25 GLORIOUS YEARS OF GBPIHED

TRANSLATING RESEARCH INTO ACTION

G.B. PANT INSTITUTE OF HIMALAYAN
ENVIRONMENT AND DEVELOPMENT

25 YEARS
1988-2013

25

GLORIOUS
YEARS OF

GBPIHED

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Editors
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सत्यमेव जयते

अशोक लवासा
सचिव
Ashok Lavasa
Secretary

भारत सरकार
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
Government of India
Ministry of Environment, Forest & Climate Change

Foreword

30th May 2015

The G.B. Pant Institute of Himalayan Environment and Development (GBPIHED) has been mandated for devising suitable R&D based strategies to improve the quality of life and ensuring ecological sustainability of the Himalaya, one of the most unique and sensitive ecosystems on the earth. In recent years with the increasing attention of Government of India towards addressing issues of sustainability of Himalayan ecosystems, the role and responsibility of the Institute have increased many-fold.

I am happy to note that on completing 25 years of its existence the Institute is bringing out a publication entitled **"25 Glorious Years of GBPIHED: Translating Research into Action"** that includes R&D based "Success Stories" of GBPIHED over the years to mark the Institute's Silver Jubilee celebration. These case studies present the major leads taken by the Institute in linking the stakeholders driven R&D pursuits with environmental conservation and societal aspirations. The variety of subject areas covered in this compendium attempts to establish relationship of an academic enquiry into environmental issues with that of the socio-economic development. The four major thematic areas (i.e., Wasteland rehabilitation technologies, Water resources management, Biodiversity conservation and sustainable use, and Livelihoods and capacity building) broadly cover most of the thrusts on Himalayan environment and development. A summary of societal relevance of R&D, presented at the end of each theme, highlights the policy relevance, contribution to technology development and outreach of research results. Therefore, the document, in my opinion, succeeds in presenting an interface between hard science and societal welfare.

I hope this document will prove useful for a variety of stakeholders including policy makers, academicians, Govt. organizations, NGOs and regional inhabitants. Also, it will improve outreach of Institute's R&D work. I congratulate Dr. P.P. Dhyani, Director and his team of scientists in pursuing R&D work in the challenging conditions of mountains, and editors of this compendium for putting hard work and bringing out this publication.

Lavasa
(ASHOK LAVASA)

Preface

Soon after its establishment in 1988, G.B. Pant Institute of Himalayan Environment and Development (GBPIHED) in 1992 came up with a document "Action Plan for Himalaya", which was released by the-then Minister, Ministry of Environment and Forest, Govt. of India and President of the G.B. Pant Society of Himalayan Environment & Development. This document, first of its kind, highlights the most important issues of environment and development in the Indian Himalayan Region (IHR), in which some critical issues were laid out such as water resource management, soil conservation, forests and biodiversity conservation, wasteland rehabilitation, farming systems sustainability, energy options, capacity building of local communities and popularization of eco-friendly and low-cost technologies, which obviously formed the immediate priority areas of R&D pursuits in the Institute. Over the years, GBPIHED carried out in-depth research into most of these priority areas, with keeping a sharp focus on its societal linkages. While this was happening, a strong need for stakeholders' demand-driven research was felt so as to increase the acceptability and outreach of the GBPIHED across the IHR.

As the Institute completed its 25 years of establishment in 2012-13, the Apex Bodies of the Institute suggested and desired the Institute to bring out a publication that includes R&D based "Success Stories". The 25 such stories presented in this document thus mark the celebration of Silver Jubilee Year of GBPIHED. It is worth mentioning, all through this journey of 25 years the Institute researchers have been engaged with diverse R&D projects, falling into diverse disciplines, making it a difficult task to shortlist the success stories. Therefore, the R&D work that has more direct bearing on societal welfare and environmental conservation, have been included in this document.

The 25 success stories presented in this document have been arranged under four major sections: (1) Wasteland rehabilitation technologies, (2) Water resources management, (3) Biodiversity conservation and sustainable use, and (4) Livelihoods and capacity building. These four sectors, I believe, broadly encompass most of the facets of environmental conservation and socio-economic development in the IHR. The endeavour is to convey the message that the Institute is committed for providing research-based solutions for conservation and development of globally important Himalayan mountains. Efforts have been made to make the stories more meaningful for entire region by way of appropriate inclusion of area-specific accomplishments of the Institute's Regional Units. More importantly, a summary containing policy relevance, contribution to technology development and outreach, as given at the end of each section highlights the wider implications of the Institute's R&D endeavours. However, I understand, the R&D based learning lessons presented in this document need further syntheses for policy uptake and dissemination for wider implication in real field conditions.

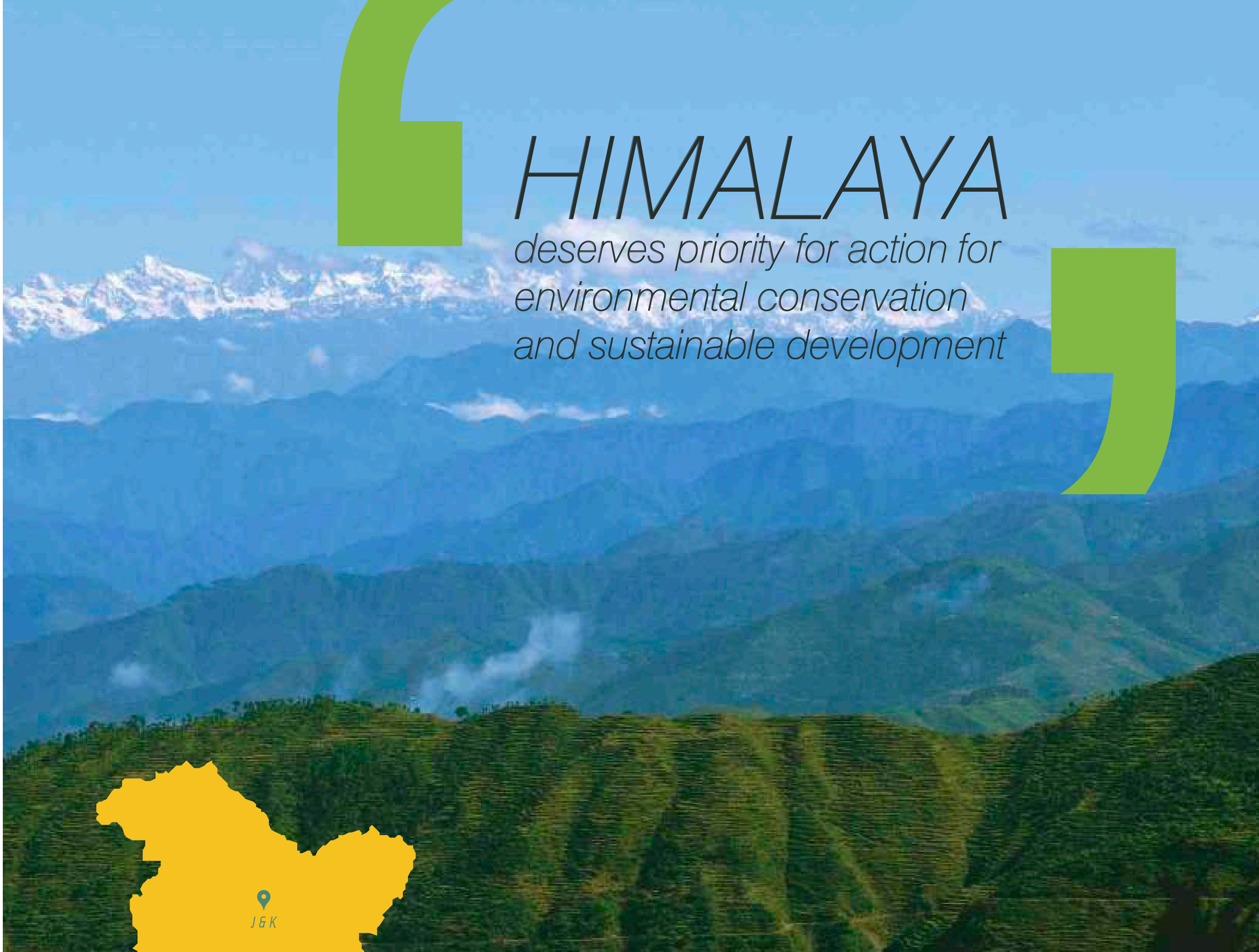
I congratulate all the contributors of these success stories for presenting their R&D accomplishments in easy to understand language. Dr. G.C.S. Negi, who made untiring efforts to give this document the present shape, deserves special appreciation. The Apex Bodies of the Institute were source of inspiration and guidance all through our journey over the years. Finally, I do hope, the readers will get benefitted from these success stories and provide us inputs for further improvements in our R&D pursuits.

P.P. Dhyani
Director

CONTENTS

INTRODUCTION

The Himalaya is vast, diverse and the youngest mountain system on the earth. It constitutes a unique geographical and geological entity comprising a diverse social, cultural and environmental set-up. Encompassing more than 2,500 km in length and 220 to 300 km in width, the Indian Himalayan Region (IHR) is spread over the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya, parts of Assam and hill district of West Bengal. It has a total geographical area of approximately 591 thousand sq. km (18% of India) inhabited by about 3.8% of the total population of the country.



HIMALAYA

deserves priority for action for environmental conservation and sustainable development

Map of IHR
(Not to Scale)

Over 170 ethnic communities with distinct socio-cultural milieu live in the IHR. The region is characterized by sparse population, undulating terrain, tiny and scattered land holdings, scanty irrigation opportunities, agro-pastoral economy, low agricultural productivity, and low access and use of modern technologies, etc. The region constitutes the principal basis for the climate system that prevails over India. This region represents diverse biomes/ climate zones (e.g., tropical, sub-tropical,

temperate, and sub-alpine and alpine) and recognized amongst 34 Global Biodiversity Hot Spots with 32% endemic flora. This region is a vast reservoir of water and referred to as the "Water Tower of the Earth". This is the home of over 9,000 glaciers storing about 12,000 km^3 of freshwater, and makes the head waters of important north Indian rivers, and influences the well-being of the Indo-Gangetic plains.

The Himalaya has historically contributed substantially to the security of its people and economic development of the country. Therefore, the region deserves "priority for action for environmental conservation and sustainable development".

MANDATE...

- *Undertake in-depth research and development studies on environmental problems of the Indian Himalayan region.*
- *Identify and strengthen the local knowledge of the environment and contribute towards strengthening research of regional relevance in the scientific Institutions, Universities/NGOs and voluntary agencies working in the Himalayan region, through interactive networking.*
- *Evolve and demonstrate suitable technological packages and delivery systems for sustainable development of the region in harmony with local perceptions.*

The G.B. Pant Institute of Himalayan Environment and Development (GBPIHED) was established in 1988, the birth centenary year of Bharat Ratna Pt. Govind Ballabh Pant as an autonomous Institute of the Ministry of Environment, Forest & Climate Change (MoEF&CC), Govt. of India. The Institute is mandated to devise suitable R&D strategies to maintain intricate balance between socio-cultural, ecological, economic and physical systems that could lead to enhance quality of life and ecological sustainability of ecosystem. To achieve this, the Institute follows a multidisciplinary and holistic approach in its R&D programmes with an emphasis on interlinking natural and social sciences keeping in view the fragile mountain ecosystems, indigenous knowledge systems and sustainable use of natural resources. A conscious effort is made to ensure training, capacity building and participation of local inhabitants for long-term sustainability of various programmes.

The R&D activities of the Institute are multi-disciplinary in nature and revolve around three groups and six thematic areas and executed in a decentralized manner through its HQs (Kosi-Katarmal, Almora, Uttarakhand), and five regional Units, viz., Northeast Unit (Itanagar, Arunachal Pradesh), Sikkim Unit (Pangthang, Sikkim), Garhwal Unit (Srinagar-Garhwal), Himachal Unit (Mohal-Kullu, H.P.) spread across the IHR, and the fifth Unit (Mountain Division) that functions from MoEF&CC, New Delhi.

Over the years, the Institute has taken significant strides in identifying problems (Box - 1), developing region specific approaches for sustainable management of natural resources, and demonstrating their efficacy in the field and disseminating the research results/ policy documents and package of practices to various stakeholders. Diverse problems thus addressed were related to ecology, resource conservation, traditional practices, livelihood opportunities, land restoration, biotechnological interventions, etc. As a result, a large quantum of data has been generated, analyzed and synthesized. This helped the Institute to be recognized at national and international forums as an Institute of eminence through its important peer-reviewed publications (Appendix - I) and R&D based policy documents and package of practices (Appendix - II). Based on the R&D work carried out at GBPIHED, the past three directors were conferred with FNA, 4 scientists with FNASc, Allahabad, 5 scientists with Vishisht Vaigyanik Purashkar of MoEF&CC and 2 scientists with LEAD India (Leadership in Environment and Development) fellowships. List of research papers (>2500) and policy documents published and list of R&D projects handled by the GBPIHED faculty so far can be accessed from GBPIHED website (www.gbpihed.gov.in).

BOX - 1 **Environmental Problems in IHR ...**

- *Accelerated soil erosion and landslides*
- *Deforestation and land degradation*
- *Scarcity of fodder and fuel wood*
- *Forest fires and wildlife attacks*
- *Rainfed farming, declining soil fertility and crop yield*
- *Water scarcity for household use*
- *Increasing waste land*
- *Invasion of alien weeds*
- *Lack of infrastructure and market for processing and sale of farm produce*
- *Limited job opportunities*
- *Lack of civil amenities*

Thus GBPIHED has a comparative advantage over other Institutions in addressing the environmental and development problems of the IHR (Box – 2). However, the concern such as: How research products can be optimally utilized by stakeholders? How the Institute can contribute to improving the quality of life of people? How interdisciplinary data sets can be made more useful? And how the Institute can develop state-of-art knowledge products, which are innovative and offer better understanding of the dynamic processes always remain to be answered fully and require guidance and support from all the stakeholders of IHR. This also implies that in this region of high ecological and social heterogeneity the task is challenging and demands high interdisciplinary skills and VISION to integrate different scientific disciplines to safeguard the environmental concerns and addressing the socio-economic development of the inhabitants.

BOX - 2 *Areas of Comparative Advantage ...*

- *A national Institute with IHR specific mandate with a satellite network of its six thematic programmes and five Units to facilitate linkages and coordination across the region*
- *Blend of research (multidisciplinary and interdisciplinary R&D activities), demonstration and dissemination*
- *Mountain-specific expertise and knowledge products (i.e. package of practices)*
- *R&D work on diverse ecosystems across IHR*
- *Building on traditional ecological knowledge for location-specific solutions*
- *Networking across IHR through Integrated Eco-development Research Programme (IERP), Environmental Information System (ENVIS), etc.*

This document entitled, "25 Glorious Years of GBPIHED: Translating Research into Action", prepared on the occasion of SILVER JUBILEE YEAR of the Institute gives an account of R&D work carried out by GBPIHED in the past 25 years after its establishment in 1988. The 25 stories presented in this document have been consciously chosen to demonstrate the societal relevance of the R&D work carried out at GBPIHED so far. However, we may have left findings of quite a few R&D projects having less societal relevance due to space constraints. These stories have been arranged under following four major sections:

- **WASTELAND REHABILITATION TECHNOLOGIES**
- **WATER RESOURCES MANAGEMENT**
- **BIODIVERSITY CONSERVATION AND SUSTAINABLE USE**
- **LIVELIHOODS AND CAPACITY BUILDING**

These four sections broadly encompass most of the facets of environmental conservation and socio-economic development in the IHR. At the end of each section a summary containing policy relevance, contribution to technology development and outreach, has been provided to show the societal linkages of the research results carried out so far by the GBPIHED.

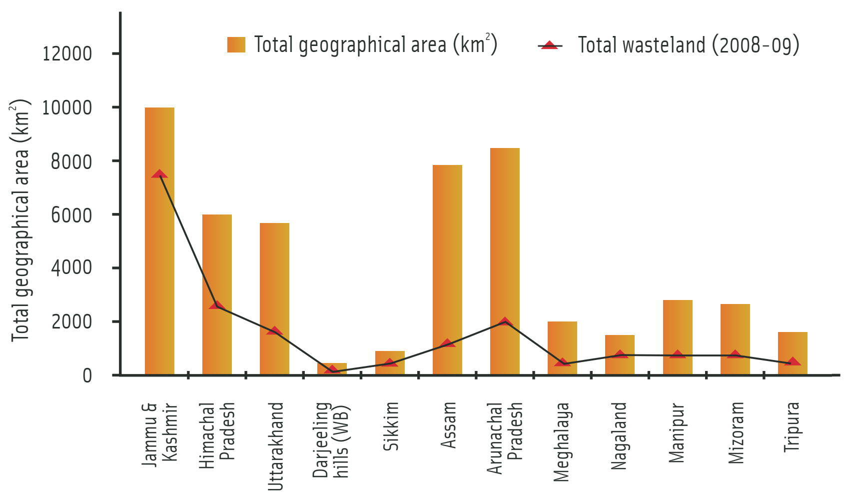
1

WASTELAND REHABILITATION TECHNOLOGIES

Suitable for Diverse Conditions Across IHR

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 properties of soil leading to long-term loss of productive capacity and biodiversity contained in natural vegetation. In India, land degradation estimates vary ranging 53-188 Mha (Wasteland Atlas of India, 2011). In the IHR, wastelands account for about 34% of the total geographical area (i.e., 180533 sq. km), 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 and does not support any biological growth (Anonymous, 2010). Out of 59 Mha total geographical area of IHR, 7.3 Mha is degraded community land, 13.5 Mha is degraded government forests, and 1.2 Mha is abandoned agricultural lands (Sharda, 2011). Among the 12 hilly states of IHR, HP comprises 40%, Nagaland 32%, and Manipur, Uttarakhand and Mizoram about 25% wasteland each of their total geographical area (Fig. 1.1). Thus, across the IHR we are confronted with three extremes- cold deserts in the Western Himalaya, degraded wastelands due to biotic pressure in Central Himalaya and shifting agriculture affected areas in Eastern Himalaya (Ramakrishnan et al., 1992).

Fig. 1.1:
Total geographical area of different Indian Himalayan states and their respective total wasteland area (for West Bengal only Darjeeling district is considered).



