten, weasels, flying squirrels, otter (*Lutra lutra*), among the others. In avian fauna threatened species like Red-headed vulture (*Sacrogyps calvus*), Bearded vulture, Egyptian vulture, Himalayan vulture, Steppe eagle, Western tragopan (*Tragopan melanocephalus*) and Cheer pheasant are recorded in the basin. Many of the faunal species in the area are listed under various categories of IUCN Red list of species and schedules of the Indian Wildlife Protection Act, 1972.

The study area is observed to be prone to landslides due to high relief and high precipitation. The average summer temperature remains around 25-30°C while the winter temperature may even drop to 0°C to -8°C. The rainfall pattern shows high spatial variability greatly influenced with slope pattern and ranged between 480 to 3000mm. The areas above 3000 meters remain snow covered for almost 3-4 months.

Socio-economic profile

The Asi Ganga Sub-basin consists of nine major villages namely Agora, Dandalaka, Dasda, Bhankoli, Naugaon, Gajoli, Seku, Uttron and Nald of the Uttarkashi district. These villages are located between 30°46.719'N to 30°55.540'N and 78°24.041'E to 78°35.021'E, are situated in the vicinity of Asi Ganga river, a tributary of Bhagirathi (Nand and Naithani 2018). As per the census 2011, the area consist of 840 households with population of 4432 individuals including 2225 males and 2207 females. The literacy rate was found about 75.16 percent of total population. Gujjars are among the forest dwellers that migrate from Shivalik region to higher Himalaya in summer and return back in winters with the herd of their livestock. The major source of livelihood and income is agriculture and animal husbandry, however, tourism activities serve as major income source over the recent decades (Balodi *et al*., 2019). Livestock include cattle (*Bos indicus*), Buffalo (*Bubalus app*), sheep (*Ovis aries*), goat (*Capra aggeagrus*), horses (*Equus caballus*) and mules (*Equus asinusx, Equus caballus*). Major crops include wheat, rice, potato (*Solanum tuberosum*), beans (*Phaseolus vulgaris*), Amaranths (*Amaranthus* spp), buckwheat (*Fagopyrum esculentum*) and various species of millets and pulses (Balodi *et al*., 2019). These community have maintained a close relationship with nature specially forest and wildlife and hold unique understanding on properties of flora, characteristic of fauna and ecosystem functioning. However, recent changes over the decades in the global economic growth and development have had an influence on the lifestyle of people of the area. The average annual income of households in the areas was estimated around INR 25000 including from all sources.

In terms of village level institution, each of these selected seven villages constitute a separate gram panchayat while Dasda and Dandalaka are administered under Dasda gram panchayat. Gram panchayats are the key institutions responsible for rural developmental activities and providing household services. Van panchayats in these villages are others key institutions responsible for community forest management and plantation activities. The recently constituted Biodiversity Management Committees (BMCs) are responsible to ensure documentation, conservation, management and sustainable use of biological diversity. Moreover, the Eco Developmental Committee (EDC) is also functional in Agora village to look after the eco-tourism related activities at Dodital Lake and adjoining areas. However, permits for logging and tourism activities are given by Uttarkashi forest division.

Sampling Procedure

The field survey was carried out from June 2014 to May 2017 in selected nine villages of the Asi Ganga Sub-basin. A structured and semi-structured questionnaire was designed and used to capture information on household details, number of family members, socio-economic status, energy resources they used. The same was also considered during the interviews of Dhaba owners on the way of Dodital and migrant Gujjars atdifferent grazing sites. The quantity of fuel wood was estimated using a weight survey method at three time a dayfrom a sample of each category. Estimation of fuelwood collected from forests was calculated through weighing the firewood bought during a single visit and total number of visits by the selected household during a month.A total of 120 households (14.29%) out of total 840 households were involved in this study (Table 1). All dhaba owners (13) and Gujjars (13) were considered for this study.

Table 1. Selection of sample households for survey on fuel-wood consumption

Villages	Households (HH)			
	Total HH	Population	Sample HH	HH (%)
Agora	92	457	19	20.65
Dandalaka	21	105	5	23.81
Dasda	38	174	6	15.79
Bhankoli	87	421	15	17.24
Naugaon	99	431	14	14.14
Gajoli	94	583	14	14.89
Seku	61	308	9	14.75
Uttron	171	1014	19	11.11
Nald	177	939	19	10.73
Asi Ganga Sub-basin	840	4432	120	14.29

Data Analysis

The data collected during the survey was processed in M.S Excel,processed and analyzed through SPSS, statisticaand ArcGIS software. The average fuelwood consumption per day by households, dhaba owners and gujjars was calculated for each season and at different altitudes.Standard deviation was measured through calculating dispersion of maximum and minimum values from the mean. The results are presented in the form of tables, figures and graphs.

The following formula was used to calculate average fuelwood consumption;

$$\bar{x} = \frac{\sum_{i=1}^{n} Xi}{n}$$

Where;

$\bar{x}$ = average fuelwood consumption/household/day (kg)

$\sum_{i=1}^{n} Xi$= sum of fuelwood consumption by all household/day (kg),

n = total number of households

RESULTS AND DISCUSSION

Energy resources and fuelwood consumption

The households rely heavily on natural resources for their energy needs especially for cooking, heating their houses and other purpose. But kerosene was also procured from government designated shop as entitled of 5 L/month for various purposes. Almost about 80% of household were having LPG connections, however, due to distance covered for refilling and also the higher cost, leads to limited consumption. The procuring cost of one LPG cylinder at these villages was estimated aroundRs. 1000-1200 including the loading charge. Such circumstanceslimits the use of an average 2-3 LPG cylinder refill annually, and thus, increase their dependence on firewood. Over the time, solar powered lights have gained widespread acceptance for lighting and especially as emergency light has considerably reduced their dependence on Kerosene for lamps. The subsidies were also provided to the household for procuring solar lights, while, many households have received solar lights as disaster relief assistance during flash flood in 2012, 2013 and 2014. The average Kerosene consumption in these villages was found 4-5 L/month limited to lightening needs and sometime for cook stoves.