Ecological restoration of wastelands is essential for re-establishing a healthy ecosystem to perform its production and other ecological functions (Kumar et al., 1996). Degradation of ecosystems and its negative impacts on biological diversity and community livelihoods are well known (Singh & Singh, 1992). Degraded mountain slopes are prone to problems of soil erosion, susceptibility for land slides, nutrient washout and invasion of weeds, etc. Siltation of water bodies, deterioration of water quality and loss of aquatic life are other negative impacts. Marginal and fragmented holdings, scarcity of water for irrigation and frequent damage to crops by wild animals also promote land degradation and land abandonment. Land degradation has thus serious consequences scaling from environmental hazards to food security and out-migration in this region (Negi & Joshi, 1996). Various government and other agencies are looking forward for suitable approaches and measures for wasteland restoration and afforestation, however, have met limited success (Dhyani, 2014). GBPIHED had identified this important issue in the early days of its establishment in 1988 and based on various R&D inputs presented a package of practice named Sloping Watershed Environmental Engineering Technology (SWEET) (Box - 1).

BOX - 1 **Sloping Watershed Environment Engineering Technology (SWEET)**

SWEET is a R&D based package aimed at to achieve twin goals of ecological restoration of degraded lands and livelihoods enhancement of stakeholders. This package is an integration of simple technologies such as water harvesting, soil conservation, selection of suitable species for wasteland plantation, nursery raising of suitable plants for afforestation, bio-fencing and after care of plantations with stakeholders participation, etc. Community feed-back is taken for ecological and socio-economic suitability of plant species. Also plants are screened for their vigour and eco-physiological parameters. As water is a crucial input for plantation, poly-ponds to store rainfall-runoff are constructed. To avoid cold conditions and frost, poly-pits and poly-tunnels are used for raising saplings. Pits (size= 60 cm x 60 cm x 60 cm) for plantations are filled with gravel free soil, mixed with well-composted farmyard manure @ 3 kg/pit for fast growth of the plants. Bio-composting of weeds and agriculture waste can be utilized to supplement FYM (Source: Anonymous, 1994). This technology was subsequently spread over a number of locations in the IHR through the Integrated Eco-development Research Programme (IERP) of the GBPIHED.

In the subsequent years, GBPIHED had taken up a number of wasteland sites across diverse ecological and socio-economic situations across IHR to demonstrate wasteland rehabilitation models among the rural areas. Based on the data sets and experience gathered across these sites, a set of multi-purpose tree species suitable for wasteland restoration was brought out (Box - 2).

BOX - 2 Suitable Multi-Purpose Trees for Wasteland Rehabilitation

In the densely populated mid-altitude belt of the western Himalayan region, a major issue is the right choice of suitable tree species for wasteland afforestation those could withstand drought and low soil fertility and also have multi-purpose value to cater to the need of 5 Fs (i.e. fuelwood, fodder, fruit, fiber and fertilizer) (Negi & Joshi, 2001). In this region a number of indigenous agroforestry trees and shrubs grow in and around the crop fields and their multi-product value fulfill diverse needs of the rural people (Table 1.1). To understand the growth and survival patterns of these species 10 multi-purpose tree species (MPTs) were planted across six degraded community wastelands located between 1000 and 1500 m asl representing a wide spectrum of ecological conditions in this region under various R&D programmes of GBPIHED. Cumulative data for four years on the growth and survival were compiled and synthesized to recommend a set of suitable MPTs for wasteland restoration (Table 1.1). Mean values of height and survival of the plantations across these six sites revealed that Alnus nepalensis (an early colonizer of moist degraded slopes with Nitrogen fixing capability) ranked Ist in terms of both height growth (241 cm) and survival (74%) followed by Albizia leebeck and Dalbergia sissoo (both N fixer). Height growth recorded for Morus alba, Quercus leucotrichophora, Q. glauca and Melia azedarach was found ranging from 82–125 cm; and survival from 56–78%. The rest of the species were characterized by low height growth < 50 cm, however their survival was comparable to the other set of species. Based on the performance of these MPTs, it can be pointed out that A. nepalensis, A. leebeck, D. sissoo, M. alba and Q. leucotrichophora need to be popularized for large scale plantations for restoration of wastelands in the western Himalaya. All these five species produce fodder and fuelwood and other multi-products. D. sissoo is particularly regarded for its high timber value. The former three species are N fixer and fast growing and also ameliorate soil fertility. M. alba produces feed for tasar silk and used for edible fruits. Mean survival of Q. leucotrichophora, which is generally not encouraged by planting agencies due to its slow growth showed a survival value (41%) about equal to that of the average recorded for all the species planted. A. nepalensis fixes nitrogen (29–117 kg/ha/yr) and regenerates profusely on fresh landslide sites (Sharma & Ambasht, 1984), thus reduces landslide vulnerability; but its fodder and fuelwood are considered inferior. With regards to the overall values viz., villagers need, biodiversity enhancement, soil and water conservation, growth and survival, Q. leucotrichophora was most suitable. G. optiva yields quality fodder (crude protein, 26%) during summer, good fuelwood, fibre (used for rope making) and endures heavy lopping. Apart from height growth and survival, people rightly attach a number of other values to each species. For example, the timber value of D. sissoo is high, M. azederach suits minor timber needs, flower buds of B. 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. Participatory afforestation of these MPTs for restoration of the wastelands in this region thus can be a promising approach. However, in this process understanding of local socio-cultural issues and sensitivity with the local traditions and resources management practices is necessary for the success of the wasteland restoration programme (Negi & Dhyani, 2014).

Table 1.1: Agroforestry trees and their multi-purpose values suitable for wasteland plantation in the western Himalaya

Species	Main use	Minor use	Crude protein (%)	Season of major use
Nitrogen Fixing Trees				
Bauhinia variegata (D)	FD, FR	AG, F	18.1	Winter
Celtis australis (D)	FD, FR	AG	8.2	Summer
Grewia optiva (D)	FD, FR	F	26.1	Winter
Melia azedarach (D)	MT, FR	FD	18.4	Rainy
Prunus cerasoides (D)	SC, S	FR, FD	19.2	Year-round
Quercus leucotrichophora (E)	FD, FR, SC	AG	18.1	Year-round
Non-Nitrogen Fixing Trees				
Albizia stipulata (D)	FR	FD	15.0	Summer
Alnus nepalensis (D)	SC	FR, FD	12.6	Year-round
Dalbergia sissoo (D)	T	FD	9.1	Summer
Ougeinia dalbergioides (D)	FD, AG	MT, M	18.2	Summer

FD - Fodder; FR - Firewood; MT - Miner timber; SC - Soil Conservation; S - Sacred; T - Timber; AG - Agriculture; M - Medicine; F - Fibre

INTEGRATING SCIENCE WITH RELIGION FOR WASTELAND REHABILITATION

A reconciliation of the interests of local communities (immediate tangible benefits) and the concern for ecology and biodiversity (long-term intangible benefits) is of utmost importance for sustainable rehabilitation of degraded wastelands. In the high altitudes of IHR, which are not inhibited by people but visited for religious purpose, participation for afforestation is a challenging task. In such a situation blending science with religion was considered an appropriate approach for wasteland rehabilitation.

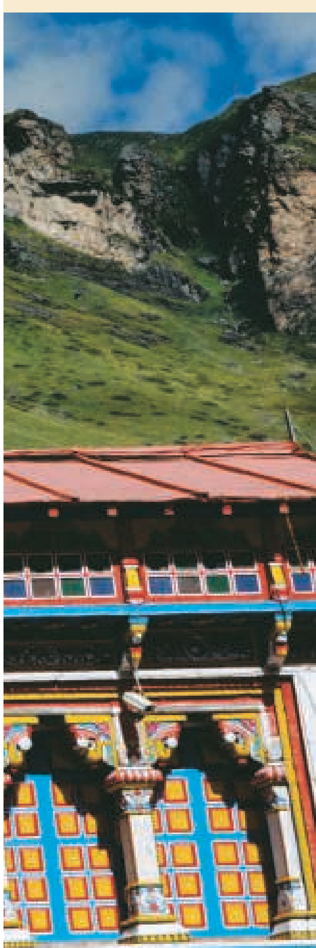
01 CASE STUDY

P.P. Dhyani
GBPIHED, Almora

Fig. 1.2: Initiation of Badrivan programme at Badrinath in 1993

This case study deals with Badrinath (3,133 m asl), the major Hindu shrine in the IHR, lies in a remote valley of Garhwal, Uttarakhand which is now visited by approximately 7,00,000 pilgrims every year from all over India. In Bhagwat Purana (a Hindu epic), it is mentioned that Adi Guru Shankaracharya named the forest of Badrinath 'Badrivan' around 815–820 AD because of the predominance of two trees, Badri (*Juniperus macropoda*) and Bhojpatra (*Betula utilis*), and a shrub species, Badriphal (*Hippophae salicifolia*). Regrettably, the sacred forest largely disappeared due to ever increasing biotic pressure. In the recent past, many organizations attempted plantation in this area but with little success due to inappropriate selection of plant species, tender and insufficiently hardened seedlings, unsuitable soil conditions and the absence of after care of plants from the harsh winter season due to heavy snowfall. Learning from the past experience, we utilized the religious authority of the chief priest of the Badrinath shrine and involved pilgrims and local priests/ inhabitants, army personnel in the reforestation programme under the name of "Badrivan Restoration Programme" (BRP) (Fig. 1.2). On the appointed day (16th September 1993), 20,000 tree seedlings brought from distant localities were blessed by the chief priest, as 'Briksha Prasada' and also gave an inspirational pravachan highlighting the Hindu beliefs and myths about the physical and spiritual importance of trees and urged the pilgrims to plant seedlings as an act of devotion.

As a follow-up to this and subsequent 6 such ceremonies, pilgrims and various stakeholders planted saplings in Badrinath valley. Subsequent harsh winter with severe snowfall resulted in mortality of many of the seedlings planted. Taking a positive cue from this 'failure', a plant nursery was established at Hanumanchatti (near Badrinath) to raise suitable native trees, acclimatized to the prevailing climatic conditions and snow protection measures to the tender plants were also put in place. Thus, our new approach and measures resulted in the survival of approximately 21,670 tree and shrub saplings, up to November 2001; most of the seedlings had attained the size of more than 3 meters. Before our initiation of BRP less than 100 trees were found growing in the entire Badrinath valley.



Successful revival of Badrivan inspired the army (Garhwal Scouts; the only year-round residents of Badrinath) to replicate our approach during 1998-2000 to establish Rakshavan (a defence forest) on a 10 ha highly degraded land at Dhantoli (Badrinath) with the participation of army personnel, locals and pilgrims. A nursery of high-altitude trees was established by them to use the hardened seedlings for plantations. Following tree plantation ceremonies 16,697 hardened saplings of various high-altitude trees and shrubs were planted. Out of these, 15,299 saplings survived till March 2000 measuring up to 3 meters height. The Rakshavan approach was further replicated by the Indian army at Siachen base camp (named as Siachen Ecological Park) in the Nubra valley of J&K.

REPLICATION OF THE BADRIVAN MODEL AT KOLIDHAIK

Inspired from the BRP, a follow-up programme was taken up to create a Sacred Forest for eco-restoration and biodiversity conservation at Kolidhaik village, Lohaghat (Kumaun region of Uttarakhand) in 2004 with the participation of local communities (Fig. 1.3 A-D). This village (1,740 m) inhabited mainly by Hindus and Muslims had a large barren and highly degraded community land. GBPIHED team approached the Imam of Kolidhaik mosque and the Priest of Kail Bakriya temple and Van Panchayat Sarpanch to motivate the villagers to establish a sacred forest in this barren land. As a follow-up, the village people offered 5.6 ha degraded community land for this purpose from where no benefit (e.g., fodder, fuel-wood and minor timber, etc.) was being accrued by them. On 28 August 2005, about 8,000 well-established tree saplings blessed by both the religious authorities were planted by the villagers. Subsequently, 3 more ceremonial plantings were done, and as a result of subsequent up-keep by the villagers, a total of 6,200 seedlings of about 20 promising tree species had survived up to May 2007. Most of the seedlings have now attained the size of more than 3–4 meters. Before initiation of this programme, only 157 trees of 3 species were found growing in this degraded land. This sacred forest is dedicated to God Kail Bakriya (the local deity), and cutting of trees is banned from the forest and only fodder collection is allowed. Till 2007, 88 families of 6 nearby villages, on an average, regularly got 2 quintal green fodder per year from this land, which has resulted in considerable time and labour saving that was otherwise routinely spent by the women for the collection of green fodder. Scientific data obtained on the eco-physiological health of the planted trees confirmed the suitability, in particular, of 5 tree species, namely Utis (*Alnus nepalensis*),

Fig. 1.3:
(A) Kail Bakriya hill project site at Kolidhaik village in Lohaghat, Uttarakhand, India; (B) Ritual plantation at the project site for establishment of a sacred forest; (C) Planting in Kail Bakriya sacred forest; (D) Fodder collection by rural women from the sacred forest.

Banj (*Quercus leucotrichophora*), Phalyant (*Quercus glauca*), Bhimal (*Grewia optiva*), and Kharik (*Celtis australis*) for reforestation/afforestation of degraded community lands in this region. This sacred forest development model manifests a beautiful example of communal harmony wherein Muslims joined hands with the Hindus. These examples demonstrate the importance of blending science and religion for environmental protection and biodiversity conservation. This unique approach has now been cited internationally. The IUCN has also included Badrivan approach in its guidelines for planning and managing mountain protected areas (Bernbaum, 1995; Dhyani, 2004).

AGROFORESTRY FOR REHABILITATION OF CULTURABLE WASTELANDS

Development of agro-forestry on degraded community lands is one way to achieve land rehabilitation. This case study deals with long-term (over a period of 20 years) R&D work on developing an agroforestry model on a 14 ha wasteland (6 ha abandoned culturable land and 8 ha highly degraded land) of Bansbara village (1200 m asl) of Rudraprayag district in Garhwal Himalaya (Uttarakhand) (Fig. 1.4).

02

CASE STUDY

R.K. Maikhuri, L.S. Rawat, & V.S. Negi
GBPIHED, Garhwal Unit

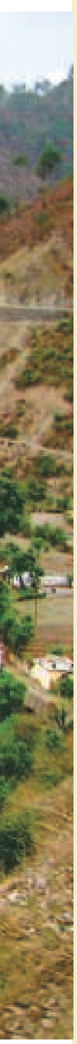


Fig. 1.4: Condition of Bansbara village community waste land before (left: 1991) and after (right: 2012). **Top:** AAL site **Bottom:** HDL site

In this case the tree species for plantation were selected based on the priority of local people/women to cater to the need of fuel wood, fodder and other products. Thus *Boehmeria rugulosa, Grewia optiva* and *Ficus glomerata* were considered to be the best quality fodder trees, *Albizzia lebbek*, *Celtis australis* and *Dalbergia sissoo* as the best quality timber trees, and *Pyrus pashia* and *Sapium sebiferum* as the best quality fuelwood species. Ten-to-twelve-months-old saplings were planted at regular intervals at these two sites in July 1991. During the first two years after plantation, vegetables including spinach (*Spinacia oleracea*), radish (*Raphanus sativus*), rai (*Brassica juncea*), lady's finger (*Hibiscus esculentus*), brinjal (*Solanum melongena*), french bean (*Dolichos* spp.), cucurbits (*Cucurbita maxima*), bitter gourd (*Momordica charantia*), sweet gourd (*Cyclenthera pedata*) and sponge gourd (*Luffa cylindrica*) were grown on the culturable wasteland. From the third year onwards when considerable shade was created by the canopy of planted trees, mustard (*Brassica campestris)*, wheat (*Triticum aestivum*), lentil (*Lens esculenta*), adjuki bean (*Vigna angularis*), cow pea (*V. unguiculata*) and pigeon pea (*Cajanus cajan*) were grown. Thus, a total of 6 ha of degraded land was transformed into a well-developed agroforestry model which is contributing in reducing drudgery of women of Banswara village by supplying fuel, fodder, timber along with cereals, cash crops, spices, etc. (Maikhuri et al., 1997).

Regular monitoring of the plantations/ crops at these sites was made. After 20 years, average survival at the abandoned agricultural land (AAL) site was 87% compared to 51% at the highly degraded land (HDL), with 970 trees ha^{-1} at the former and 564 trees ha^{-1} at the latter site. Across the various planted tree species height growth varied from 5–17 m/tree and biomass stock varied from 20–160 t/ha (Figs. 1.5 & 1.6) after 20 years of plantation. Fodder grass harvested from the site amounted to 14.4 t ha^{-1} over the entire period. Over 20-year period, aboveground carbon pool increased by 15.6 times at the AAL site as compared to 8.0 times at the HDL site, with the mean rate of carbon sequestration of 2.09 t C ha^{-1} $year^{-1}$ at the AAL site and 0.95 t C ha^{-1} $year^{-1}$ the HDL site (Maikhuri et al., 2000). This R&D site of GBPIHED served as demonstration model for many training programmes sponsored by different development agencies and Govt. line departments, NGOs, etc. The earlier barren and waste land and abandoned cropland has come up as an inspiring model and requires to be implemented under similar agro-climatic conditions elsewhere in the region. Participatory afforestation of community wastelands was also undertaken in other parts of western Himalaya (Box – 3).