These villages are provided with electricity coverage, however, only 60-70% of the households were having an electricity connection. The household in the villages also use force of running water to run water mill or Gharat, the traditional use of water resources for energy. However, due to the remoteness of the area with limited accessibility as well as affordability to renewable energy sources and easy availability of woods, forcingthe households to collect firewood from nearby forests. As the study area is known for various tourism related activities, the dhaba owners are catering the need of tourists and local people during their visits to nearest market at district headquarter Uttarkashi. The area is also preferred by Gujjar community for the grazing of their livestock during summer and monsoon months. The dhaba owners and gujjarswere completely relied on fuelwood for their energy requirements. However, the consumption of fuelwood by dhaba owners and gujjarsin higher altitudes (2300m and above) was limited to about 5-6 months, while households and dhaba owners (Sangamchatti) were regular fuelwood users. Moreover, gujjars were observed moving constantly in the area and preferred forest sites above 2300m for setting their temporary shelters much far away from the permanent villages.

Fuel wood consumption pattern among different users

Mostly, all the respondents from households have claimed that they collect dried and fallen wood for firewood purposesfrom their adjoining forests and cutting of treespreferred only during social and cultural ceremonies such as rituals and marriages. Women were observed as the main force in collecting, carrying and storage of firewood. There is a huge drudgery on the woman as they covered a distance of 3-4 kilometersaway from their villages to forests, while sometimes5-6 km and more for collecting fuelwood. The households periodically gathered and stock fuelwood, also for severe winter months. A single trip to the adjoining forests allows them to fetch approximately 30-35 kg fuelwood and an average of 374±83 kg/household/month was collected in a total of 10-15 collection days. The consumption rate was varied with different season and observed to be increased up to 5-10 kg/household/day in comparison to normal consumption during summers (Table 2).

Table 2. Fuelwood consumption pattern in each villages during different season

Villages	Fuel wood consumption in selected villages in different season (per household/day)		
	Summer	Monsoon	Winter
Agora	15.67±2.68	17.93±4.38	19.01±4.68
Dandalaka	14.70±1.05	15.05±2.23	17.75±3.05
Dasda	15.65±3.50	16.10±3.65	17.67±4.35
Bhankoli	14.84±4.27	16.45±3.49	18.68±4.84
Naugaon	16.43±3.72	17.01±4.02	18.35±4.90
Gajoli	15.75±2.87	17.09±3.45	17.64±3.74
Seku	16.31±2.97	17.68±3.59	18.26±3.16
Nald	15.20±3.51	16.32±3.80	17.12±3.74
Utaron	15.35±2.86	17.41±3.13	17.49±2.64
Asi Ganga Sub-basin	15.54±3.05	16.67±3.53	18.01±3.90

The fuelwood consumption reported to be increased during the rituals, festival season and marriages due to sole dependency for cooking on it.

In summers, per day household consumption of fuelwood is slightly higher in Agora, Dasda, Naugaon, Bhankoli and Seku villages that are at higher elevations (>1800m) and much far away from the nearest road head. Villages like Gajoli, Utron and Nald being at lower elevation (<1800m) and connected to roads shows slightly lower consumption of fuelwood. In monsoon and winters, the fuelwood consumption rate was mostly similar and higher in the villages above 1800 m asl. In Monsoon, consumption rate was found maximum in Agora (17.93±4.38) and Seku (17.68±3.59) villages, whereas lowest in Dandalaka (15.05±2.23) and Dasda (16.10±3.65). In winters maximum consumption was observed in Agora (19.01±4.68) followed by Bhankoli (18.68±4.84) and Naugaon (18.35±4.90) while lowest in Nald (17.12±3.74) and Utron (17.49±2.64) villages. The dhaba owners set up their dhabas only for a period of 4-5 month during the peak tourist season and mostly were situated in the reserve forest at different locations in routes to Dodital (Sangamchatti, Bevra, Kacheru, Manjhi and Dodital). The firewood was collected nearby their establishments with easy access and availability. The fuelwood consumption rate was estimated about 20 to 30kg/day/dhaba throughout the operational period.

Fuelwoodconsumption is a common socio-economic activity for survival of human being throughout the globe and seen especially in societies with low income and poor developmental status. The Himalaya supporting about 40 per cent of the world's poor (Bhatt *et al.*, 1994; Samant *et al.*, 1996), reflects a greater percentage of communities depends on its natural resources for water, fuelwood, food, fodder, grazing, shelter, medicine, minerals, tourism among many others (Nand and Naithani 2018). In other words Himalaya play an important role in livelihood security of the inhabitant communities as well as the downstream communities (ICIMOD 2012). However, due to the over dependence and over exploitation of resources along with the global climate change scenario, the biologically diverse landscape are most vulnerable ecosystems on the planet earth (ICIMOD 2012; Nand and Naithani 2018). The limited alternative energy options makes the Himalayan communities to over depend on firewood, however, consumption pattern varies with altitudes and access including preference of a particular species over the others (Bhatt and Sachan 2004; Maiti *et al.*, 2022; Singh *et al.*, 2010).

The consumption level is estimated about 148-242kg/capita annually in India (Bhattacharya and Nanda 1992), however, it was calculated much higher (about 1110.2kg/capita/year) in the present study. It was calculated approximately 3.37/kg/

capita/day. Although, the value recorded in the present study was higher than 1.49kg/capita/day estimated for some lower altitude villages in western Himalaya (Bhatt *et al.*, 1994), 1.23kg/capita/day in Himalayan range of Nepal and 1.9–2.2kg/capita/day for Southern India.The average fuelwood consumption of households, dhaba owner and migrated gujjars is given in Fig. 1. The family size in these villages was observedto 5-6 individuals, and average fuelwood consumption was about estimated about 16.74±3.50 kg/day. The value of fuelwood consumption was recorded from 14.65kg/household/day from Garhwal Himalaya (Awasthi *et al.*,2003). Similar pattern of fuelwood consumption 1003.75kg/capita/year consumption was also reported in earlier study from Himalayan region. Moreover, per capita consumption of dry wood is observed to be ranging from between 500 kg to 1200 kg in various parts of the Himalaya(Singh *et al.*, 2010). The higher value of consumption could be due to the altitudinalvariations and cold climatic conditions that contribute to double consumption compared to lower altitudes (Bhatt and Sachan 2004).The overexploitation of firewood disturbed the natural ecosystem and mostly the forests adjoining to human habitations (Samant *et al.*, 1996; Singh *et al.*, 2010). In the study area forests are observed to be open forest in and around the villages that might be due to heavy dependence of communities for their firewood demands (Malik *et al.*, 2014). Moreover, the lopping of alpine scrub like Rhododendron and Juniper for fuelwood is very critical to the fragile ecosystem and may leads to various consequences like soil erosion. The average consumption of fuel wood by each dhaba owners was 21±6.68kg/day and by each gujjars was estimated 34.45±9.75 kg/day. Singh *et al.*, (2010) also reported use of fuelwoodconsumption by dhaba owners about 90-120kg/dhaba/day in Chopta region of Kedarnath Wildlife Sanctuary.

The Gujjars, migrating from Shivalik ranges of Uttarakhand to the reserve forests of Asi Ganga sub-basin during summer season also heavily depends on forests for fuelwood and fodder.The study revealed that 30 to 40 kilogram of fuelwood per day is used by each gujjars and their consumption pattern was found verydamageable to natural forests, as shrubs and other scrubs at alpine zone were cut and lopped.Mostly,Pinusroxburghii, *Alnus nepalensis, Quercus leucotricophora, Rhododendron arboreum, Pyrus pashia* and *Acer* spp., are used in lower elevations and *Quercus semecarpifolia, Abies pindrow, Aesculus indica, Acer spp, Rhododendron arboreum* and *R. campanulatum* in higher altitudes, and *Rhododendron campanulatum, R. anthopogon, R. lepidotum,Juniferous communis, J. indica* and *Ribes himalayensis* as fuelwood species by the all user types. The fuelwood consumption pattern by each user group is given in the Fig. 2 and 3.

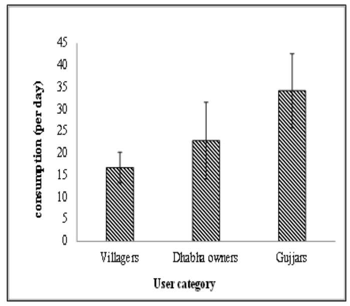

Fig. 2. Average consumption of fuelwood by different user communities

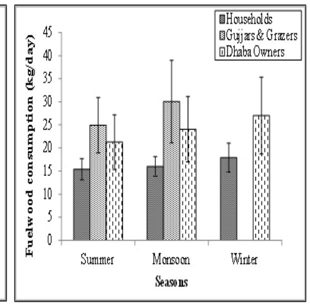

Fig. 3. Seasonal variation in fuelwood consumption by different users

Fuelwood consumption pattern along with altitudinal gradient

All the selected villages are located between 1200-2300m in the study area and use firewood for various purposes throughout the years. The dhabas, seasonal grazing by local households and gujjar were the firewood users at above 2300m asl in the area and uses fuelwood during March to September. The box plots (Fig. 4 and 5) show average fuelwood consumption pattern of households and other user group at different elevation zones. In lower elevations (1200-1800m) summer and monsoon consumption has not shown very much difference, however, in higher elevation (1800-2300m) it was much higher in monsoon. In winters consumption was seen similar throughout the climatic zones. The consumption of fuelwood by local households during seasonal grazing, dhaba owners and gujjars vary with altitudesin both the season and found about 40-50% higher in monsoon than summer. The increased consumption of fuelwood during monsoon at higher altitudes was observed due to coldness of atmosphere after rainfall.

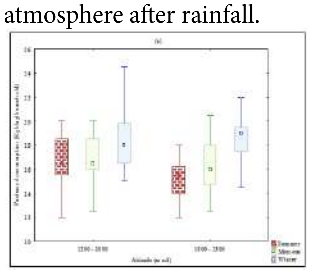

Fig. 4. Fuelwood consumption by household during different seasons at different altitudes

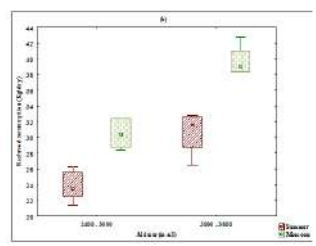

Fig. 5. Fuelwood consumption by gujjars, dhaba owners and households at different altitude

Major Fuelwood species

The preference to a particular tree and shrubs as fuelwood species was observed as per their availability and usability in different altitudes. It was observed that preferred species varies with varying in the altitude (Table 3). A total of 78 species were recorded being used as firewood by the communities, among which 27 of these species contribute about 70-80% of total consumption (Table 3).

The households and dhaba owners in lower altitude (1800-2300m asl) were usingtree species like P*inusroxburghii,*

Table 3. Major plant species preferred for fuelwoodin different zones

Local name	Species	Climatic zones (m asl)			
		1200-1800	1800-2300	2300-2800	2800 & above
Banj	*Quercus leucotrichophora*	+	+	-	-
Chir	*Pinus roxburgii*	+	+	-	-
Anyar	*Lyonia ovalifolia*	+	+	+	-
Uteesh	*Alnus nepalensis*	+	+	-	-
Buransh	*Rhododendron arboreum*	+	+	+	+
Kail	*Pinus wallichiana*	-	+	-	-
Mol	*Pyruspashia*	+	+	-	-
Kingod	*Berberisaristata*	+	+	+	-
Moru	*Quercus floribunda*	-	+	+	-
Kharsu	*Quercus semecarpifolia*	-	-	+	+
Deodar	*Cedrus deodara*	-	+	-	-
Kajal	*Acer caesium*	-	+	+	+
Akhrot	*Juglans regia*	+	+	+	-
Papdai	*Buxus wallichiana*	-	+	-	-
Jamnai	*Prunus cornuta*	-	-	+	+
Pangar	*Aesculus indica*	-	-	+	-
Rai	*Picea smithiana*	-	-	+	-
Simaru	*R. campanulatum*	-	-	+	+
Ringal	*Arundinaria sp.*	+	+	+	+
Bhojpatra	*Betula utilis*	-	-	+	+
Morind	*Abies pindrow*	-	-	+	+
Morind	*Abies spectabilis*	-	-	-	+
Bhotiana	*Salix spp.*	-	-	+	-
Thuner	*Taxus wallichiana*	-	+	+	-
Kathbhoj	*Betula alnoides*	-	-	-	+
Juniper	*Juniperus spp.*	-	-	+	+
Himoch	*Ribes himalayensis*	-	-	+	+