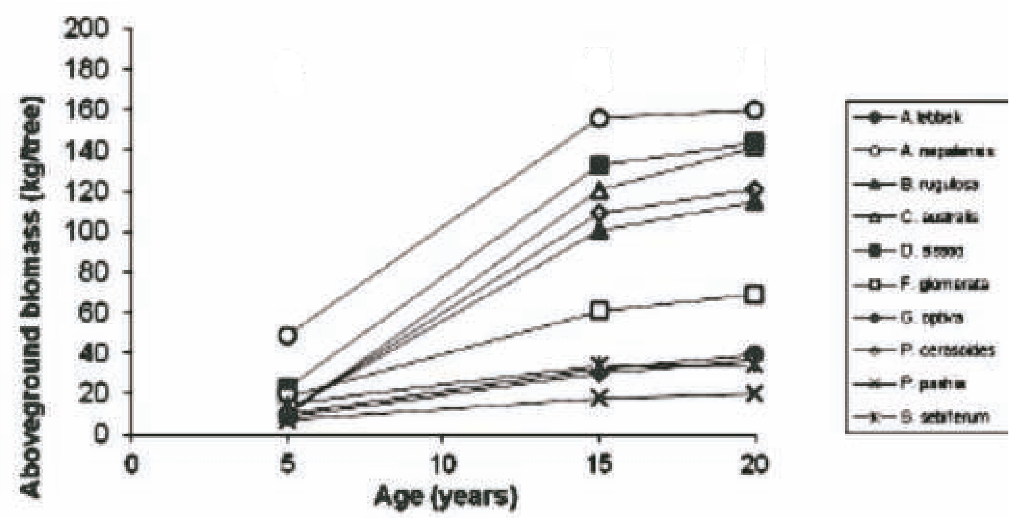


Fig. 1.5:
Above ground biomass of traditional agroforestry tree species after twenty years of plantation at the AAL site in Banswara

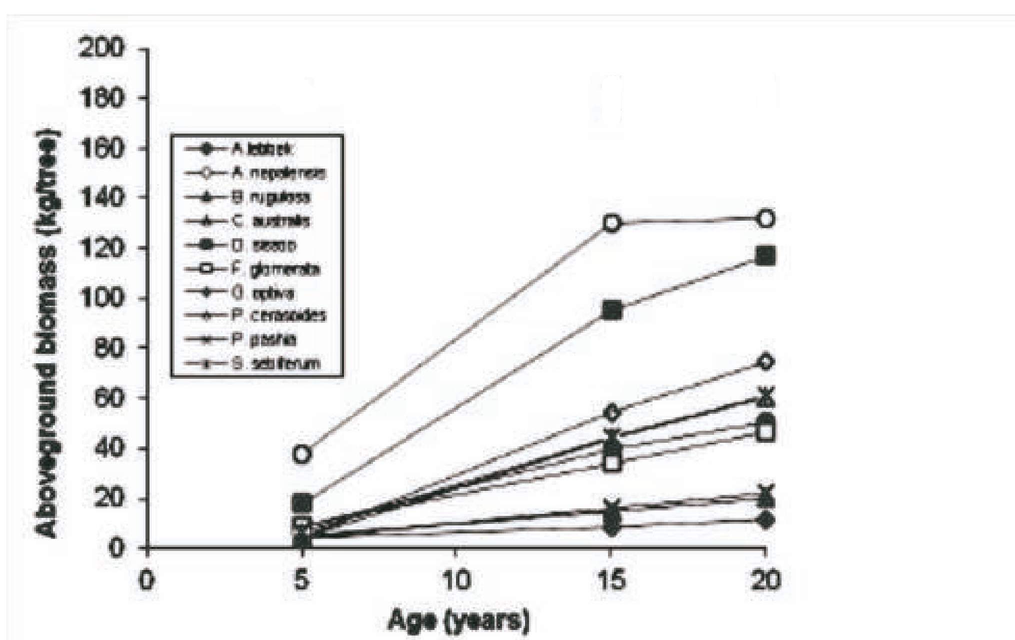


Fig. 1.6:
Above ground biomass of traditional agroforestry tree species after twenty years of plantation at the HDL site in Banswara

BOX - 3 *Participatory Afforestation of Community Wasteland*

In this study, trust building with the local communities made them understand about the long-term benefits of wasteland rehabilitation. With this premise, a community wasteland (open grazingland) Balgara (9 ha area under partial cultivation until 1975) in Arah village (Distt. Bageshwar in Uttarakhand) belonging to 68 households was taken up in 1992 by GBPIHED for rehabilitation (Fig. 1.7). To boost up the participation in project activities we arranged video-shows of participatory activities and tutorial classes for school going children. To begin with, a participatory proposal was developed with Van (forest) Panchayat wherein the role and contribution of villagers, benefit sharing mechanism, access to resources, and post project management by the Van Panchayat were defined. Activities like plantation of MPTs, protected cultivation, water harvesting in poly-ponds, small scale fish farming, cultivation of high yielding crop varieties and nutritious fodder grasses, nursery development, etc. were executed to provide short-term benefits and to encourage participation of the villagers training camps on appropriate technologies for capacity building of the stakeholders were organized.

As a result of various activities and build up in soil fertility, ground grass cover and canopy of planted fodder and firewood species continued to increase. The rainwater runoff and soil loss from this wasteland was reduced by over 60% after 12 years of project initiation. A total of 2.7 tons (equivalent to Rs. 4,050) of fodder grass was harvested during post monsoon period in 1993, which increased up to 16.4 tons (equivalent to Rs. 75,020) in 2006. Green fodder leaves harvested from the fodder trees also increased from 12 head loads in 1998 to 136 head loads in 2006; most of the families could thus save up to Rs. 5,000 per year, and a gradual reduction in women's workload was achieved. It is worthwhile to mention that young generation started to plant bamboo despite a common myth associated with this "cradle to coffin" timber among the villagers in this region and achieved 100% survival. This success story was full of stumbling blocks and frequently required ingenuity to overcome mindsets that involved adjustments in working approach to bring about a change in attitude of the village community (Kothyari & Bhuchar, 2010).

Fig. 1.7: Saplings of selected tree species being transported by the village women and their plantation by people of Arah village (Distt Bageshwar)

[Contributors: B.P. Kothyari & P.P. Dhyani, *GBPIHED, Almora*]

WASTELAND RESTORATION THROUGH SILVI-PASTURE DEVELOPMENT

In the western Himalayan mountains people depend upon community lands for fuelwood and fodder for subsistence agri-sylvi-pastoral mode of living. Due to increasing pressure of cattle grazing and biomass harvesting in many areas the community land has degraded and has turned into wasteland, supporting only inferior trees and grasses. These community wastelands are prone to soil erosion, rapid depletion of soil fertility and have very low water retention capacity. Therefore, such areas has to be brought under silvi-pasture management introducing promising fodder species to support livestock and also to restore soil fertility and achieve soil and water conservation (SWC).

In a project funded by Ministry of Rural Development, 40 ha community wasteland was taken up for silvi-pasture development in Uttarakhand (20 ha in Dobh-Srikot and 5 ha in Bhimli villages in Pauri-Garhwal, and 15 ha in Katarmal village in Almora district) (Fig. 1.8) after detailed consultations with the village communities. Subsequent to their willingness, these sites were cleared up for weeds and bushes, and measures such as, gully plugging, land leveling, maintenance and repair of terrace risers and cropfield bunds were executed for SWC. A nursery was also developed, in which 8990 plants of different fodder species (viz., *Acacia catechu, Albizia stipulata, Bauhinia retusa, Dalbergia sissoo, Melia azedarach, Ougeinia dalbergioides, Quercus leucotrichophora, Sapindus mukorossi, Sapium sebiferum* and *Lucanea leucocephala*) were raised. Plantations of fodder trees, shrubs and grasses were undertaken across these three sites during 2002–2005, also the plant mortality was filled up

Fig. 1.8: Silvi-pasture developed in Bhimli village (Pauri-Garhwal)

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subsequently. At the Dobh-Srikot site (3429 saplings planted) the maximum survival after two years of plantation was recorded for *D. sissoo* (88%) and *B. retusa* (86%) and the minimum for *G. optiva* (8%), with mean survival 45%. The maximum height was recorded for *A. lebbek* (498.9 cm) and the minimum for *T. ciliata* (47.9 cm) for *A. catechu* (41.7 cm). At the Katarmal site, out of the 850 fodder trees planted maximum survival was recorded for *Q. leucotrichphora* (94%) and minimum for *Henia* spp. (24%), and the mean survival was recorded 68.2%. Mean height of the plants at this site recorded after one year was 37.8 cm. Similarly, at Bhimli site 3600 fodder trees were planted. Apart from fodder trees fodder grasses planted at these sites were: *Cassia tora, Cenchrus ciliaris,* Fodder maize *Crotolaria juncea, Panicum maximum, Prosopis juliflora, Styloxanthus hamata,* and *Trifolium alexandrium*. At the Dobh-Srikot site, total harvest of grass fodder after one year was 100 Q. Next year the luxuriant growth of fodder grass was sold by the stakeholders in Rs. 1000. Total fodder harvest from this site was recorded appx. 750 Q. Similarly, at Katarmal site fodder harvested by the stakeholders was recorded 214 Q. Some good quality native grasses (*Apluda mutica, Chrysopogon fulvus, Digitaria cruciata, Setaria* spp.) were also regenerated within these sites through plantation of root stock from the nearby areas. Thus the fodder productivity of these wastelands rose from 0.5 to 4 t ha^{-1} through silvi-pasture development. To achieve SWC digging of trenches along contours (numbers 1000, total length of about 5 km), and seed sowing of fodder grass on the cut-and-fill side of the trenches was executed in these sites. Soil fertility (30 cm depth) of these sites was raised substantially (soil carbon from 0.44% to 0.96%), organic matter (from 0.75% to 1.66%) and soil moisture from 13.2% to 20%. These sites revived and served the purpose of silvi-pasture demonstration and training in the region among a variety of stakeholders. Also, to revegetate the cold desert regions of Himachal Pradesh, a technology based on willow shoot cuttings has been studied by the GBPIHED faculty at Himachal Unit (Box – 4). Similarly, in the Garhwal hills fodder bank development in the community wasteland successfully motivated the women and reportedly increased the milk yield of livestock (Box - 5).

BOX - 4 Willow Shoot-Cuttings Can Revegetate Cold Deserts

Willow (Salix fragilis L.) is an important tree for fodder, fuel wood, small timber, etc. in cold deserts in HP. Young saplings of Willow mostly fail to establish due to snow deposits, prolonged sub-zero winter temperature and xeric soils. As an alternative strategy, it is extensively propagated through shoot-cuttings traditionally along the margin/edges of the terraced fields. In this method, healthy trees are pollarded during winters, leaving 4–5 coppices on top of main trunk and used for making shoot-cuttings to raise new plantations. Normally 3–5 shoot-cuttings of similar height, thickness and age are tied together in a bunch and planted in a pit (75 cm depth and 45 cm width) during March–April immediately after snow melt in the moist soil. To protect planted shoot-cutting from grazing animals, they are wrapped with gunny bags or branches of locally available seabuckthorn (Hippophae rhamnoides) and wild roses. New plantations are regularly irrigated on weekly interval during summer season. We studied survival and growth of Willow cuttings grown at Khoksar (3200 m), Jahlma (3000 m), Hinsa (2700 m) and (Kuthar 2600 m) villages of cold desert of the Lahaul valley. The highest survival was recorded at Hinsa (80.3±10.53%) followed by Jahlma (73.75±12.11%), Kuthar (68.6±11.45%) and lowest at Khoksar (52.4±10.38%). The emergence of a number of sprouts from newly planted shoot-cuttings was highest at Hinsa (23.03±.61) followed by Jahlma (19.83±1.14), Kuthar (17.58±1.07) and minimum at Khoksar (14.57±1.99). Willow shoot-cuttings from healthy parental material can thus be suitably used for wasteland plantations in cold desert environment.

[Contributor: S.C.R. Vishwakarma, *GBPIHED, Almora]*

BOX - 5 **Fodder Bank Development on Community Wasteland**

In the Western Himalaya agriculture along with animal husbandry is the principal occupation and source of livelihood for over 70% population. Fodder is thus the prime resource that turns the wheel of agriculture in the region. Insufficient fodder availability from arable land leads to as much as over 60% dependence upon the forests (trees, shrubs and herbaceous ground flora). The ultimate burden of fodder collection rests on the already overburdened women folk. Keeping this in view, a Fodder Bank was developed in Maikhanda village cluster in District Rudraprayag, Garhwal Himalaya by taking up 6 ha village community wasteland and a small piece of arable land for raising nursery. Subsequently, meetings with village people and women folk were held for their participation in species selection, pit digging, fencing, plantation of fodder species and aftercare (Fig. 1.9). Among a total of 48 local fodder species (including trees, shrubs and herbs) the preferred species for fodder by locals were the ones having high crude protein and organic matter digestibility. Indigenous grasses considered useful for enhanced lactation and better nutrition viz., Ringal Bamboo (Chimnobambusa falcata, Thamnocalamus spathiflorus, Arundinaria spp.), tree species (Bauhinia variegata, Celtis australis, Debregeasia salicifolia, Ficus nemoralis, F. auriculata, F. subincisa, Morus alba, Quercus glauca, Q. leucotricophora) and introduced grass species (Napier, Pennisetum purpureum, Joint star, Makuni, Cox foot, etc.) were planted during monsoon (2009–2012). A rain water harvesting tank (12×5 ft length, width and 4 ft depth) was constructed around it a nursery was also developed that provided saplings of fodder species for plantation. Five hundred saplings each of F. auriculata and D. salicifolia and 250 saplings of F.

Fig. 1.9: Motivation and capacity building of village women for fodder bank development (Right: Napier grass grown in the waste land)

A typical landscape with nicely maintained rainfed terraces in Kosi valley, Almora

nemoralis) were mass propagated and successfully planted on fodder bank site. Napier grass proved to be very successful in terms of fodder yield (Fig. 1.9) as 65 women of Maikhanda village reported 8 times harvesting and stall feeding of Napier grass to their milking animals every 2 months from June 2010 onwards from the fodder bank, thus saving about a week to collect fodder from forests. Milk yield of the animals in 16 households (among 65 households of Maikhanda) reported to be increased due to feeding the nutritive grasses, particularly Napier, D. salicifolia, F. auriculata and M. alba. Fodder supply enhanced in the village and reduced the fodder deficit. For example, during winter the fodder harvest was computed to be 7,488±199.36 kg/HH that increased by 11,342±163.23 with the development of fodder bank (Dhyani & Maikhuri, 2012). Training workshops were also organized for women folk and the Fodder Bank was handed over to women self help group (Mahila Mangal Dal) of the villages on the completion of the project in 2012. So, the entire Maikhanda village is now having rich fodder source on their wasteland with active women involvement.

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PARTICIPATORY REHABILITATION OF BHIMTAL LAKE CATCHMENT

GBPIHED implemented a project entitled, "Participatory Management of Bhimtal Lake Catchment", (funded by Govt. of Uttarakhand under the National Lake Conservation Plan of MoEF&CC, Govt. of India) in Bhimtal lake catchment for afforestation of degraded land involving local communities vis-à-vis livelihood enhancement. To achieve the aim, vegetative and engineering measures were employed in about 55 ha degraded community land using four land use models (viz., Multi-purpose tree species; Silvi-pasture development; Aromatic plants cultivation; and Agri-horticulture). In the Multi-purpose tree species model, a total of 38,322 saplings of more than 20 multi-purpose species were planted on the barren hill slopes those registered 16–37% mean survival after 5 years. Manipuri Oak (*Quercus serrata*) recorded maximum survival (47.0%), followed by *Grewia optiva* (44.3%), *Q. leucotrichophora* (32.3%), *Bauhinia* spp. (30.9%) and minimum by *Celtis australis* (15.7%). Highest growth was recorded by *Alnus nepalensis* (211 cm height; 5.6 cm collar diameter), followed by *B. retusa* and *Q. leucotrichophora*. Among the shrubs, *Flamingia macrophylla* and *Tephrosia candida* germinated very well with 40–45% survival.

In the degraded sites, soil depth, soil fertility and rain water retention were very poor due to rock outcrops and fast slope and even digging a pit for planting was difficult. To overcome this challenge contour trenches (5–6 m long; 1–1.5 ft wide at 5 m interval) were dug out across 1378 m length and seeds of shrub species (viz., *Desmodium rensonii, Flamingia macrophylla, Indigofera anil, Leucenea leucocephala* and *Tephrosia candida*) were sown on the sloping ends of these contours in double hedgerow to arrest soil loss and increase rainwater retention. A community nursery was established in which 2000 seedlings of *B. retusa, Q. leucotrichophora, G. optiva, C. australis*, etc. were raised by the women group, and through a buy-back system they earned Rs. 3000 during 2008. Early (e.g., *A. nepalnesis*) and late successional (e.g., *Q. leucotrichophora*) species were planted in combination. Also, some soil amendments and modifications in planting techniques were done. To ensure survival of the plants each pit was filled with mud along with farmyard manure (20:80 ratio) and biocompost (IG-Hariyali). Plantation was done in earthen pots (pitchers) of 16×12 inch height × breadth with an opening of 4 inch diameter or Jute-bags of 3×2 ft size and buried in the pits and filled with soil and FYM in 20:80 ratio to ensure requisite substratum for plants during initial establishment by improving soil fertility and moisture regime. Also fodder grass such as Napier, Broom grass, Tall fescue, Rye and Cocks foot were sown in between the two rows of the pits to check soil erosion and increase water infiltration. Napier and broom grass had shown good survival and growth and until 2010, 214 head loads (one head load 35–40 kg costing Rs. 40) of fodder were harvested from this site.

Similarly, under the Agro-horticulture model, 13,876 saplings of improved varieties of different fruit trees such as Pear (var. Victoria), Apple (var. Golden delicious, Red sheaf and Organ spear), Peach (var. Red zone), grafted Walnut, Lemon, Apricot, Orange, Mango, Guava, Aonla and Pomegranate were planted in about 35 ha area belonging to 129 households of the catchment and recorded about 65% survival in December 2010. The Peach and Pomegranate planted in 2005 have started bearing fruits.

Under the Aromatic plants model, 23000 slips of Lemon grass (*Citronella* spp.) treated with Bavistin fungicide were planted in wasteland soil amended with biocompost (IG Hariyali) and neem-cake to supplement soil fertility, and Agrisorb plus for moisture retention to boost germination and growth of the plants. The root slips registered 71% survival and 1.083 t lemon grass was harvested from this site during 2008–09 yielding 8.7 litre of lemon grass oil with an average 0.80% oil content.

Among the SWC measures, 24 roof-top rainwater harvesting tanks (8000 liter capacity each) and three polyponds, 10 water percolation tanks (18 × 10 × 8 ft), 34 gabion structures and several contour trenches (5×1×2 ft) were constructed. To harvest the rainwater and improving soil moisture a number of trenches (5 × 1 × 2 ft), 10 water percolation ponds (18 × 10 × 8 ft), and 4 polythene lined rain water harvesting tanks were constructed in different plantation sites (Fig. 1.10). Due to availability of water the number of vegetable growers increased from 2 in 2005–06 to 43 in 2011. The net return obtained from vegetables was found ranging from Rs. 2000–29000 per farmer per year. Farmers acknowledged the gains in water use, improvement in production and income from the land they irrigated from the rooftop water tank (Table 1.2). Trainings were imparted on off-season vegetable cultivation, improved composting, contour hedgerow plantation, food processing and preservation, bio-briquetting, candle, scented sticks, fancy bags and alpna making among the marginalized women farmers/unemployed youths. Demonstrations on biobriquette making, poly house, vermi composting and zero energy cool chamber were established at Jan Sikshan Sansthan (an HRD Ministry supported Institute in Bhimtal) for imparting training. The project has been successful in sensitizing the people of the catchment through our various demonstrations for

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wasteland plantation, lake conservation and sustainable utilization of resources. However, rapid urbanization in the lake catchment and influx of uncontrolled tourists remains a challenge to restore the aesthetic value of lake and surrounding catchment areas and improved its water quality (Khanka & Jalal, 1985).

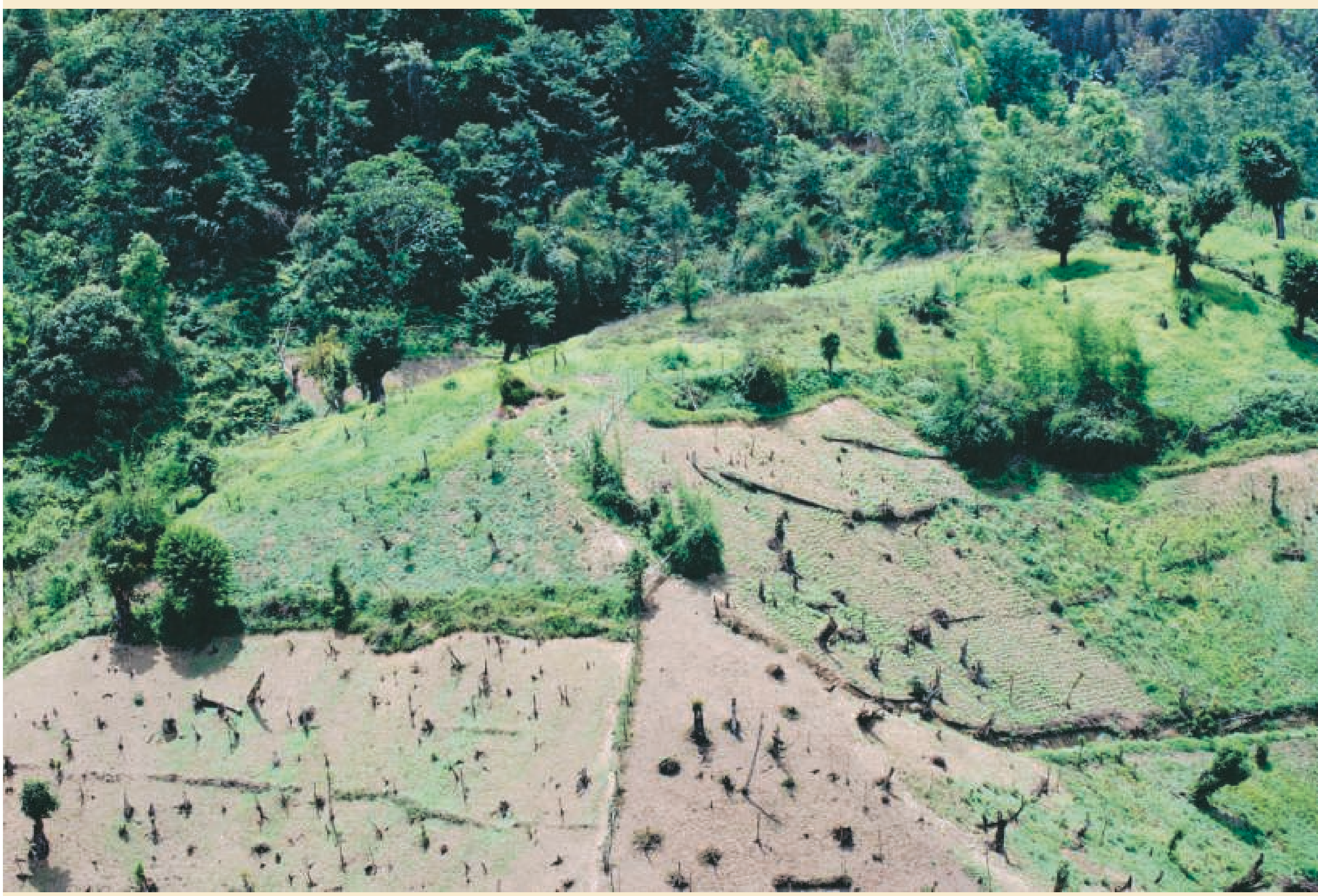
Table 1.2:
Perception of beneficiaries about roofwater harvesting tanks constructed in 2009-10 in Bhimtal
(*1 ha = 50 Nali)

Name beneficiaries constriction year	Use of tank water (%)			Improvement in production (%)	Improvement in income (%)	Area irrigated (Nali)*
	Winter season	Summer season	Rainy season			
Mrs. Tulsi Joshi	90	80	40	95	100	7
Mr. Harender Satwal	60	60	40	70	40	6
Mrs. Deepa Mehara	80	70	55	50	20	12
Mr. Mohan Singh	80	90	60	15	15	11
Mr. Devi Datt	65	80	70	25	25	11
Mr. Bhuwan Chandar	60	80	60	30	30	7
Mr. Khim Ram	60	80	70	100	100	6
Mr. Bhuwan Arya	60	80	70	100	100	5
Mr. Reva Dhar	80	90	60	90	100	12

Fig. 1.10:
Rain water harvesting in polythene lined thanks in the plantation sites
Left:
Luxuriant growth of Alnus nepalensis with fodder grass

CONTOUR HEDGEROW FARMING SYSTEMS TECHNOLOGY FOR NE REGION

Shifting cultivation in north-east India is a major environmental issue. With the increasing population and shortening of jhum cycle (15-20 years in the past to <5 years now) crop yield has dropped down drastically as recuperation of soil fertility is greatly weakened due to manifold increase in soil erosion. Thus how to build the soil fertility and control soil erosion remain the two major challenges. To address this issue, the NE Unit of GBPIHED devised a contour hedgerow farming system technology (CHFST) that involves planting two rows of nitrogen-fixing native hedge species (viz., *Crotalaria tetragona, Desmodium rensonii, Flemingia macrophylla, Indigofera anil, Leucaena leucocephala* and *Tephrosia candida*) along the contour lines at a distance of about 1.5–2.0 m, which may depend on the slope of the furrow. The space between the contour hedgerows, i.e., the alley, is used for food crop production (Fig 1.11). Two planting lines at a distance of 15 to 30 cm (depending on the slope steepness) are prepared on the contour lines for growing food crops. The seeds of hedge row species, before sowing are soaked in water. Replanting and gap filling was done to make the hedgerows dense.



05
CASE STUDY

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In our experimental demonstration site, the mulch of these hedgerow species when applied to alleys improved soil fertility and crop yield. Soil fertility (total nitrogen) in the mulched plots increased from 0.165% to 0.173% and crop yield of tapioca, cauliflower, lady's finger, chilies, tomato and zinger increased from 20% to 100% (Sundriyal & Jamir, 2005). This technology also ensured adequate control of soil erosion (about 50% reduction in average annual soil loss over control over a period of 3 years (Fig. 1.11), help restore soil structure and conserve soil moisture. CHFST meets the requirement of fodder, fuel and timber along with improved crop yield and income generation and thus can be applied by marginal farmers in culturable wastelands using local resources. It also provides green manure and reduces fertilizer input in the field. This technology is being replicated by NE Unit of GBPIHED in other parts of the NE region and holds promise for large scale replication in the soil erosion prone forest blanks, left after jhum cultivation (Fig. 1.12).

Fig. : 1.11
Planting nitrogen fixing shrubs along contours and subsequent growth of shurbs

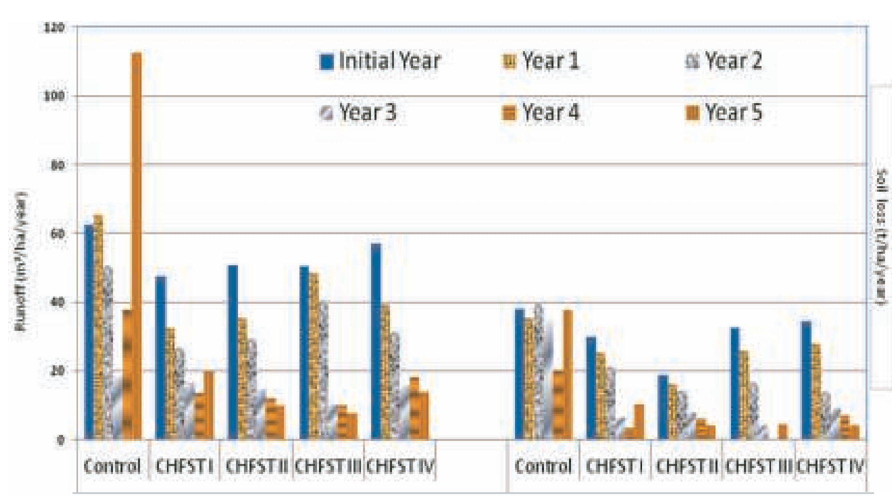

Fig. : 1.12
Runoff and soil loss from CHFST model executed in Doimukh (Itanafar)

REHABILITATION OF DEGRADED LAND THROUGH AGRI-HORTICULTURE

Under this NAIP funded project rehabilitation of degraded land along with enhancement of rural livelihoods was attempted through people's participation in five villages of three clusters viz., Jamnikhal, Manjgaon and Hadiya of Tehri Garhwal (Uttarakhand). Before making any interventions, meetings and discussions were held with local communities and nearly 300 households were consulted. The community people then offered 18 ha community waste land (9 ha of village common lands for horticulture development and 9.5 ha land for silvi-pasture development) and a MoU was signed with the village community. To develop silvi-pasture model, 16000 seedlings of the MPTs viz., *Amomum subulatum, Bauhinia purpurea, Cinnamomum tamala, Celtis australis, Grewia optiva, Emblica officinalis, Melia azedarach, Morus alba, Quercus glauca, Syzygium cumini, Sapindus* spp. and *Pennisetum purpureum* were planted. Under the horticulture model, a total of 3900 seedlings of improved varieties of various fruit trees viz., Pear (*Prunus persica*) – 350, Apricot (*Prunus armenica*) - 1100, Walnut (*Juglans regia*) - 800, Apple (*Malus* sp) - 200 and Peach (*Pyrus communis*) - 400, and Plum (*Prunus domestica*) - 600 were planted in three village clusters. To irrigate the plants, two water harvesting tanks with 12500 liters capacity were constructed in Manjgaon and Jamnikhal village clusters. In horticultural model, Plum trees showed the maximum survival (88%), followed by Walnut (87%), Apple (87%), Apricot (83%), Peach (79%), and Pear (77.3%). Among the sylvi-pasture model *Q. glauca* had maximum survival (79%) followed by *Sapindus* spp., *G. optiva* and *M. alba* (76%), *S. cumini* (71%), *B. purpurea* (69.3%), *C. australis* (69%) and *M. azedarach* (64%). Local people were involved at each step during implementation of the programme while developing their capacity through participatory approach. Initially, the farmers were mostly interested in earning income from the labour activities in field-based activities. They got interested once the silvi-pastoral models started to produce fodder and grasses. The community took responsibility of watch and ward on rotation. A cooperative was formed at the village level for harvesting and marketing the fruits. The returns were shared among the group members. Farmers harvested around 775 kg of apricot, 1240 kg of pear and 1640 kg of plum from the entire land area with the total value of fruit harvest estimated at Rs. 1,99,620. In the silvi-pastoral model after three year, a total of 2134 kg/ha green fodder (grass) was harvested worth Rs. 4268/ha. This pilot initiative in erstwhile wasteland helped in improving livelihoods as well as arresting land degradation. Neighbouring farmers have now started to adopt and replicate this horticulture model in their abandoned lands.

A similar intervention was undertaken in Dharaunj (14 ha) and Gumod (6.5 ha) villages of Champawat district of Uttarakhand to rehabilitate the community waste and non arable lands with fast growing and high yielding nutritious fodder species under the NAIP funded project (Fig. 1.13). Plantation of multi-purpose tree and fodder species were made on the basis of the villagers' preferences as well as on ecological suitability of the species. Twelve multi-purpose tree species viz., *Alnus nepalensis, Bauhinia purpurea, B. rugulosa, C. tamala, Ficus palmata, M. alba, Phyllanthus emblica, Pittosporum nepaulensis, Quercus glauca* and *Q. leucotricophora* were raised as mixed plantations to ensure conservation of

Fig. 1.13: Participation of local people for planting of MPTs in Champawat

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GBPIHED, Garhwal Unit; [1]GBPIHED, Almora

biodiversity and provisioning of nutritious fodder to livestock. In addition, medicinal plants such as *Sapindus mukorossi* and *Terminalia chebula* were also planted. Nutritious grasses like *Pennisetum purpureum* (Hybrid Napier grass), *Thysonalena maxima* and *Cymbopogon citratus* (Lemon grass) were planted along slopes to prevent soil erosion and rain water runoff and enhance fodder yield. Bio-engineering measures like terracing, bunding, grassed waterways, gully plugging, check dams, etc. were adopted aiming at SWC. Seven rainwater harvesting tanks were constructed for irrigation. As a result of these sylvi-cultural activities, survival rate of the MPTs was recorded 80–90% in these project sites and fodder yield was increased by 4–6 times within a period of 4 years. The project has thus helped in enhancing awareness regarding management of natural resources and apart from participation in the wasteland rehabilitation. In similar other R&D projects of the Institute village people were given polyhouses as a demonstration for growing off-session vegetables and earned good income (Box -6).

BOX - 6 **Income Generation Through Vegetables Cultivation in Polyhouse**

In Patharkot village (Distt. Almora) seven polyhouses were built by the progressive farmers in which off-season vegetables were grown. Average annual income from the vegetables (self consumed + sold) was around Rs. 3800.00 (Table 1.3). Also in this village a 5.6 ha community waste land was planted with 4220 fruit trees those recorded 38% survival; whereas 360 fruit trees those distributed to village people recorded 60% survival after one year. Also a total of 6115 fuel/fodder saplings were planted in the village community land that recorded 48% survival with a standing biomass of about 15497 kg.

Table: 1.3
Vegetable production and income generation through poly houses in villages of Patharkot

Month	Vegetable grown	Production (kg or bundle)	Consumption/Sale				Total income (Rs)
			Self consumed (kg or bundle)	Cost of self consumed (Rs)	Sold (kg or bundle)	Income from market (Rs)	
Aug-Sep 2010	Radish	15	8	120.0	7	105.0	225.0
	Brinjal	20	10	100.0	10	100.0	200.0
	Bell pepper	15	10	150.0	5	75.0	225.0
Oct-Nov 2010	French beans	20	10	220.0	10	220.0	440.0
	Tomato	10	2	36.0	8	144.0	180.0
	Brinjal	15	5	80.0	10	160.0	240.0
	Radish	25	10	120.0	15	180.0	300.0
Dec-Jan 2010-11	Spanich	20	10	30.0	10	30.0	60.0
	Coriander	20	10	30.0	10	30.0	60.0
	Fenugreek	20	8	24.0	12	36.0	60.0
Feb-March 2011	French beans	32	12	240.0	20	400.0	640.0
	Lady finger	15	06	150.0	09	225.0	375.0
	Brinjal	25	10	150.0	15	225.0	375.0
	Tomato	18	06	132.0	12	264.0	396.0
Total				**1582.0**		**2194.0**	**3776.0**

[Contributor: G.C.S. Negi, *GBPIHED, Almora*]

REHABILITATION OF LANDSLIDES USING BIOENGINEERING MEASURES IN SIKKIM

About 70% of the road network in Sikkim lies in mountainous terrain with steep slopes and fragile rocks that are prone to landslides of various types such as debris flow, earth flow and rock slide etc. frequently causing road-blocks during monsoon. One such 13-year-old active landslide is Bojeck landslide (named after Bojeck village situated on the top of this landslide and prone for risk) on the way of Gangtok to West Sikkim (Fig. 1.14 A-H), affecting approx. 0.5 km^2 area. Geotectonically this landslide presents a translational failure with 10 m depth, 160 m vertical height and 180 m width, and debris generated blocks road and hinges further 800 m down slope choking agricultural land, open forest and scrub.

Bioengineering Technology to Control Landslide

To reduce soil erosion and control landslide engineering and bio-engineering technology has been devised by GBPIHED (Agrawal & Rikhari, 1998). Bio-engineering is the use of vegetation, either alone or in conjunction with civil engineering structures to reduce instability and erosion on slopes. Measures such as modification of slope geometry, rip-rap drainage, filling of cracks and retaining structures and internal slope reinforcement using locally available plant material are applied which would be less expensive, more effective, and more adaptable over the long term. Four basic interventions were used to achieve landslide slope stability: (i) Unloading the head of the slope, (ii) Ground and surface water regime modification, (iii) Buttressing the toe of the slope, and (iv) Shifting the position of the potential failure surface. To reduce the lubrication effect of seepage water, three approaches are taken into account: (i) Preventing water entering the slide through open or discontinuity traction cracks, (ii) Reducing water pressure in the vicinity of potential breakage surfaces through selective shallow and sub-shallow drainage, and (iii) Placing drainage in order to reduce water pressure in the immediate vicinity of the hillside.