Lyoniaovalifolia, Q. leucotricophora,Cedrus deodara, Alnus nepalensis, Pyrus pashia, Rhododendron arboreum and shrubs like *Berberis aristata* while the dhaba owner, gujjars and households migrated for seasonal grazing (above 2300m asl) mostly preferred *Piceas mithiana, Abies pindrow,Abiesspectabilis, Q. floribunda, Q. semecarpifolia, Rhododendron* spp., *Acer* spp., and *Juglans regia* among the others. The alpine zone that is mostly inhabited by gujjar community for their seasonal grazing shrubs species like *Juniperous communis, Rhododendron campanulatum, Ribes himalayensis*, etc are used as firewood. The requirement of fire wood is fulfilled from the reserve forests and major fuelwood species were *Quercus* spp., *Lyonia ovalifolia, Abies pindrow, A. spectabilis, Acer* species, *Alnus nepalensis, Taxus wallichiana, Rhododendron arboreum, Pyrus pashia, Berberis* species and many others. Many of these species used as fuelwood are listed in various threat category of IUCN and requires immediate conservation inputs. Fuelwood is observed as necessity for cooking and space heating in the study area and under the present scenario no viable alternativeto fuelwood is in place. Although, the present governmental subsidies on LPG connection and refilling under Ujjwala scheme for householdsand similarly, subsided LPG cylinder and other alternative energy options such as solar water heater can be provided to dhaba owners. These initiativesmay contribute positively in reducing over dependence on fuelwood at least for cooking purposes.However, to mitigate negative impacts on forest ecosystem in the area a self-regulated and rotational practices in collecting fuelwood from a particular forest is the need of hour.

Apart from fuelwood consumption, the households, dhaba owners and gujjars in the area, extract forest resources for making Chhanis or Dera(temporary huts with roof of wooden poles, branches and grasses). These structures above 2500m asl, need to repaired every years due to damage by heavy snowfall during winters. Moreover, timber for building construction, collection of medicinal plants and other Non-timber Forest Produces (NTFPs), grazing of livestock and tourism (trekking, camping, etc)in the forest areas are other anthropogenic activities leading to resource alteration and depletion.

Wasteland restoration for meeting fuelwood demand

About 83.5 percent (approximately 163km^2) of the total geographical extent of the Asi Ganga Sub-basin is under different forest types and remaining other is agricultural land and other non-forest classes (Fig. 6).

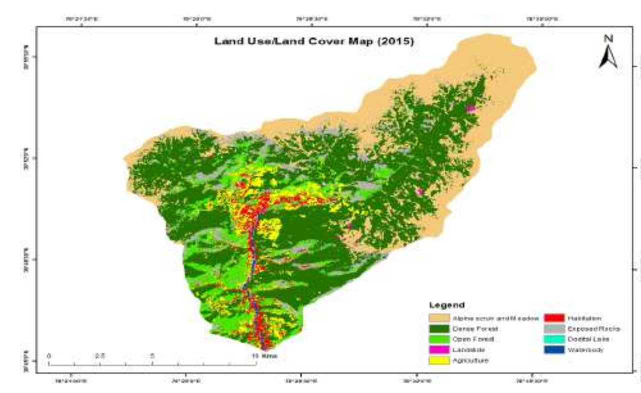

Fig. 6. Land Use and Land Cover map of the Asi Ganga Sub-basin

About 40km^2 (18% of total land) land lies under the open forests, agriculture and human habitation and below 2300m asl. The area is exposed to high level of anthropogenic pressure such as deforestation, grazing, linear infrastructure as well as natural calamities such as flash flood and landslides. Forest adjoining to human settlements are severely degraded due to household dependence and classified as open forests (Table 4).

Table 4. Land Use and Land Cover estimation of the Asi Ganga Sub-basin

S. No.	Land Use Types	Area (km^2)	Area (%)
1	Alpine Scrub & Meadow	53.36	27.39
2	Dense Forest	87.02	44.66
3	Open Forest	22.31	11.45
4	Landslide	0.44	0.23
5	Agriculture	11.07	5.68
6	Habitation	6.63	3.40
7	Exposed Rocks	13.38	6.87
8	Dodital Lake	0.08	0.04
9	Water body	0.54	0.28
Asi Ganga Sub-basin		194.84	100

The pattern of fuelwood extraction from adjoining forests seems to be the most influencing factor to forest degradation. Thus, to prevent forest degradation, alternative options to meet fuelwood demand such as cultivation of woody species could be an appropriate option. In addition, eco-restoration of wasteland, degraded forests and landslide areas along with adopting agroforestry practices on agricultural land for this purpose could be a win-win approach for the households and forest managers. Plantation activities in agricultural, abandoned and wastelands can be initiated under various government scheme such as MNREGA, NAP, MIDH, Green India Mission, JICA, etc.

The potential firewood species may include the fast growing and multipurpose tree species such as *Alnus nepalensis*, *Quercus leucotricophora, Bauhinia variegate, Hippophae* spp., *Populus* spp., *Grewia* spp., *Aesculus indica*, *Celtis australis, Dalbergia sissoo, Melia azedarach, Tuna ciliata, Morus* spp., *Salix* spp among the others (Table 5).

These species are considered useful for fuelwood and meeting different other household demands of fodder, food, timber, medicine and fiber.