Treatment of Bojeck Landslide

In the Bojeck landslide, for the safe discharge of overland flow of rain water, 5 catch water drains (longest drain measured 120 m) were constructed (Fig. 1.14B), and these drains were covered by polysheet (Fig. 1.14C). Draining of excess water was achieved through making perimeter pole drains to reduce surface flow over the natural hillside and diverted to natural drains (Joshi & Krishna, 2000; Joshi & Naithani, 2002). To drain the existing seepage horizontal perforated pipe (use of locally available bamboo) was made (Fig. 1.14D). Cracks (21 nos.) were sealed by filling boulders and soil those may cause surface water percolation leading to reactivation of slide and accelerate the slope instability (Fig. 1.14E). Slope trimming was carried out by removing debris masses and inherently unstable slope sections from the top of the slope segment, and the slope made sufficiently sound for civil and bio-engineering works. Minor trimming of the slopes was done keeping rill or gully pattern intact and the slope along the slide boundary was kept 15 to 30 degree (Fig. 1.14F). Landslide stability increased when ground water percolation was prevented by directing surface water away from the landslide thus lubrication of surface due to ground water label reduced. The native plant species (e.g., *Alnus nepalensis, Albizzia marginata, Cephalostachyum capitatum, Jatropha curcas, Myrica esculenta, Prunus nepalensis, Thysanolaena maxima*), rather than exotic species were grown in the nursery and planted after winter rains as well as during rainy season. Contour plantation was carried out in the area where the slope angle was < 30°C and vertical plantation where slope angle was >30°C (Fig. 1.14G). After six months of plantation the survival percentage was 85%. Slope stability also increased when debris weight on the top of the landslide was removed thus making the slopes stabilized (Fig. 1.14H).

Benefits of Bioengineering

The bioengineering measures brought in immediate hydrological benefits to the landslides by providing mechanical support to soil, while controlling the retention and movement of water. As the vegetation established and root system expands the effectiveness of treatment increased, which permits the natural vegetation to grow. Therefore, bio-engineering technology can prevent soil erosion and control minor landslides from developing into larger, complex ones. The benefits of integration of mechanical measures with vegetation include: (i) Foliage interception and plant residues absorb rainfall energy and prevent soil compaction; (ii) Resistant root systems physically bind soil particles while above-ground residues filter sediment moving through run-off; (iii) Retardation of above-ground residues increases surface roughness and reduces run-off velocity; and (iv) Transpiration by plants depletes soil moisture and delays onset of soil saturation and run-off. This site served as a demonstration site for landslide control and visited by many agencies for further implementation.

07
CASE STUDY

M.S. Rawat & Varun Joshi
GBPIHED, Sikkim Unit

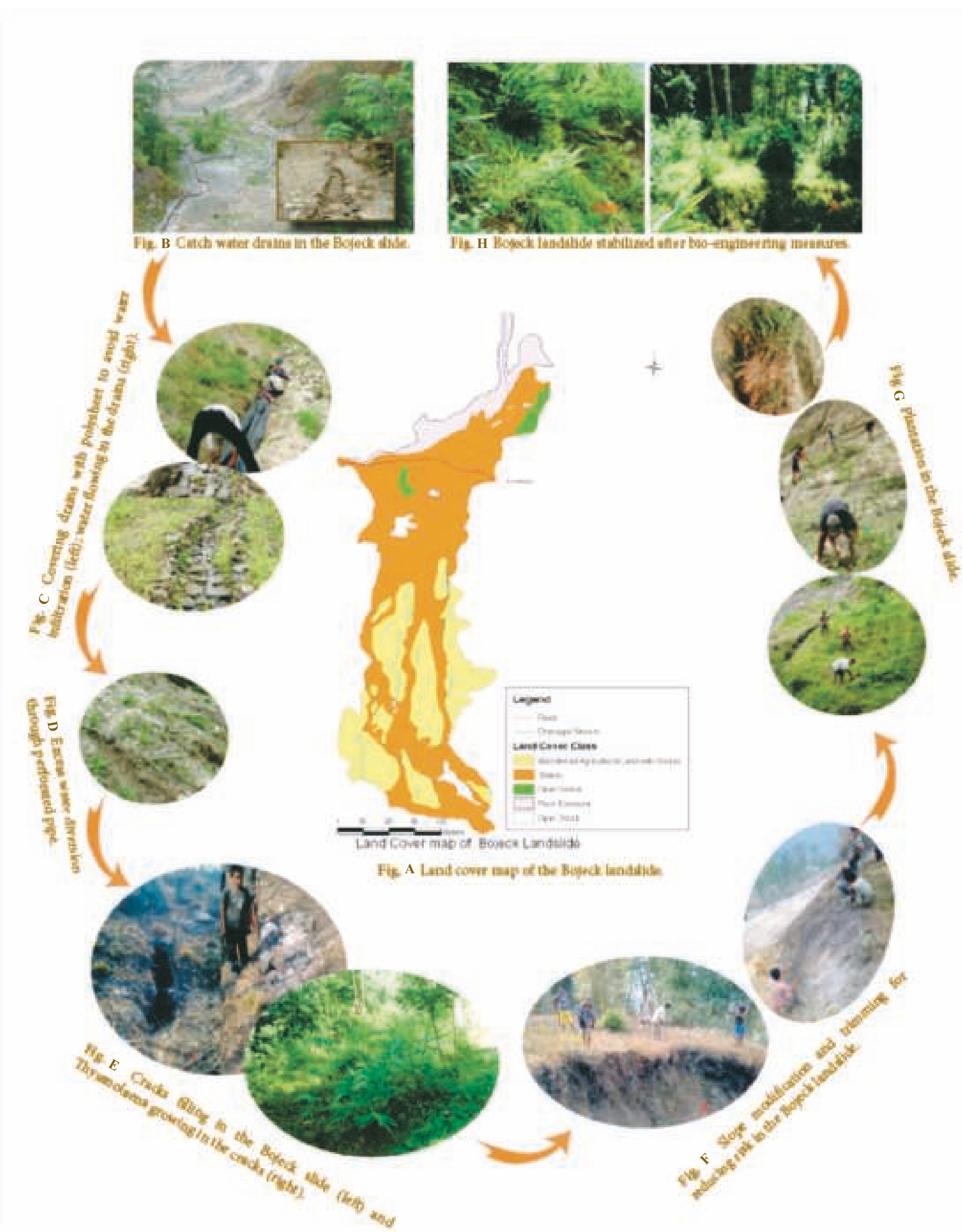

Fig. 1.14 (A-H): Progressive steps involved in treatment of a landslide site through bio-engineering measures in Sikkim

SOCIETAL RELEVANCE OF R&D WORK ON WASTELAND REHABILITATION TECHNOLOGIES

ANNEXURE - I

POLICY RELEVANCE

- Integration of science and socio-cultural and religious ethos for ensuring people's participation for community wasteland restoration across a number of sites in IHR. The IUCN has also included this approach in its guidelines for planning and managing mountain protected areas
- Recognition of indigenous knowledge of rural communities on ethnobotanical uses of plants and NRM and incorporating it in planning process for wasteland rehabilitation.
- Inclusion of livelihoods /economic/socio-cultural concerns in wasteland rehabilitation and plantation programmes.
- Choice of multi-purpose tree species (MPTs) for plantation should be need-based and stakeholder demand driven suiting to socio-economic and ecological conditions.
- Micro-plan development for land-use planning and plantation of wastelands based on participatory approach with local people/stakeholders for efficient management.
- Strengthening village community institutions for participatory action plan for NRM.
- Technological backstopping during implementation of wasteland rehabilitation technologies.
- Develop monitoring indicators of success of wasteland restoration for mid-term correction.
- Community mobilization for seeking people's participation employing entry-point activities e.g., health camps, video-shows, farmer's schools etc.

CONTRIBUTION TO TECHNOLOGY DEVELOPMENT

- Sloping watershed environmental engineering technology (SWEET) and contour hedgerow farming systems technology (CHFST) were devised for western Himalaya and Jhum affected areas of NE region. The existing sloping agriculture land technology (SALT) was modified.
- CHFST was found soil fertility and crop yield improving and SWC. Thus increased soil nitrogen and vegetable yield by 20–100%, and soil erosion decreased by 50%.
- Suitable set of MPTs was identified based on eco-physiological screening and trail plantations across a range of socio-economic and ecological conditions in the IHR.
- Saplings of native tree species were acclimatized and grown in local nursery for better adaptation and establishment after plantation in high altitude sites.
- In the dry, stony and nutrient-poor sites with low moisture pitcher/gunny bag technique (filled with soil:FYM in 20:80 ratio) was used for better survival and growth of tree saplings.
- In the cold deserts of HP a new technique of using Willow shoot cuttings with induced rooting was found a promising technology for growing healthy plants.
- To increase fodder availability improved fodder grass for wasteland restoration (fodder maize, Cenchrus ciliaris, Styloxanthus hamata, Trifolium, Cox foot, Tall fescue, etc.) were tested and proved potential to increase fodder yield. Napier grass was proved useful to increase milk yield.

OUTREACH

- Agroforestry, silvi-pasture, agri-silvi-silvipasture, agri-horticulture, MAPs cultivation along with MPTs were tested in diverse ecological and socio-economic conditions across the IHR to rehabilitate community wastelands and ideal tree-crop combinations were demonstrated.
- Over 200 ha community wasteland was brought under various prototypes of tree-crop cultivation across various ecological and socio-economic set up in the IHR.
- Soil and water conservation (SWC) measures such as contour trenches, water percolation tanks, rain water harvesting ponds and mulching were applied in experimental wasteland sites.
- These demonstration models served as learning sites (Farmers School) for various stakeholders including farmers, women, NGOs, ex-army personnel, Govt. implementing agencies and helped these models in other parts of IHR.
- A special training programme has been launched for "Eco-task Force" to train them on wasteland rehabilitation in Uttarakhand.
- Training and capacity building programmes conducted frequently across the region and adoption of model ensured by several individuals/communities.
- Govt. agencies (Forest/Agriculture/Animal Husbandry) were benefited through our demonstration models in terms of knowledge products.

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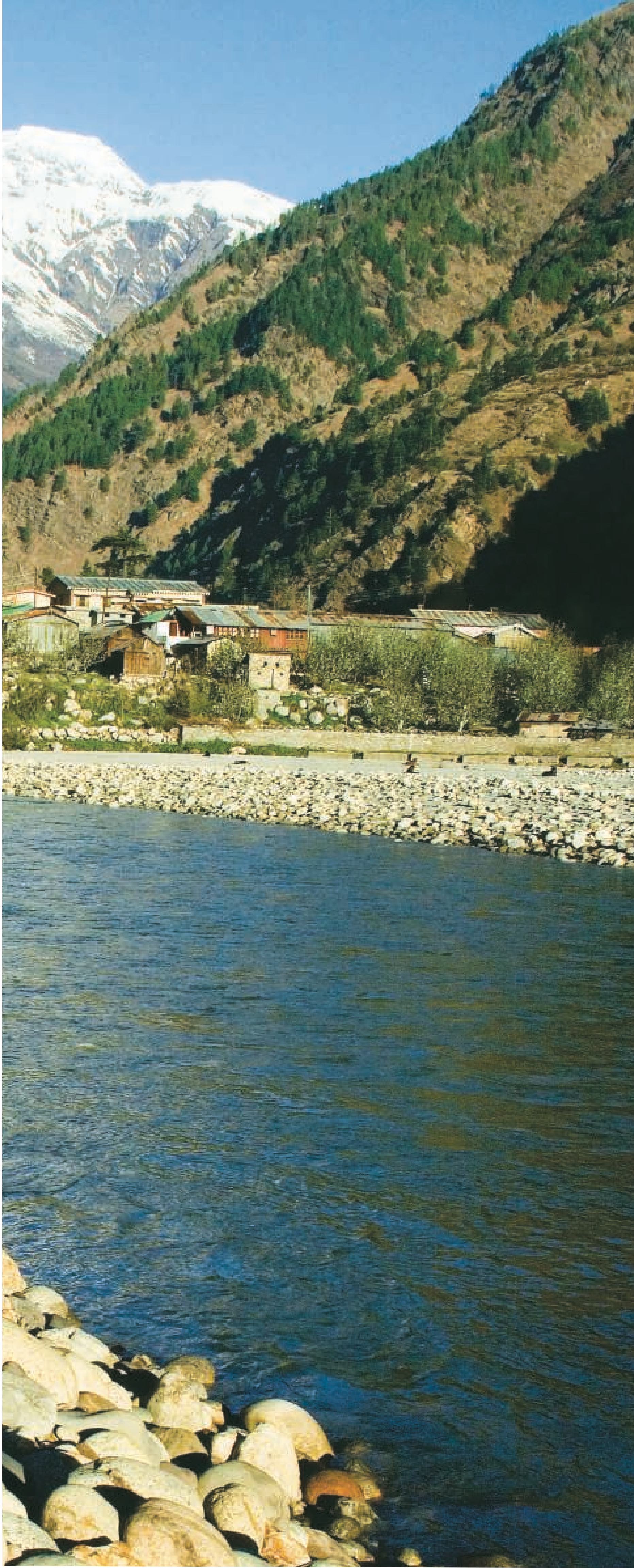
2

WATER RESOURCES MANAGEMENT



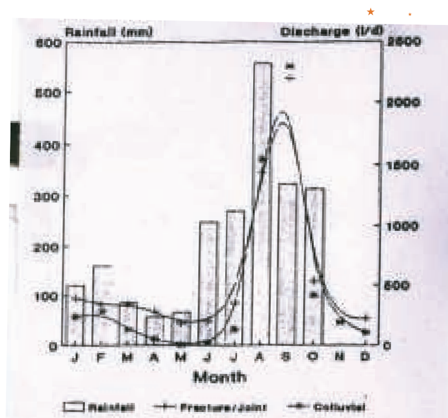
Moving from Research to Land-based Actions

The Himalayan mountains are complex, fragile and unique in geomorphology, and highly sensitive to climate change. Mountain watersheds function as a hydrological unit in which the relationship between the inputs (rainfall) and output (streamflow) is determined by various hydrological processes (evapo-transpiration, interception, infiltration, surface runoff, soil moisture storage, sub-surface flow, ground water storage and discharge) and the bio-physical characteristics of the watershed (topography, soils, vegetation cover, land use practices and anthropogenic disturbance) (Fig. 2.1). In this region, rainfall is the major source of freshwater for irrigation and household consumption. The rainfall is concentrated within three months of the monsoon season (mid-June to mid-September) with >80% of the annual rain (100–250 cm) falling during this period. Due to the strong seasonality of rainfall and reduced capacity of soil stratum to store the water mountain springs are drying up or have become seasonal (Box – 1).

BOX - 1 Mountain Springs are Drying ...

In the Himalayan mountains springs and seepages are the main sources of potable water. The water sources of such springs, in most cases, are unconfined aquifers where water flows under gravity. Spring water discharge fluctuation is mainly controlled by amount and infiltration of rainfall in the spring recharge zone although geology, land use and land cover and certain anthropogenic activities also play an important role. In the western Himalayan region two types of springs are found based on rainfall-spring discharge patterns (Fig. 2.2): (i) Fracture and joint related geologically controlled springs in which rainfall has less control on water yield- perennial springs; and (ii) Colluvial related springs in which water yield is mostly controlled by rainfall- seasonal springs. Studies on weekly water yield of six springs over a period of 5 years in Pauri-Garhwal revealed that the mean rate of spring discharge (2.87–8.78 liters/minute) and total annual discharge varies from 1.51–8.78 x 10^6 litres which is only 0.5–2.9% of the annual rainfall (Negi & Joshi, 2004). Availability of potable water thus drops to a low of 25–30 L/day during summer due to strong seasonality in spring discharge. However, water quality of these springs was found well within the WHO norms.

Fig. 2.1: An overview of degraded mountain watershed devoid of vegetative cover leading to high soil erosion and rainwater runoff



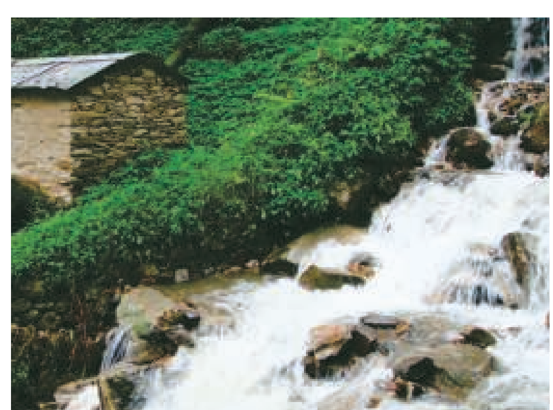


Fig. 2.2: Rainfall and discharge relationship in colluvial land fracture/joint related springs in Western Himalaya

Fig. 2.3: Springs and stepwells – the traditional sources of freshwater run dry during summer
Below: Water is a crucial input for agriculture

Thus, this region which has enough water during the monsoon is confronted with **"a too-much and too-little water syndrome"** (Valdiya & Bartarya, 1989). For example, Cherrapunji, the rainiest place on the earth with over 10000 mm annual rainfall has started facing water scarcity of various magnitudes now. Springs and Stepwells (seepages), the fresh water sources for drinking water and household consumption are drying up rapidly in the deforested watersheds (Fig. 2.3). As the concern over water demand is increasing in this region, understanding of the intricate relationship between ecological factors (vegetation type and its density), hydrological factors (water retention characteristics and saturated hydraulic conductivity) and geometric factors (shape, size of hill slope and channel network topology), which governs the hydrological response of watersheds is being considered in water resource management planning. Studies (e.g., Valdiya and Bartarya 1991, Negi 2002) have indicated that many natural and human induced reasons such as loss of vegetation cover, grazing and trampling by cattle, soil erosion, forest fire, road cutting, mining, and construction on the fragile hill slopes has reduced the "sponge function" and water retention capacity of the fragile watersheds, and much of the rainwater run away downstream without infiltrating into the soil stratum that recharge the groundwater. The aforementioned activities lead to hydrological imbalance and impairment of the geological set up disturbing control on recharge and discharge pattern of springs (Valdiya & Bartarya, 1989; Negi & Joshi, 1996). The storm rainfall generated runoff leads to adverse impacts, such as landslides and flash floods in downstream. However, quantitative knowledge of storm-runoff generation in the forested watersheds is limited in this region (Bruijnzeel & Bremmer, 1989), and values on streamflow (9–62% of the annual rainfall) and soil erosion (2–59.3 t ha^{-1} yr^{-1}) vary over a wide range (cf. Negi, 2002).

Environmental problems, as outlined above with multifarious ecological and socio-economic implications have led to consider "watershed" as a unit for land and water resource management and development planning in the hilly regions. In this context, watershed management can be defined as process of guiding and coordinating use of land and water resources in a watershed to provide environmental services and goods, without adversely affecting resources upstream or downstream. This approach has been regarded as a key vehicle for restoration of hill ecology, mitigation of floods, enhanced and sustained land productivity and a self-reliant economy, if coupled with appropriate infra-structural facilities like transport, market and necessary institutional arrangements.

GBPIHED conceived integrated watershed management program in its early years of establishment and identified two representative watersheds to carry out detailed R&D work – one in eastern Himalaya and other in western Himalaya. These watersheds were found ideal for research and demonstration and also learning through multidisciplinary approach. A starting point was thus considered to build baseline data set on bio-physical and socio-economic dimensions of these watersheds. For this purpose a detailed inventory on natural resources, e.g., land, water, forest, agriculture and socio-economic aspects were made to devise suitable management options. To offer alternative land use options aiming at SWC certain long-term experiments on agriculture, agroforestry and water resources conservation were carried out and apart from providing R&D based solutions policy interventions were also suggested. These studies also led to formulation of many important policy documents and guidelines (Box – 2 and 3).

BOX - 2 Environmental and Social Management Framework for Watershed Management

GBPIHED prepared an Environmental and Social Management Framework (ESMF) and Environmental and Social Guidelines (ESG) under a Decentralized Watershed Development Project funded to Watershed Management Directorate, Govt. of Uttarakhand by World Bank in 2003-04. This document dwelt with enhancement of biological productivity and development of rural people following the principles of watershed management in degradation prone watersheds covering 450 Gram Panchayats of middle altitude belt of Uttarakhand. Implementation and Monitoring Manual for project activities such as arable land (agriculture and horticulture), non-arable land (forest and silvi-pasture), water harvesting, animal husbandry, natural hazards mitigation, income generating activities and infrastructure development was made keeping in view the environmental and social considerations as per the World Bank guidelines (Samal et al. 2002). Another similar assignment was undertaken to prepare Strategy-cum-Action Plan for Integrated Watershed Development Programme- Hills under a World Bank Project for Siwalik Region of Haryana, Himachal Pradesh, J&K, Punjab and Uttarakhand which was accepted by Ministry of Agriculture, Govt. of India (Agrawal et al., 2002).

Box - 3 Village Environment Action Plan (VEAP)

VEAP is a Community Manual developed by GBPIHED for sustainable management and use of physical and biological resources within a village unit. It aims at maintaining ecological balance of the village without adversely affecting the environment. It presents a systematic participatory approach wherein the community people assess the resources and prepare a micro-plan. VEAP contains easy to handle methodology and involves following six steps: (i) Preparation of resource map (physical and biological land, water, forests and other bioresources including waste materials), (iii) Resource availability vis-à-vis consumption (e.g., fuelwood, fodder, food grain, water, etc.) (iii) PRA based prioritization of environmental problems, (iv) Selection of management options and relevant technologies, (vi) Execution of action plan, and (vi) Monitoring and evaluation. It provides various environment-friendly and low-cost technologies appropriate for mountain villages based on R&D of the Institute. The VEAP was implemented under World Bank funded SWAJAL scheme in several villages of Uttarakhand (Kumar et al., 2002).

The IHR has vast amount of fresh water reserves in its lakes and glaciers. About 17% of the total area of IHR is under permanent cover of ice and snow with over 9,000 glaciers containing 12000 km^3 of fresh water (Anonymous, 2010). These glaciers are important in maintaining ecosystem stability and act as buffer for regulating runoff water, supply stream and rivers. However, since continuous glacier recession is becoming a distinct possibility in the context of global warming, spatio-temporal monitoring of its mass and dynamics has become important. In a wider context, the possible impact on the operational efficiency of downstream hydro-power and irrigation projects would have to be proactively assessed. This led to the initiation of concerted scientific efforts to identify and examine the fluctuations along the front-snout of glaciers, and Gangotri glacier system was studied extensively (Box – 4).

Box - 4 Glacier Retreat in Himalaya

Glacier studies undertaken by GBPIHED, Almora on Gangotri and Milam glaciers in Uttarakhand using differential GPS have shown lower rate of retreat (11.95 ± 0.04 m/yr) in 2004-07 than the past reports of approx 17.15 m/yr (1971–2004) without any significant influence on melt water discharge. Between the years 2005–07, the Gangotri glacier retreat was recorded much lower (11.80 ± 0.035 m/yr). Hydrometry and sediment load studies of Gangotri glacier system revealed marginal shift in discharge peak towards late summer months with several sporadic sediment flushing events. Mean monthly melt water discharge in last 9 years varied from as high as 114.55 m^3/s in July 2004 to as low as 13.56 m^3/s in September 2007, with no specific trend of these variations. Lower discharge was observed after 2004, when retreat has also been lower. Chemistry of the melt water of Gangotri glacier system revealed that magnesium and calcium are the dominant cations while bicarbonate and sulphate are dominant anions, and the melt water chemistry is controlled mostly by carbonate weathering and only partly by silicate weathering (Kumar, 2002).

This section provides some key success stories based on long-term R&D experiments conducted on hydrology and watershed management in diverse conditions across the IHR. A summary of societal relevance of the R&D work emanated from these studies is summarized in Annexure – II.

INTEGRATED WATERSHED MANAGEMENT IN SIKKIM HIMALAYA

Mamlay watershed (area= 30.14 km^2; 300–2650 m above amsl) is located in one of the most populated zones in south district of Sikkim. It comprises different vegetation zones and cropping patterns, cultural and ethnic diversity and land use patterns. This watershed was taken up in 1990 for developing baseline data-set on land, soil, structural and functional aspects of forests, water resources dynamics, agriculture and agroforestry system and also to see the impact of rural technology intervention in selected villages on natural resource management and economy of rural people (Sharma et al., 1992). There are 34 villages in the watershed, and nearly 95% population is concentrated in lower altitudinal zone. Nearly 80% of the population was engaged in primary sector (cultivation) and remaining 20% in secondary (agriculture labourer) and tertiary (private and government sectors, military services, carpentry, blacksmith, construction workers, etc.) sectors. This watershed is mainly dependent on the rainfall (range = 1235–2600 mm/year) and perennial streams flowing through this for domestic consumption as well as a small fraction of cultivated land for irrigation. Mamlay watershed has a large network of streams locally known as "Khola" and five major and perennial streams of the watershed are:

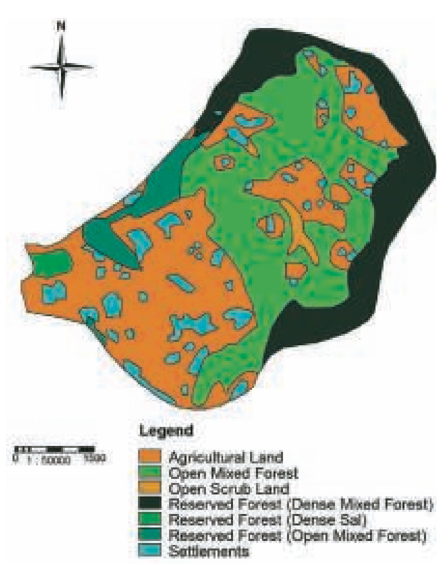


Fig. 2.4: Land-use pattern of Mamlay watershed, Sikkim

08
CASE STUDY

Y.K. Rai, L.K. Rai, J. Dhakal, K.K. Singh, & R.C. Sundriyal[1]
GBPIHED, Sikkim Unit; [1]GBPIHED, Almora

Pokchekhola, Chimcheykhola, Kholaghari, Tirikhola and Rinjhikhola which join the Rinjhikhola and further in the Rangit river. Agriculture is the main occupation of the people and occupies over 60% area of the watershed (Fig. 2.4). A total of 6 different types of cereals, 8 varieties of pulses, 42 vegetable forms, 6 spices, 14 fruit species and 23 types of wild edible plants are found in the watershed (Sundriyal & Sundriyal, 2001)). Large cardamom (*Amomum subulatum*), ginger (*Zingiber officinale*), mandarin orange (*Citrus reticulata*) and potato (*Solanum tuberosum*) are important cash crops (Box - 5). Land capability classification showed that hardly 25% area of the watershed falls in capability class I and II, which is suitable for crop cultivation. However, marginal farmers cultivate crops also on land unsuitable for agriculture. Reserve forest occupying 12% area of the watershed has a great biodiversity contained in sub-tropical and temperate forests (Sharma et al., 1992). Dominant tree species in these forests are: *Alnus nepalensis, Castapnosis indica, Shorea robusta, Quercus lamellosa*, etc., and biomass in these forests range from 362 to 764 t/ha.

BOX - 5 **Large Cardamom Farming under Alder is Sustainable**

Production of large cardamom (Amomum subulatum) has been a boon to the mountain people of Sikkim. It is a perennial cash crop grown beneath the forest cover on marginal lands. Studies have revealed that the household income almost doubled in the large cardamom system than maize and potatoes (Sharma et al., 2002; Singh, 2008). In addition, ecological sustainability is even greater with cardamom, when the Himalayan alder (Alnus nepalensis) is used as a shade tree, as this tree regenerates naturally on sites affected by landslides and grows within the same agro-climatic range as large cardamom. Study of nutrient cycling, nutrient use efficiency and nitrogen fixation in an age series of Alnus–cardamom plantations in the Mamlay watershed in Sikkim revealed that in mixtures of N2-fixation (A. nepalensis) and non-N2 fixing (large cardamom) plants the leaf nutrient concentration of Alnus decreased with increasing age of plantations. Annual N fixation increased from the 5-year-old stand (52 kg/ha), peaking in the 15 year old stand (155 kg/ha) and then decreased with increasing plantation age. Nitrogen and phosphorus uptake was lowest in the 40 year old and highest in the 15 and 5 year old stands, respectively. Nutrient cycling and dynamics indicated that Alnus–cardamom plantations performed sustainably up to 15–20 years. Therefore, the management practice should be altered to incorporate re-plantation of these species after this age (Sharma et al., 2002).

Agroforestry for Soil and Water Conservation

The micro-catchments in this watershed have different land use practices, and there is no uniform land use and land cover across the streams. Hydrological studies indicated that the sediment load was highest in rainy season in all the streams owing to high intensity rainfall, steep slopes and cultivation on terraces carved out of steep slopes. High overland flow, soil and nutrient loss was estimated from open agricultural fields (9.6% of the rainfall) and least in Cardamom forestry (2.17%) (Rai & Sharma, 1998). Similarly, soil loss was greatest in open agricultural area (477 kg/ha) and lowest in dense mixed temperate natural forest (6 kg/ha) (Table 2.1). The hydrological studies are thus indicative of the fact that in the fragile watersheds agroforestry needs to be practised replacing agriculture in the sloping areas. Such practice would help in soil and nutrient conservation consequently enhancing the soil fertility and productivity. An inverse relationship was found between forest floor interception and soil erosion. Therefore, it can be recommended that the dense mixed forest cover should be maintained at higher elevations in the watershed to regulate and ensure stream flow and also to minimize the risk of landslides. In this watershed conversion of forest land into cultivated land has been conspicuous in the last few decades that need to be substituted with agroforestry practices. As a follow-up GBPIHED worked upon agroforestry combinations such as *Alnus neplanesis* (Alder) with Large Cardamom in temperate zone (Chhamgaun village), and *Albizia stipulata* with mandarin orange in sub-tropical zone (Debrong village) of this watershed. Both these species are nitrogen fixing. It was found that the yield of Large cardamom increased by 2.2 times under the canopy of Alnus. Similarly, under *A. stipulata* with mandarin orange agroforestry practice, the fruit production was recorded higher (Sharma et al., 1992).

Table 2.1: Overland flow, soil and nutrient loss in the Mamlay watershed under different land-use in three rainfall events during rainy season

Land-Use	Overland flow (% of rainfall)	Soil loss (kg/ha)	Nutrient loss through eroded soil (kg/ha)		
			Total nitrogen	Organic carbon	Total phosphorus
Temperate forests	2.56	6	0.068	0.308	0.007
Subtropical forests	4.53	137	0.537	3.887	0.089
Cropped area	9.55	477	2.345	11.863	0.677
Cardamom agroforestry	2.17	30	0.415	1.865	0.020
Mandarin	4.76	145	1.072	9.793	0.020
Fallow	3.77	43	0.398	2.324	0.103

Developmental Interventions

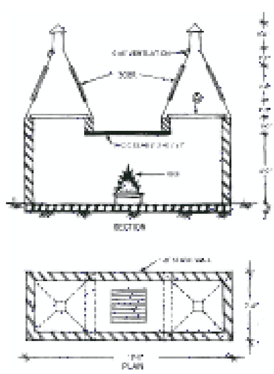
Realizing the fact that traditional agriculture is not suitable for SWC, alternative forms of agriculture were taken up as a topmost priority for R&D-based interventions in this watershed. Thus, scientifically sound large cardamom under natural forest cover, agro-horticulture practices, multiple-cropping practices and crop rotation using legumes were promoted over traditional practices in the watershed. With an aim to enhance crop productivity, demonstrations on rural technology were implemented among 15 households in village blocks viz., Lower Mamlay, Chhamgaon and Jaubari covering 15–20 ha land across tropical and sub-tropical zone of the watershed. These demonstrations were: (i) Polyhouse/polypits for growing vegetables, ornamentals, foliage plants, etc. was found particularly useful for increasing seed germination and crop growth and also for growing off-season vegetables due to favourable temperature in cold conditions of high altitudes. (ii) Construction of polythene lined low-cost water harvesting tank (3×8×2 m) for storing water from nearby spring and stream and utilized by these households for growing off-season vegetables. (iii) Improved indigenous drying kiln (Bhatti) for drying large cardamom to reduce fuel requirement to 50%, and the consequent pressure on surrounding forests and damaging the natural maroon colour of the fruit (Box - 6). (iv) Making bioglobules (smokeless fuel) using weeds for keeping houses warm in the winter and also reducing pressure on forests. The bioglobules are prepared by burning weeds in anaerobic condition, charcoal mixed with garden soil, hand-rolled into globular shapes of 3–4 cm diameter and sun dried. (v) Bio-composting of weeds into nutrient rich compost. Mostly, weed, poultry waste, soil, waste paper, dairy and vegetable wastes, egg shells, plant materials and old compost mixed with fresh cow dung and put into compartments (1 m^2) made of hollow bamboo blocks which is ready for use between 3–4 weeks and used for fertilizing the field crops. As a result of these demonstrations, 46 families (Chhamgaon-10, Mamlay-16, Jaubari-20) of these villages started reclaiming uncultivated land for more diversified agriculture, rain water harvesting and introduced off-season vegetables and started getting benefits. The polybed method of farming coupled with water harvesting ponds was found quite remunerative, and on an average provided more than five-time (Rs. 404 vs. 77 m^{-2}) increase in net income, provided employment opportunity, market link development and utilization of abandoned agriculture fields.

Box - 6 Improvised Curing Kiln for Cardamom Farmers of Sikkim

Cardamom (*Amomum subulatum*) constitutes one of the main cash crops of Sikkim. It is a labor-intensive crop where irrigation, plantation care, harvesting, drying of fruits and storage are important (Singh, 2008). Drying of cardamom fruits is performed in traditional kiln (Bhatti) due to ease of handling and virtually as a zero-cost investment. The main drawback of the Bhatti is the large amount of firewood consumption and dark colour and smoky aroma of the dried fruits that does not fetch good market prices. Thus with these two concerns GBPIHED-Sikkim Unit worked on improvising the traditional Bhatti to reduce fuelwood consumption, and improve the colour and aroma of the dried fruits.

Considering the above, a prototype of improvised Bhatti was developed and repeatedly worked upon for adjustment of flame reach, size of final receptacles, size and height of gas chamber and chimney structure, etc. The air flow and heat content was maximized so that a faster drying cycle could be realized with less use of fuel wood and better quality dried cardamom. Structurally simple and easy to construct the improvised Bhatti consisted two components: (i) the body, and (ii) the ventilator (Fig. 2.5). The cost of construction of the improved Bhatti comes to around Rs. 20,000.

Fig. 2.5: Improvised cardamom curing kiln developed by GBPIHED, Sikkim Unit



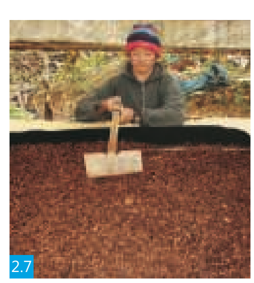
During the trial runs the improvised Bhatti was loaded with 200–250 kg of fruits and the drying operation stretched from 9 to 11 hours. The normal conversion ratio of green to dry capsules is 4:1 to 5:1 which varied according to the size and method of curing. Improvised cardamom curing kiln developed by us improved seed quality and took lower curing time (9.50 hr) and fuel wood consumption (2.18 kg/kg of dry fruits) as compared to the traditional Bhatti (Singh, 2008), which requires 25–40 hrs and fuelwood consumption from 3.8-8.5 kg/kg of dry fruits and retains the natural maroon capsule colour, which fetch higher cost. In a season 1500–2000 kg capsule can be dried which normally is the produce of about 15-20 households of marginal farmers. Thus one kiln can cater to the need of a cluster of cardamom growers. This improvised kiln technology saves trees and labour for drying cardamom capsules, which helps in the ecological sustainability of the system (Fig. 2.6-2.8). The technology is risk-free of any environmental hazard and can be applied anywhere in the cardamom growing area. With the aid of NABARD and Sikkim Consultancy Services some cardamom growing areas in the state have been provided with the improvised Bhatti that needs to be further popularized and distributed through Govt. departments.

Fig. 2.6 Close up view of Large cardamom bush

Fig. 2.7 Separating cardaom capsules from the receptacles

Fig. 2.8 Cardamom fruits being shifted during cardamom curing process


2.6


2.7


2.8

BRAODLEAF VS. CONIFER FORESTS FOR SOIL AND WATER CONSERVATION

Long-term hydrological monitoring of micro-watersheds has been considered as a starting point for understanding the hydrological behaviour of watersheds and improve decision making for land use and land cover alterations conducive for SWC in the Himalayan region. With this rationale an investigation was carried out about a decade ago in two micro-watersheds (MWs) of Pauri District of Garhwal Himalaya. Geologically, both these MWs were alike, located about 5 km away and experience almost similar weather conditions. These MWs were about 300 ha in size and had contrasting land use/cover. Srikot-Gad (MWs-I) had 50% of the area under evergreen broadleaf forest (Oak; *Quercus leucotrichophora*) and 12% under wasteland and scrubs. Dugar Gad (MWs-II) had only 10% of the area under evergreen conifer forest (Pine; *Pinus roxburghii*) and a large chunk (53%) under wasteland and scrubs. Both the MWs had almost one-third of the area under rainfed agriculture. Data on streamflow and sediment output were recorded in these MWs during 1994–1998 on 24 h interval using a silt and runoff post that consisted of a trapezoidal flume designed for mountain WS. Both the MWs received almost equal amount of rainfall. Of the mean annual rainfall of 1845 mm in MWs-I and 1875 mm in MWs-II, about 59% was received during the rainy season (July–September).