Table 5. Potential species for eco-restoration activities in the Asi Ganga sub-basin

Common name	Scientific Name	Uses	Remarks
Uteesh, Alder	*Alnus nepalensis*	Fuelwood, litter, medicinal	Useful in restoration of landslide areas, grows in riverine areas at lower elevations.
Banj Oak	*Quercus leucotricophora*	Fuelwood, litter, fodder	could be planted in open forests and wastelands
Guriyal, Kachnar	*Bauhinia variegata*	Fuelwood, food, fodder, medicinal	Could be grown in lower elevation along with crops as an agroforestry species
Aamal, Seabuckthorn	*Hippophae spp.*	Fuelwood, medicinal, fodder	Useful to restore wasteland and riverine areas
Popular	*Populous spp.*	Fuelwood, Timber	Could be grown in riverine or valleys at lower elevation
Bhimal	*Grewia spp.*	Fuelwood, fodder, fibre, medicinal	Could be grown in lower altitudes along with crops as an agroforestry species
Pangar	*Aesculus indica*	Fuelwood, litter	Could be grown at mid altitude in wastelands
Khadik, Khirak	*Celtis australis*	Fuelwood, fodder, medicinal	Could be grown in lower altitudes along with crops as an agroforestry species
Shisham	*Dalbergia sissoo*	Fuelwood, timber, litter	Best growing species in riverine areas
Bakain	*Melia azedarach*	Fuelwood, litter	Could be cultivated in agricultural or abandoned areas
Tuni	*Tuna ciliata*	Fuelwood, fodder, timber, litter	Can be cultivated in wastelands
Sahtut, kimu	*Morus spp.*	Fuelwood, food, fodder, timber, litter, medicinal	Can be cultivated in all available lands up to 2000 m asl
Bhotiana, salix	*Salix spp.*	Fuelwood	Can be cultivated in mid altitudes

CONCLUSION

The increasing rate of fuelwood consumption among the communities is a result of inaccessibility to alternative energy resources. The poor socio-economic status of the rural population is also the responsible factor in preference to fuel wood as primary energy source and overdependence on forest resources for other livelihood activities.However, the degradation of natural forest and fragile meadows cannot be ignored. Thus, with identifying and provision of alternative energy option to the households and other users, and proper implementation of existing legal measures need to be initiated. Moreover, eco-restoration of degraded and wastelands in the area with regular monitoring on over exploitation is important in order to protect the natural ecosystem and to sustain the well-being of local communities.

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BIODIVERSITY CONSERVATION AND CLIMATE CHANGE MITIGATION THROUGH PLANTATION IN CAMPUS OF EDUCATIONAL INSTITUTIONS: A CASE STUDY FROM MANIPUR

H Birkumar Singh[1], SP Saikia[2] and RC Sundriyal*[3]

[1]CSIR-North East Institute of Science & Technology, Branch Laboratory, Lamphelpat, Imphal, Manipur, India
[2]CSIR-North East Institute of Science & Technology, Jorhat, Assam

[3]Department of Forestry and Natural Resources, Chauras Campus, HNB Garhwal University, Srinagar (Garhwal), Uttarakhand, India

***Crosspondence:** sundriyalrc@yahoo.com

ABSTRACT
The project was planned to cultivate economically important, indigenous and religiously significant trees and shrubs in the vacant land available inside the school campus in the form of mini botanical garden or herbal garden to increase area of green coverage and also for preservation of indigenous and economically important plant species like medicinal, aromatic, edible, dye yielding, timber yielding, gum yielding, etc. The garden will be an important place for students of biology subject to study biodiversity. Besides, the botanical garden will arrest noise and environmental pollution inside the campus of schools and colleges. Under the present project, a total of 4,045 saplings of economically important tree and shrub under 19 families, 28 genera and 32 species are cultivated in the campus of 5 selected schools of Manipur (one army school, one Central Govt. school and three State Govt. schools).Now the herbal or botanical gardens are coming up very well thus creating a good green surrounding environment campus. It has been observed that plantation and conservation of biodiversity inside the campus of schools and colleges are very effective as teachers and students are directly involved in it and the campus is also protected from any strangers including livestock grazing that may damage the plantation.Under the project, various awareness programs were conducted at the beneficiary schools for teachers and students on various topics related to biodiversity, environment and conservation. Competition programs for students like spot-painting, essay writing and ex-tempore speech were conducted to create enthusiasm, competitive spirit and active participation in biodiversity conservation programs. Prizes were awarded to the winner students. Also celebrated World Environment Day, International Day of Biodiversity, etc. in the respective schools where invited lectures and tree plantation programs were conducted. Students and teachers were invited to the herbal garden of the CSIR-NEIST Branch Laboratory, Imphal for study of biodiversity, plant identification, herbarium making and imparting knowledge on economic uses of the plants.

Keywords: Herbal garden, School campus, Biology education, Environment, Climate change, Mitigation, Biodiversity conservation

INTRODUCTION
"Could you live without plants? There is an easy way to find out; hold your breath. As we take in a lungful of air, our bodies absorb the oxygen, a chemical that is essential to our life. Without oxygen we simply cannot live. And all the oxygen we breathe, all the oxygen that sustains our lives was produced by plants" (Mauseth 2013; Maiti *et al*., 2022).

India, with one of the richest and most diverse floras, ranks among the 17 mega diverse and top 10 species-rich nations (Singh *et al*., 2015). The Manipur state falls within the Indo-Burma centre of biodiversity hotspot of global significance. It is true that survival of human beings depends upon the biodiversity around us and protection of those resources is our sensible bound duty and responsibility. The resources provide us food, cloth, shelter and pure air we respire. The importance of herbal and botanical garden is paramount in terms of biodiversity conservation and preservation, collection of germplasm, crop improvement, scientific studies and climatic and environment related issues. It is an important place of systematic study and research of flora of the region. It is the institutions that maintain the living plant collections of different species and varieties of plants, including the ornamental and cultivated ones, wild medicinal, aromatic, edibles and economically important species of various geographical regions, of special interest. They are of value not only to the botanists, horticulturalists and forester but also to the huge number of tourists and herbalists. Small botanical garden or herbal garden is very important to students especially biology students for their studies practical works and research.

Climate change and global warming is becoming a big challenge and is critical in the survival of human beings on this earth due to increase in emission of Green House Gas (GHG) by various factors. Anthropogenic pressure is the major cause for the above. Increase in industrialization, urbanization in one hand and decrease in vegetation or forest or biodiversity on the other hand is the prime cause for the global warming. The best and most effect means of mitigation of climate change is to increase green coverage of the earth surface and conservation of biodiversity.

It has been observed that most of the campus lands of schools, colleges and offices in Manipur are lying vacant without trees or shrubs. If trees with good canopy are cultivated inside the campus then there will be a congenial place to relax for the students and teachers. It will check significantly the environmental and noise pollution. The fruits produced by the trees will be available for consumption by the students and teachers thus helping in combating malnutrition to some extent. In addition, the students and teachers will become more familiar with the plants and their corresponding traditional and scientific information, thus creating a holistic view of their education. Thus botanical or herbal garden in the campus of schools and colleges play a vital role in many educational, biological conservation and environmental aspects (Singh and Saikia 2019).

The three main objectives of the study are (i) Cultivation of at least 20 biologically and economically significant plants in the campus of 5 selected schools of Manipur in the form of mini botanical garden. (ii) Creation of awareness amongst students and teachers about the importance and conservation of biodiversity. (iii) Providing sheds, enhancing aesthetic look of campus and checking of noise pollution through plantation and make available the fruits of the trees to the student and teachers for consumption.

STUDY AREA AND METHODS

The Manipur state,one of the north-eastern states of India has a geographical area of 22,327 sq. km. that lies between latitude from 23º83´N to 25º68´N and longitude from 93º03´E to 94º78´E. The State hasa total of 16 administrative districts in which around 9% are centrally located low-land valley while the rest 90% are periphery hilly districts. Imphal, the state capital located at the centre of the state is at an altitude of 790m above sea level.According to 2011 census the state had a population of 28,55,794 (Statistical Handbook of Manipur 2017).The State falls within "Indo-Burma" centre of Biodiversity hotspot of global significance.The state has forest coverage of about 78% in which 6.57% are reserve forest, 18.68% are protected forest and 52,76% are unclassified forest (Statistical Handbook of Manipur 2017).But according to the latest report, Manipur has lost 499 sk. km forest area within a span of 2 years (from 2017 to 2019) period thus the forest coverage of the state is now around 75% (People's Chronicle 2019) thus the situation of forest depletion is quite alarming. Based on the Botanical Survey of India (2000), the forest or vegetation of Manipur are broadly classified into six major types namely, (i) Tropical moist deciduous forest, (ii) Tropical evergreen and semi-evergreen forest, (iii) Sub-tropical mix forest, (iv) Sub-tropical pine forest, (v) Sub-tropical & temperate grassland &(vi) Temperate forest.

Under the present sanctioned project, a total of 5 schools were selected from the valley area for tree plantation scheme/ program in their campuses (one central Govt. school, three state Schools and one Private/Army School). These schools are; (i) Assam Rifles Public School, Mantripukhri, Manipur (Army School). (ii) Praja High School, Lamshang, Manipur (State Govt. School). (iii) Wangkhei High School, Imphal (State Govt. School). (iv) CC Higher Secondary School, Imphal (State Govt. School) and (v) Kendriya Vidyalaya, Lamphelpat, Imphal (Central Govt. School). Additionally, a herbal garden covering an area of 1.5 acres of land is also established at the campus of the CSIR: North-East Institute of Science & Technology, Branch Laboratory, Lamphelpat, Imphal (project implementing Agency). The reason being selection of valley schools are due to less forest coverage as compared to the hill region.

Selection of schools was done in consultation with officials of Education Dept. and visit to schoolsfor verification of land availability inside the campus.The selection of the plant species cultivated were based on the economic importance through available information/literatures (Deb 1961; Santapau 1966; Polunin and Stainton 1984; Sinha 1996; BSI 2000; Singh *et al*., 2003; Singh and Devi 2014). An MoU was signed between the selected School Authority and CSIR-NEIST agreeing upon the terms and conditions of the project. Most of the planting materials were prepared in the nursery of the CSIR-NEIST, Branch Laboratory, Lamphelpat, Imphal and some were procured from the State Forest Department.

RESULTS AND DISCUSSION:

Tree plantation

Under the project a total of 4,045 economically, ecologically and religiously significant tree or shrub saplings were planted in the campus of the selected 5 beneficiary schools. The plants belong to 19 families, 28 genera and 32 species (Table 1).

The brief information of religious association and traditional uses of the plant species cultivated in the herbal gardens are documented (Table 2). Tree plantation was done with mass involvement of students, teachers and staff of CSIR-NEIST Branch Laboratory, Lamphelpat. Very interestingly many students had collected saplings of many plant species of their own and cultivated in the school campus thus, students were actively involved in the program and brought a big impact.

Table 1. The tree/shrub species cultivated in the campus of each schools

Species/Botanical name	Family	Local name	No. of sapling (per school)	Total no.of sapling (5 schools)
Aegle marmelos Corr.	Rutaceae	Hei-khagok	8	40
Artocarpus heterophyllus Lamk.	Moraceae	Theibong	82	410
Artocarpus lakoocha Buch-Ham	Moraceae	Hari-kokthong	8	40
Aquilaria malaccensis Lamk.	Thymeliaceae	Agor	13	65
*Azadirachta indica*A Juss	Meliaceae	Tairel	18	90
Bauhinia variegata Linn.	Caesalpiniaceae	Chingthrao	33	165
Bixa orellana Linn.	Bixaceae	Ureirom	8	40
Cinnamomum camphora (Linn.) Nees & Eberm.	Lauraceae	Karpur	18	90
Citrus latipes Tanaka.	Rutaceae	Heiribob	6	30
Citrus maxima Linn.	Rutaceae	Nobab	21	105
Dillenia indica Linn.	Dilleniaceae	Heigri	14	70
Dillenia pentagyna Roxb.	Dilleniaceae	Larong	13	65
Emblica officinalis Gaertn.	Phyllanthaceae	Heigru	83	415
Ficus palmate Linn.	Moraceae	Heibam	30	150
Litsea cubeba Pers.	Lauraceae	Usingsha	8	40
Mangifera indica Linn.	Anacardiaceae	Heinou	50	250
Melia azadirach Linn.	Meliaceae	Seijrak	16	80
Mesua ferrea Linn.	Clusiaceae	Uthrao	7	35
Michelia champaca Linn.	Magnoliaceae	Leihao	30	150
Mimusops elengi Linn.	Sapotaceae	Bokul	32	160
Oroxylum indicum Vent.	Bignoniaceae	Shamba	43	215
Parkia roxburghii G. Don	Mimosaceae	Yongchak	112	560
*Persea american*a Mill.	Lauraceae	Avocado	6	30
Phoebe hainsiana Nees.	Lauraceae	Uningthou	21	105
Rhus semialata Murr.	Anacardiaceae	Heimang	12	60
Sapindus mucorossi Linn.	Sapindaceae	Kekru	19	95
Tamarindus indica Linn.	Tamarindaceae	Mange	15	75
Tectona grandis Linn.	Verbanaceae	Chingsu	7	35
Terminalia citrina Roxb. ex Flem.	Combretaceae	Manahi	18	90
Toona ciliata Roem.	Meliaceae	Tairel	11	55
Zanthoxylum acanthopodium DC.	Rutaceae	Mukthrubi	12	60
Zanthoxylum rhetsa (Roxb.) DC.	Rutaceae	Ngang	35	175
Total	-	-	809	4045