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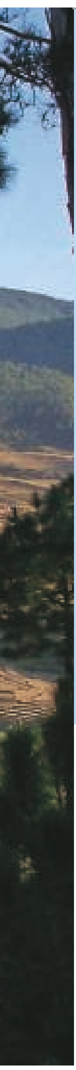
CASE STUDY

G.C.S. Negi & [1]Varun Joshi
GBPIHED, Almora; [1]GBPIHED, Sikkim Unit



During the study years, rainfall-streamflow-sediment output relationships varied from one year to another considerably; and these three parameters were positively correlated in both the MWs. The landuse/cover of the MWs had a direct bearing on annual streamflow. MWs-I water yield recorded was about half of that for MWs-II (3825 vs. 6775 m^3/ha). Peak streamflow, baseflow and sediment load were recorded in August (mean monthly data basis), which coincided with maximum rainfall (Figs. 2.9–2.10). Similarly, minimum runoff, baseflow and sediment loss were recorded in May. Mean monthly baseflow for MWs-I (10.2 mm) was markedly low as compared to MWs-II (18.3 mm). High slope of MWs-I and fast stream gradient and accumulation of debris on the stream bed might have contributed to deep seepage and sub-surface flow of water that could not be gauged during the lean months. In MWs-I, out of the annual streamflow of 382.5 mm (21% of annual rainfall), 71% was recorded during rainy season, and out of the annual sediment loss of 4.8 t/ha, 93% was transported during rainy season (Fig. 2.9). Similarly, in MWs-II, out of the annual streamflow of 673 mm (36% of annual rainfall), 79% was recorded during rainy season, and out of the annual sediment loss of 7.9 t/ha, 92% was transported during rainy season (Fig. 2.10).

Thus, in terms of water retention (relative to rainfall) and soil conservation, MWs-I was better as compared to MWs-II. MWs-I with high proportion of broadleaf Oak forests the streamflow and sediment transport peak was delayed for about one month as compared to MWs-II with low proportion of area under conifer forest. Streamfow declined rapidly with the cessation of rainfall at the end of the wet season, an indication of very limited storage (soil moisture and groundwater) in the MWs-II. This lag in the peak streamflow has important implications for flood hazard reduction and water resource management in the mountain MWs and calls for maintenance of evergreen broad leaf forests in the fragile watersheds for soil and water conservation (Fig. 2.11).

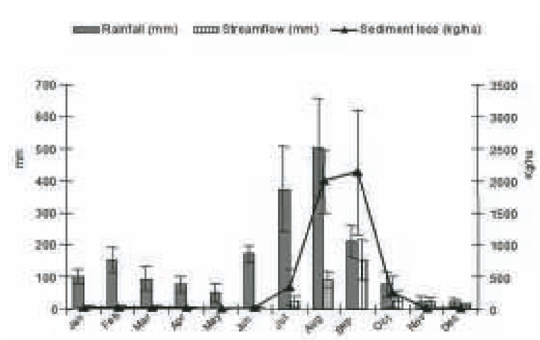


Fig. 2.9 Rainfall, streamflow and sediment transport for Srikot Gad micro-watershed (Average 1994-1998)

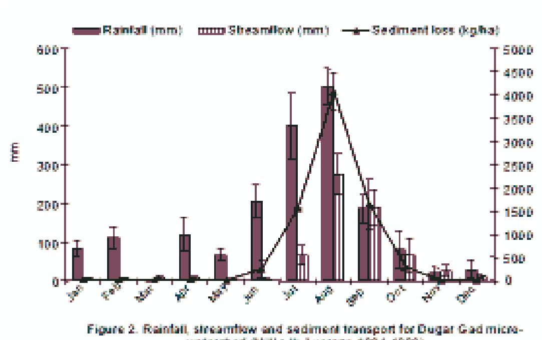


Fig. 2.10 Rainfall, streamflow and sediment transport for Dugar Gad micro-watershed (Average 1994-1998)

Fig. 2.11 Mixed Oak forest conducive for soil and water conservation

A SIMPLE ECO-TECHNOLOGY TO REVIVE WATER DISCHARGE IN DRYING SPRINGS

Fig. 2.12:
Long queue of people around water sources (step well, locally named as Naula) is a common scene during summer in western Himalaya

The socio-economic implications of the hydrological imbalance are perceptible on agriculture, animal husbandry and livelihood support activities in the Himalayan mountains. People are forced to reduce water consumption, consume unhygienic water, prone to water borne diseases and face social conflicts over water issues. Studies have indicated that access to potable water during the summer drops to a low of 25–30 lire per capita per day (lpcd) that is half of the WHO norms. Long queue of women and children around the water sources during summer is a common scene in the region (Fig. 2.12). Sometimes to fetch a pale of water a distance of 4–5 km has to be travelled thus spending about 2–4 hrs of human labour. Several instances are there when water is sold @ Rs. 5–20/ container of appx. 20 litres during summer in the hill townships in Uttarakhand. In the face of water scarcity adaptations to cope up the water shortages such as, installation of hand-pumps, locking the naula (1–2 m deep appropriately stone-lined step wells to recover seepage water), roof top rainwater harvesting, digging pits on dried stream beds, and use of pump-sets to lift water from distant sources, recycling of wastewater is emerging in the region. Thus limited water resources face competing demands particularly during lean months. An interdisciplinary approach with hydrological, hydrogeological and ecological interventions was thus felt necessary to be demonstrated for conservation and sustainable utilization of water resources by GBPIHED. As a follow-up, a long-term experiment was conducted employing engineering and vegetative measures to rejuvenate a drying springs in a rural watershed in Pauri-Garhwal during 1994–2000. Based on this research, a simple eco-technology was devised, and trainings were imparted among the user agencies including NGOs and this technology was implemented in over 150 villages under SWAJAL project in Uttarakhand.

10

CASE STUDY

G.C.S. Negi, Varun Joshi, & Kireet Kumar
GBPIHED, Almora

Ecotechnology at Work

This eco-technology emphasizes that infiltration of rainwater into the spring recharge zone be increased through engineering and vegetative measures, so that there is an augmented discharge in the springs down stream. With this aim, a near-extinct spring (which used to have enough discharge in the past and utilized by the village people) in Dugar Gad watershed (Pauri-Garhwal, Uttarakhand) was selected for "spring sanctuary development" as has been suggested earlier (Valdiya & Bartarya, 1989). Geological mapping of recharge zone of this spring was carried out using survey of India toposheets (1:25000). Different rock types were identified and structural discontinuities related with them as folds, faults, fractures, joint patterns, dip, strike and direction of the joint sets of the rocks were also determined and marked in the base map (Fig. 2.13). This spring was recognized as fracture/joint-related and the underlying thinly-bedded quartzite act as an impermeable stratum for this spring. Recharge zone of this spring (18.5 ha) was treated with engineering, vegetative, and social measures, as summarized in Table 2.2. The cost of bio-engineering treatments was worked out to be Rs. 10,050 per ha, excluding barded wire fencing. Spring discharge was recorded three times a day (9 am, 1 pm and 5 pm) for five years (1994–98).

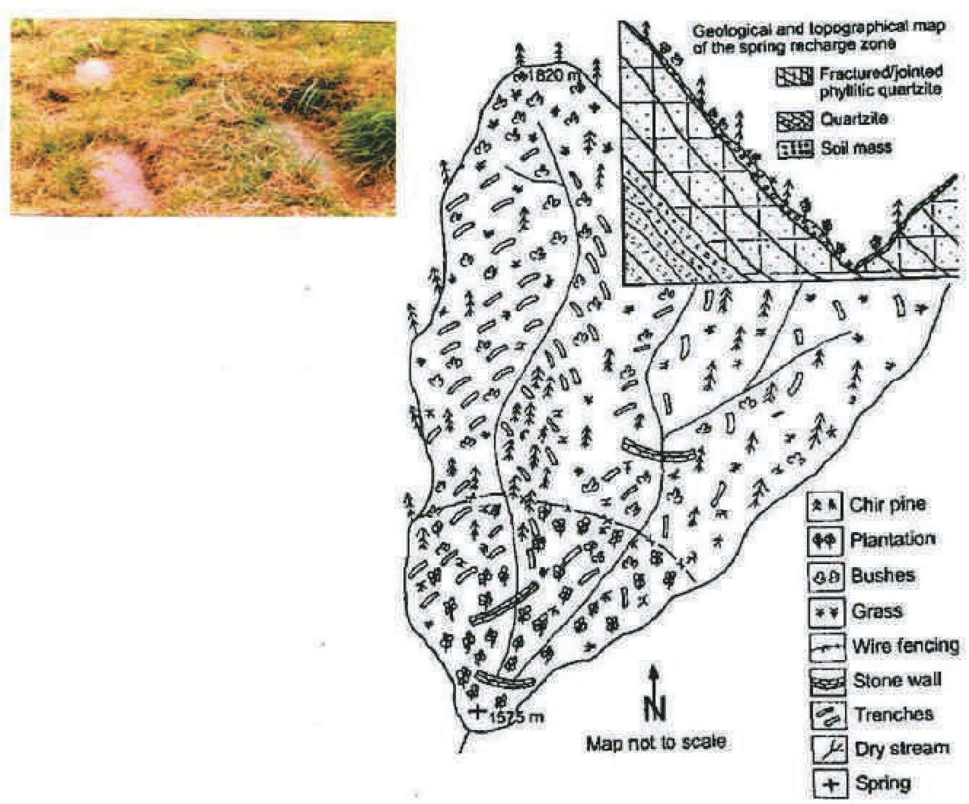


Fig. 2.13: Spring sanctuary development measures implemented in a micro-catchment of drying spring in Dugar Gad Watershed (Inset: Rainfall-runoff water harvested in trenches in spring recharge zone).

Table 2.2: Ecotechnological measures applied in the recharge zone of a drying spring based on: Negi & Joshi (2002)

Engineering measures	Vegetative measures	Social measures
Trenches (15-30 cm deep and 1-20 m long) dug along the contours; Raising bunds along the crop fields; Gully plugging using mud and stone	Planting of *Alnus nepalensis*, *Prunus cerasoides* (deciduous), and *Quercus leucotrichophora* (evergreen) trees in micro-catchment of the spring away from the water source	Local community taken into confidence and explained about the value of implementing engineering and vegetative measures in the spring recharge zone
Mud-and-stone walls (1 m high and 10 m long) constructed for water retention and pounding of water	Application of leaf litter to barren spots to enhance infiltration and reduce evaporation of soil moisture	People were also informed that the water scarcity could be overcome if the spring discharge was allowed to store in leak-proof tanks, and loss of water could be reduced
Pits dug for plantation and water infiltration. Barbed wire fence built around the spring	Protection of recharge zone from grazing, cutting of fuelwood and grass, and wildfires	Community rationalized the distribution of available water

Increase in Spring Water Discharge

In 1994–95 water year (1 July–30 June), of the total rainfall, discharge was measured only 0.7% in the experimental spring (Table 2.3) before it was treated with bio-engineering measures. Subsequent to the implementation of the bio-engineering measures the discharge increased up to 1% in 1995–96 water year and 6.8% of the annual rainfall in 1996–97 water year. When considered in terms of monthly discharge, the increase in spring discharge during summer was found 3.7 times greater, from 595 L/d in June 1995 to 2170 L/d in June 1998, indicating the positive impact of eco-technology executed by us to revive the spring discharge. However, it can be pointed out that much of this increase in discharge was due to the greater rainfall during summer 1997 and 1998, as compared to the control year 1995. A substantial decline in total discharge of the spring during 1997–98 water years may be attributed to the loss of water due to evapo-transpiration demand of the revived vegetative cover of the recharge zone and siltation of trenches and other engineering measures implemented by us. In the control year, the vegetative cover (89%) consisted of a few scattered pine trees, bushes and intensively grazed forage, which gradually grew up to 96% including the plantation raised by us. It may be possible that the ET losses override the benefits accrued due to plantation, and manipulation in vegetation of the recharge zone becomes important for the water yield and water quality (Box-7) in future that needs further research.

Table 2.3 : Revival of water discharge in a near-extinct spring following treatment with simple engineering and vegetative measures in Dugar Gad watershed (source: Negi & Joshi, 2002).

Water year	Rainfall (mm)	Spring discharge (l/d)		Total discharge (10^3 l/yr)	Water retention (% of rainfall)
(1 July - 30 June)		April-June	July-March	April-June	July-March
1994-95	110	846	1055	50388 12403	0.7
1995-96	201	1366	1271	59009 16494	1.0
1996-97	428	831	2311	56700 15881	6.8
1997-98	243	1052	4093	31790 9190	3.9
1998-99	154	1183	1360	109024 30409	12.3
1999-00	505	982	2153	124036 34416	12.5

BOX - 7 *Water Quality of Mountain Springs*

In the Himalayan mountains spring recharge zones have a complex land use/land cover under anthropogenic influence that determines the quantity and quality of water discharge (Fig. 2.14). A study on spring water chemistry of ten representative springs emanating from a variety of recharge zone in the of western Himalayan region revealed that quantities of both cations (Ca^{++}, Mg^{++}) and anions ($SO4^-$, F^-, Cl^-) vary markedly from one spring to another. The perennial springs were characterized by markedly higher concentration of all cations and anions, compared to the seasonal springs. However, some variations were found among different water quality parameters, which were associated with differences in recharge zone characteristics and diverse geological characteristics of these springs. In the spring recharge zones having crop lands and human habitation were characterized by higher concentration of Cl^- (25 mg L^{-1}), NO_3^- (3 mg L^{-1}) and electric conductivity due to ploughing and application of FYM. Nitrogen compounds (ammonium salts, nitrates and nitrites) are mainly associated with proteinaceous compounds and seepage from agricultural fields. In general different physico-chemical parameters analyzed for the spring water were found well within the WHO norms prescribed for drinking water and thus suitable for household water consumption. Based on this study, ideal recharge zone characteristics for safe drinking water supply and health of the connected water bodies downstream have been identified (Negi et al., 2001).

Fig. 2.14 : Mountain spring - a fresh water source

Drinking Water Management at a Micro-Watershed Scale

In Dugar Gad watershed, four springs utilized mostly by the watershed people for household consumption were measured for water yield at a weekly interval during the above mentioned period. Simultaneously, daily water consumption of the watershed population was recorded for summer, winter and rainy season. Looking at the discharge of these springs, it is evident that these springs can nearly meet the normal household water demand (Table 2.4), provided discharge of all the springs is pooled in suitable tanks and distribution schedule among the four villages is fixed through gravity schemes. Usual practice is that people collect water when the demand arises, rest of the time the water goes waste. Often people with surplus water in their village geographical area considering it as private resource do not allow water tapping by the nearby villages, considering that if discharge in their water sources diminishes, they may use this buffer stock.

This study has improved an understanding of the relationship between spring water yield and spring recharge zone characteristics that hold applied value with regard to long-term water conservation strategies. Clearly, geology and rock types (phyllite with quartzite bands, quartzite and limestone) favoured the water holding capacity of rocks and spring water yield. Also, moderate slope, south-west aspect of the recharge zone and deep soil promote the water infiltration and recharge of the ground water. Besides, land use / land cover influence the spring discharge. It can be pointed out that oak forest (broadleaf), terraced land, moderately grazed pasture land and low biotic interference in the spring recharge area are conducive for spring water recharge and need to be maintained in the micro-watersheds to sustain the flow of water in springs downstream.

Table 2.4: Spring discharge and water availability in Dugar Gad watershed (Source: Negi & Joshi, 2002).

Name of the spring (village)	Population	Spring discharge (l/d)			Water availability (l/capita/day)			Deficit (-) / surplus (+)*
		Summer	Rainy	Winter	Summer	Rainy	Winter	
Ali	167	2885	11910	4908	17.3	71.3	29.4	-9.7
Bhimli Malli	142	10005	29162	11364	70.5	205.4	80.0	+43.5
Bhimli Talli	398	5044	13449	6099	12.7	33.8	15.3	-14.3
Palsain	250	845	11689	4020	3.4	46.8	16.1	-23.6
Sainchar	-	3380	12015	4542	3.5	12.6	4.8	+
Average/Total	**957**	**22159**	**78225**	**30933**	**23.2**	**81.7**	**32.3**	**-0.3**

**Deficit (-) / surplus (+) from normal consumption (lpcd) in summer*

HYDRO-GEO-METEOROLOGICAL STUDIES IN A LESSER HIMALAYAN WATERSHED

The high mountain basins of the IHR though act as water tower for millions of people downstream but access to adequate amount of fresh water for meeting the basic water needs has become a cause of concern especially during the summer season. Limited understanding of the groundwater aquifer and processes that governs the functioning in these hardrock catchments at different spatial scale ranging from hillslope transects to larger mesoscale (typically 100 km^2 area) river basin is required to be addressed with sound long-term inter-disciplinary research. Thus apart from ecological factors (like vegetation type), land use and land cover, hydrological factors (like mean residence time and saturated hydraulic conductivity) and watershed geometry (like shape, size of hillslope and channel network topology) which governs the hydrological response of catchments has become the prerequisite for water resource management. This study was carried out in a micro-watershed of Pauri-Garhwal using modern tools and techniques like isotope, remote sensing and geographic information system to assess the long-term goal of water resource sustainability (Tarafdar et al., 2012).