Table 2. Traditional uses of the trees cultivated in the school campus

Species/Botanical name	Habit	Brief uses
Aegle marmelos Corr.	Small tree	Fruit pulp used in treatment of stomach ulcer; leaf and shoot used in religious ceremonies. Generally cultivated nearby temples.
Artocarpus heterophyllus Lamk.	Medium tree	Tender fruit cooked-eaten, ripe fruit & seed edible, bark resin used in treating boils & burns, leaf given as fodder, wood used in making idols.
Artocarpus lakoocha Buch-Ham	Big tree	Fruit edible, wood bark yields a dye. Wood used in making agricultural implements.
Aquilaria malaccensis Lamk.	Medium tree	Essential oil is highly commercial, oil applied on insect-bites and as an anaesthesia.

*Azadirachta indica*A Juss	Big tree	Leaf used as insecticide/pesticide, manure, fondly cultivated as an avenue tree. Leaf boiled in water and soup given to treat fever.
Bauhinia variegata Linn.	Big tree	Pod is cooked-eaten, prepared pickles, pod paste applied on insect-bites.
Bixa orellana Linn.	Small tree	Fruit/seed yield a dye, used in treatment of nail infection and pus formation
Cinnamomum camphora (Linn.) Nees & Eberm.	Medium tree	Leaf used in treating cough; plant is fondly cultivated as an avenue tree.
Citrus latipes Tanaka.	Small tree	Fruit cover is used as spice in various cuisines of Manipur particularly in fish and meat cooking; fruit used in treatment of asthma.
Citrus maxima Linn.	Small tree	Fruit edible.
Dillenia indica Linn.	Big tree	Wood gum is applied on toothache; fruit is used in religious ceremonies.
Dillenia pentagyna Roxb.	Big tree	Leaf used in religious offerings.
Emblica officinalis Gaertn.	Small tree	Fruit edible, prepared pickles, a religious festival called Hiegru-hitongba (boating competition) is being celebrated based on the fruit of this plant.
Ficus palmate Linn.	Medium tree	Shoot and tender leaf eaten as vegetable. Plant latex is used in treatment of skin diseases.
Litsea cubeba Pers.	Medium tree	Inflorescence and fruit edible as local spices
Mangifera indica Linn.	Big tree	Fruit edible, leaf used in religious ceremonies, wood used as timber.
Melia azadirach Linn.	Big tree	Leaf and fruit used as pesticide/insecticide, cultivated in avenue plantation. The liquid obtained by boiling the plant is taking bath to treat skin diseases.
Mesua ferrea Linn.	Medium tree	Flower used in menstrual disorder. Flower paste with honey is given.
Michelia champaca Linn.	Big tree	Flowers widely used in various religious ceremonies, flowers kept inside almirah to keep cloths with sweet scent and keep away insects, women decorated their hairs with this flower.
Mimusops elengi Linn.	Big tree	Bark applied against toothache, flowers made into garland & offer in religious ceremonies, fondly cultivated as avenue plantation; flowers kept inside almirah to keep cloth sweet scented and insects/fungus away.
Oroxylum indicum Vent.	Small tree	Pod decoction is given against bone strangulation, pod as decorative piece, tender pod cooked-eaten.
Parkia roxburghii G. Don	Big tree	Pod prepared traditional dishes called Eronba and Shingju.
*Persea american*a Mill.	Medium tree	Fruit edible, sold in markets
Phoebe hainsiana Nees.	Big tree	State tree of Manipur. Timber is graded as A grade timber
Rhus semialata Murr.	Medium tree	Fruit and shoot edible, fruit extract is water is given to treat constipation and dyspepsia.
Sapindus mucorossi Linn.	Big tree	Fruit cover used in treatment of fever and also used in cleaning jewellery, used as herbal shampoo; seed is edible after roasted.
Tamarindus indica Linn.	Big tree	Fruit edible, used in a local dish called Hei-thogngba. It is taboo to cultivate this plant is home garden.
Tectona grandis Linn.	Big tree	Tender shoot and leaf used in treating malnutrition and menstrual disorder. It is cooked with fresh prawn.
Terminalia citrina Roxb. ex Flem.	Big tree	Fruit extract is given as general appetizer & treated cough. Fruits sold in local markets.
Toona ciliata Roem.	Big tree	Leaf and shoot used in various religious ceremonies, timber highly used in construction and furniture making, used in treating warms.
Zanthoxylum acanthopodium DC.	Small tree	Fruit, leaf used as spices specially in snail cooking. Leaf extract is applied on various skin diseases. Fruits and shoots occasionally sold in local markets.
Zanthoxylum rhetsa (Roxb.) DC.	Medium tree	Shoot cooked-eaten, fruit used as spices especially in meat and fish cooking, fruit used in toothache.

These innovations and developments were not seen before.

We all know that we the human cannot survive without biodiversity, water, forest and good environment. Illegal felling and rampant cutting down of trees is happening here and there (Jain and Singh 2012) and indiscriminate clearing of forest lead to severe degradation of forest soil and stream flow regimes (Hamilton and King 1983). Govt. of India and State Govt. sanctioned and spent huge money for tree plantation programs (aforestation programs) but many times failed to achieve the targetsbut cultivation of trees in the campus of schools, college, university and institutes are very successes because the trees cultivated are taken care by students and teachers and also got protection inside the campus. In the campus many indigenous and rare tree or shrub species can be cultivated thus a source of germplasm materials for further research and development.Cultivation of tree and shrub species inside the campus of schools and colleges will establish a green zone that will help in checking environmental and noise pollution and also will help in combating global climate change (Fig. 1).

Fig. 1. View of some of the herbal gardens developed under the project

Organization of Awareness and competition programs

Awareness program was conducted at the CSIR-NEIST Branch Laboratory, Lamphelpat, Imphal on March 07, 2017 by inviting teachers and students from identified beneficiary schools. There was a very fruitful lecture and discussion on biodiversity, identification, conservation, prospection and research. Experts advised the students and teachers to take active part and role in cultivation and conservation of economically and ecologically important plants in the campus of their schools.

Competition programs on (i) Essay writing, (ii) Spot-painting and (iii) Essay writing were conducted amongst the students. The hidden talent and knowledge of the students on biodiversity and conservation were clearly seen in these competitions. They wrote many informative compositionand depicted in their paintings on biodiversity, conservation and the importance of it on human survival (Fig. 2).

(i)Spot painting (ii) Essay writing (iii) Ex-tempore speech

(i)1st prize (ii) 2nd prize (iii) 3rd prize

(i) Consolation prize (ii) Consolation prize (iii) Consolation prize

Fig. 2. Conducted spot-painting, Essay writing and Ex-tempore speech competition for students on the theme "Biodiversity and Conservation" and prizes were given to the winners

Field visit for biodiversity study

Students and teachers of the identified beneficiary schools under this project were visited regularly to the herbal or mini botanical garden of the CSIR-NEIST for study of biodiversity. The program created awareness to students and teachers about the importance of conservation of biodiversity. Plant identification techniques were taught students and teachers. Importance of biological elements in ecosystem service were taught to the students and teachers. Economic importance of the plants cultivated in the gardens was explained. Students were assigned small project works to collect economically important plants like medicinal, aromatic, wild edible, dye yielding, fibre yielding, gum yielding and religiously associated plants and asked them to write a brief write up about them. It was practically observed that most of the students had knowledge about the economically important plants but they had never seen the plants in their life form. These field visit programs provide opportunity for the students and teachers to see the plants physically. Citing an example that the State Tree of Manipur is *Phoebe hainsiana* Brandis locally called "Uningthou" in Manipuri but when the students and teachers were asked whether they have seen the actual plant, but most replied that they have not seen. Most of the students and teachers lack field or practical knowledge. Therefore, the herbal or mini botanical garden in the campus of schools, colleges will really help the teachers and students in learning about the biodiversity.

Scientists-students-teachers interaction program

Regular programs of interaction of Scientists-students-teachers were conducted regularly under the project to discuss various aspects of biodiversity and its importance and conservation which enhance the students and teachers knowledge and involvement in biodiversity conservation programs. Techniques were taught to students and teachers on how to make herbarium and the importance of herbarium, botanical garden and its importance. Such programs should be conducted regularly in Schools and educational Institutions.

Conducted awareness programs on plant identification, value, traditional association and conservation of biodiversity and importance of herbal garden especially in the school campus for students and teachers. During the project period, around 1,000 students and 60 teachers from the beneficiary schools have participated in various programs conducted at the CSIR-NEIST Branch Lab, Imphal.

Conducted awareness and interaction program between students-teachers-experts 4 times in the respective beneficiary schools during the project period as celebration of World Environment Day, International Day of Biodiversity, etc.

Conducted competition programs like (i) Spot-painting, (ii) Ex-tempore speech, (iii) Essay writing on the topic "Biodiversity, Conservation and Sustainable Utilization" for school students of 5 selected schools of Manipur. Cash awards were given to the prize-winning students (Rs 2,000/- to First prize, Rs 1,500/- to the 2nd prize Rs 1,000/- to the 3rd prize and Rs 500/- to the 3 consolation prize winners of each category). These activities enhance the creativity and activity of the students and teachers in biodiversity conservation programs.

Cultivated a total of 4,045 saplings of economically important plants (trees and shrubs) under 32 species (under 19 families and 28 genera) mostly indigenous, religiously associated and economically important plant species are cultivated in the campus of the 5 beneficiary schools of Manipur. Some of the species cultivated are very rare like *Aquilaria malaccensis, Artocarpus lakoocha, Bixa orellana, Dillenia pentagyna, Sapindus mukorossi*, etc.

Most of the plant species attain height from 3 to16 feet. It has been observed that many biodiversity specially birds and butterflies are seen to establish their habitats on the botanical or herbal gardens thus creating a place for biodiversity study. The project really created a good mindset for students and teachers to participate in various biodiversity conservation activities.

The establishment of herbal or botanical gardens inside school or college campus is very effective as students and teachers are directly involved in it. Besides, their campuses are protected from livestock grazing and trespassers.

CONCLUSIONS

Recommendation including remedial measures relevant to the environmental problems under the present study are

Encouragement for cultivation, plantation and maintenance of tree and shrub plant species especially economically important and indigenous and endemic species in the campuses of schools and colleges in the country by providing some special funds. Under the present project, herbal or mini botanical gardens are established in the campus of 5 identified schools and also a herbal garden in the campus of the CSIR-NEIST Branch Laboratory, Lamphelpat, Imphal. The herbal or botanical gardens attract numerous biodiversity especially birds and butterflies thus helping in conservation of animal biodiversity too.The GB Pant National Institute of Himalayan Environment & Sustainable Development, Almora may plan or propose a National Mission Project for establishment of herbal or botanical garden in the campus of schools and colleges of the whole Country under a common banner. That will significantly increase the forest/green coverage of India.

Project works may be assigned to the teachers and students of the schools and colleges on herbal garden development and biodiversity study in the campuses. The work may be initiated with some small funds from the Education Dept. of State Govt. for which certain amount of the budget may be specifically reserved for herbal or botanical garden development and its maintenance.

Students and teachers from those schools or colleges having no botanical garden in their campus or having no suitable space to establish gardens in their campus may encourage and arrange to visit to the nearest school or college botanical or herbal gardens for biodiversity study.

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G.B. Pant National Institute of Himalayan Environment

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ENVIS Team :

- G.C.S. Negi, ENVIS Coordinator
- Mahesha Nand, Programme Officer
- Kamal Kishor Tamta, Information Officer
- S.K. Sinha, IT Officer
- V.S. Bisht, Data Entry Operator

E-mail: gbpihed@envis.nic.in **ENVIS URL:** http://gbpihedenvis.nic.in **GBPNIHESD URL:** http://gbpihed.gov.in