11
CASE STUDY

S. Tarafdar & Kireet Kumar[1]
GBPIHED, Garhwal Unit; [1]GBPIHED, Almora

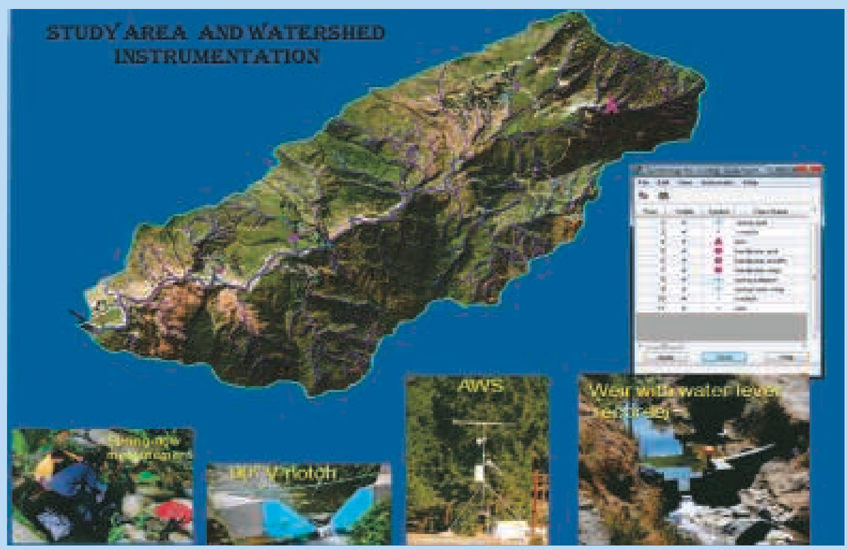
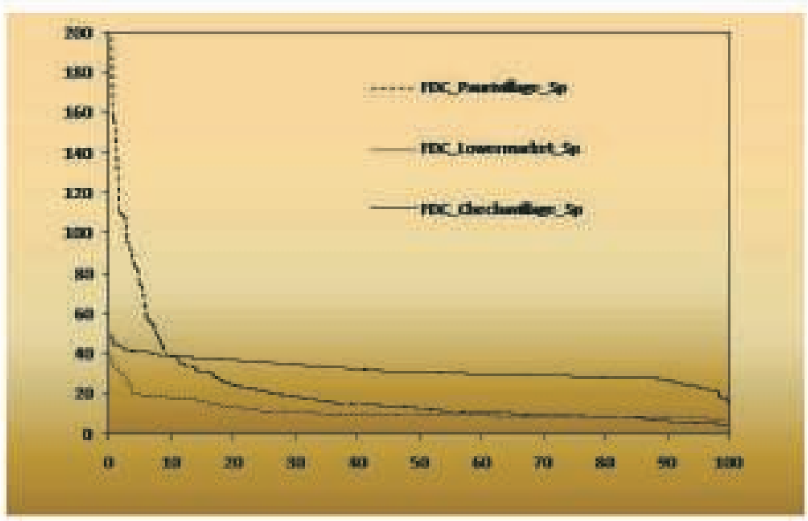


Fig. 2.15: Study area and watershed instrumentation in Garhwal

Study Area and Instrumentation

Study area is located in and around Pauri urban area which falls in Khanda Gad watershed, a tributary of river Alaknanda (Fig. 2.15). Geologically the study area falls in Lesser Himalaya which ranges between 1500 and 2500 m asl, and is represented by Pauri Phyllite and Khirsu Quartzite members of the Maithana formation in the Dudatoli Group. In these micro-watersheds daily rainfall was measured by manual rain gauge as well as digital rainfall event logger. To understand the annual and seasonal variability and availability of spring discharge through time, flow duration curves (FDC) were plotted and recession analysis was carried for winter period most ideally suited for present climatic conditions. Subsequently, the dynamic flow volume that is storage before and at the end of recession period is calculated. Most importantly, an understanding of the spring discharge that may be available during the leanest months is also being investigated using the exponential decay equation. Applications of stable isotope of oxygen and hydrogen (δ2H and δ18O) have been used for establishment of local meteoric water line and to work out the altitude effect crucial for recharge area identification.

Table 2.16: Flow duration curve for three springs from Pauri - Garhwal



Altitude Effect and Flow Duration of Springs

The average winter recession characteristic is derived using the Maillet exponential linear model for the winter period for three springs of Pauri urban area. The average recession coefficient of springs ranges between 0.01 and 0.02, indicating faster half-life of one to two months time period. A closer inspection of the winter recession curve reveals that nearly two and half months of winter recession period can be seen as a combination of initial faster recession period where the major flow comes from large fractures and pronounced foliation planes present in the meta-sedimentary rock mass having a recession coefficient of 0.02, followed by recession coefficient of the order of 10^{-3} indicative of slow drainage through the matrix porosity (Kresic, 1997). The flow half-life for the initial recession period is 32 days and the subsequent slower drainage having a half-life of more than three months. It can be inferred that the finer matrix porosity is sustaining the spring flow during the winter recession period.

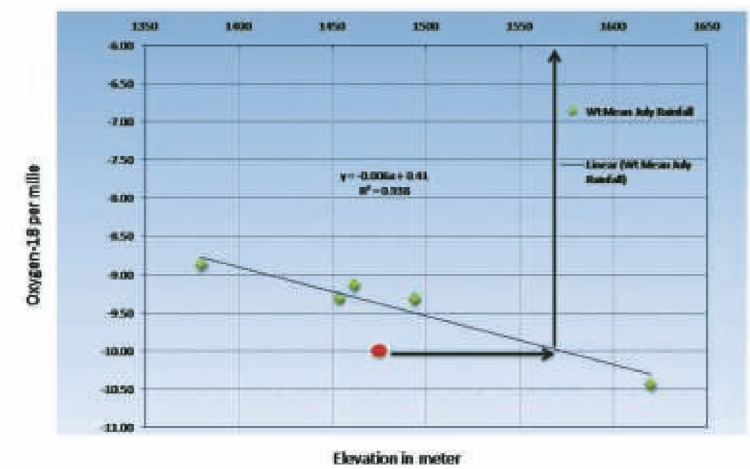
The variability in availability of discharge during the leanest summer period (March to 15 June) and the surplus monsoon period (16 June to September) is presented in Fig. 2.16. Since the study area had received the weakest monsoonal rainfall in 2009, summer of 2010 can be considered as one of the leanest period in recent time. The observed difference in the flow volume of discharge from spring outflow in this contrasting period (summer and monsoon of 2010) is 2.7 times. Monthly flow duration curve in terms of spring discharge availability of springs also illustrate that August, September and October are the surplus months of the year and the leanest months start from January to June. The assessment of the leanest period suggests the minimum dependable water availability in the spring is at least 10 litre per minute, suggesting the need for storage tank of 15,000 litres capacity. In addition to that there is a scope for storage of surplus water available during the three surplus months. The study highlights that wise water resource planning should be based on lean period water availability as well as surplus season assessment also.

Future Prospects

Based on the success of the study, a new project has been initiated in collaboration with Space Application Centre, ISRO, Ahmedabad in Nayar river sub-basin, western Himalaya. Under this project local meteoric line and altitude effect was studied. Applications of stable isotope of oxygen and hydrogen from 44 rainfall event samples from June to September 2010 collected at three different locations within the study area revealed that the samples from both the groundwater sources i.e., the springs and hand pump tapping different depths, all plot on the regression line, indicating that rainfall as a common source of recharge and the recharge process is faster as effect of evaporation is not visible on the isotopic signatures of groundwater from hand pumps. In the Dugar Gad watershed –0.6‰ per 100 m is observed in the precipitation sampling during the monsoon period of 2011 which is indicating that local rainfall within the micro-watershed is the source for springs and streams and groundwater recharge structure should be constructed within the 1550 to 1650 m elevation (Fig. 2.17).

The study highlights that any framework of urban or rural water management should give more focus on conserving the surplus water available during the monsoon through appropriate storage structures, which can be used during the lean months. The stable isotope method enables identification of the altitude effect at regional (basin) and sub-basin scales. Its application at a local micro-watershed scale can be confounding as the interaction between the monsoonal cloud mass, local moisture source, surface topography, and microclimates become complicated at a local micro-watershed scale and hence requires a much detail long-term study.

Table 2.17: Altitude effect calculated for July 2011 and possible recharge zone for a spring in Dugar Gad Microwatershed



MELT WATER DISCHARGE, SEDIMENT LOSS AND RETREAT OF GANGOTRI GLACIER

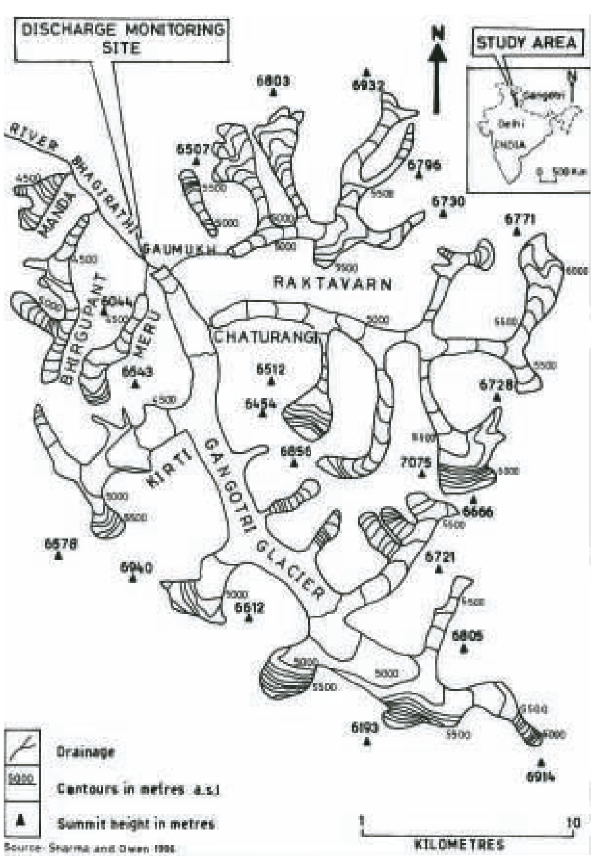
In the recent decades, global warming and its impact on glacier retreat and water resources in the Himalayan region has drawn world wide attention (IPCC, 2007). The relatively young age of the Himalayan mountains, with their large and rapidly moving glaciers, high seismicity, steep valleys with frequent landslides and avalanches and intense monsoonal rainfall, contributes to high erosion rates. Thus the concentration of suspended sediment (SS) in the melt waters of Himalayan glaciers is highly variable due to variability in sediment sources, rock type, relief, weathering state, climatic influences, ice flux, thermal conditions and the debris entrainment processes. Also subglacial channel system contributes to sediment transport, which may reflect the seasonal development of the subglacial drainage system. The case of proglacial river draining the Gangotri Glacier are examined herein, with a view to identify relationships between hydrological characteristics and the sediment delivery.

12
CASE STUDY

Kireet Kumar
GBPIHED, Almora

This case study is based on melt water sample and discharge measurements taken close to the Gangotri glacier snout (appx. 500 m down stream) during entire ablation season of 10 successive years (1999–2009) (Fig. 2.18). Measurements were taken three times a day (morning, afternoon and evening, i.e. 9.00, 13.00 and 17.00 hrs.). Also, hourly measurements were taken during every fortnight to check the diurnal variation of discharge and suspended sediment load. In the Gangotri valley, average annual rainfall over the entire monitoring period was 215.58 mm, which is very low in comparison to other valleys in the area. In addition, velocity of the stream and cross-sectional area was measured time to time to construct rating curves showing water stage level variations. Wooden float method was used to compute the velocity of flow.

Fig. 2.18: Study area map (Gangotri glacier). Right: Snout of Gangotri glacier, 1999



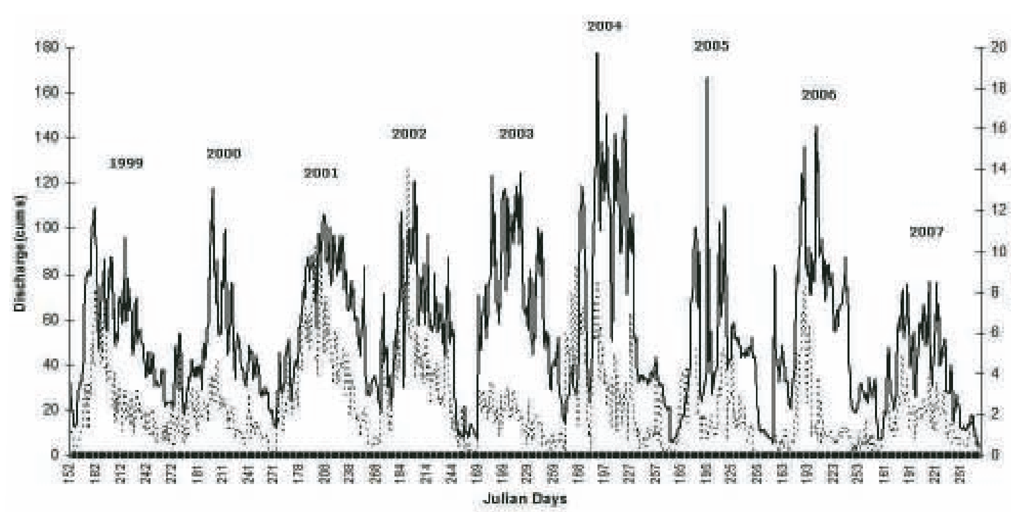
Melt Water Discharge

Melt water discharge of Gangotri glacier (1999–2009) showed almost similar pattern with large variations on a seasonal scale (CV ranging from 0.44–0.57) during ablation season when active melting takes place. Mean daily discharge was highest in 2004 (114.55 cum/s), whereas the lowest value was recorded in 2007. The mean monthly discharge events related to high flow mostly occurred in the months of July and August confirming that these events were caused by opening up of drainage network and excessive melting of glacier. However, the glacial flow also includes the contribution from rain, snow and ice melt, and separation of runoff components is normally not possible. Also, outburst of water bodies in different part of glacier valley caused by excessive rain and rising temperature in late summer was evident by peaks in the hydrographs (Fig. 2.19). In case of large glacier systems like Gangotri glacier, several discharge peaks can also be generated due to variation in melting rate of various tributary glaciers.

Suspended Sediment Loss

The glacier melt water transport sediment as a suspended sediment (SS) and bed load transport. Sediment is derived from different parts of the glacier such as ablation zone, accumulation zone, moraines and valley walls. The sediment transported by the glacier follows three basic routes supra glacial, englacial and subglacial. A wide range of SS concentration (10.24–0.03 g/l) was recorded in the meltwater stream during the entire study period (1999–2007) (Fig. 2.19). Suspended sediment was recorded higher in the start of ablation period in April and in the later part of season, i.e., from June to Oct. high meltwater flow was not accompanied with high SS. Relationship between discharge and suspended sediment load in meltwaters of Gangotri glacier becomes very complex by the occurrence of subglacial hydrological events. That is, the rate of increase in discharge does not always give the same rate of increase in sediment load, depending on whether sediments are available for transport.

Fig. 2.19: Discharge (solid lines) and SS (dotted lines) of Gangotri glacier.



Retreat Rate of Gangotri Glacier

Differential GPS derived retreat rates (with cm level accuracy) of Gangotri glacier taken 1999 onward have shown lower rate of retreat in recent years than the past (pre-1971) without any significant influence on melt water discharge volumes. Results from these two of the largest glaciers of Central Himalaya indicate that regional and local climatic variations (temperature and past winter snowfall) could be mainly responsible for annual retreat pattern and require continuous monitoring to relate with climate change. Also, similar studies were undertaken elsewhere in the IHR (Box -8).

BOX - 8 Glacier Retreat Studies in Tista Basin, Sikkim and Gori Basin, Uttarakhand

Inventory of snow and glaciers in Tista basin of Sikkim Himalaya was carried out jointly with Space Application Centre, Ahemedabad using RS & GIS (LANDSAT, TM of 1990, IRS-1C, 1D, LISS –III, LISS-IV of 1997 and 2004 and AWiFS data for snow monitoring) indicated a loss of 2.77% during 7 years in glaciated area of 57 glaciers (from 403.20 km^2 in 1997 and 393.05 km^2 in 2004) located in 57 valleys, although the number of valley glaciers have remained the same. Loss in glacier area was as high as 33%. However, it was interesting to note that some glaciers also recorded an increase in size (Table 2.5). In a similar study in Goriganga valley (Kumaun Himalaya) out of total 32 glaciers studied, 20 glaciers (66%) are showing retreat with a total loss of 3.99 % area (11.99 km^2) in the last 15 years (1990–2005), and the retreat was high for smaller glaciers in comparison to large glaciers indicating that smaller glaciers respond quickly to climatic variations.

Table 2.5: Summary of loss in area of glaciers from 1997 to 2004 in Tista basin.

Glacier Size (Area in sq km)	1997 Numbers	1997 Area (Sq km)	2004 Numbers	2004 Area (Sq km)	Change in area (%)
0-3	27	46.77	27	45.31	-3.12
3-6	12	50.08	13	53.77	+7.36
6-9	7	51.77	6	44.77	-13.52
9-12	5	54.19	6	62.97	+16.20
12-15	3	38.94	2	26.02	-33.17
15-18	0	0	0	0	0
>18	3	161.42	3	159.16	-1.40
Total Glaciers	**57**	**403.20**	**57**	**392.02**	**-2.77**

[Contributors: R.S. Rawat & Varun Joshi, *GBPIHED, Sikkim Unit]*

GLACIER RETREAT, BLACK CARBON LOADING AND SNOW CHEMISTRY OF GLACIERS

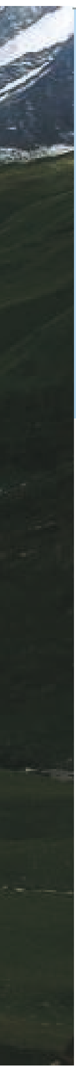
Rapid urbanization and associated anthropogenic influence in the last few decades has led to a substantial increase in the atmospheric aerosols in this region, which can significantly affect climate and glacier snow dynamics. Moreover, air pollutants transported from other regions and deposited over the Himalaya can decrease the surface albedo and accelerate the melting of snow/glacier (Xu et al., 2010). The emission sources may include black carbon (BC) due to biomass and fossil fuel burning, biological activities and mineral dust. Understanding BC and other aerosol loading on glaciers is therefore important to anticipate the likely changes in snow dynamics and its ramifications on the economic activities such as hydropower projects and siltation of reservoirs downstream (Kulkarni et al., 2005). With this background a study was carried out on the aerosols loading, snow/ice chemistry, and changes in the glacier area and their snouts in Parbati, Hamta and Beas Kund glaciers in the headwaters of River Beas in Himachal Pradesh.

Monitoring Glacier Retreat and Snow Chemistry

Glacier retreat estimation was based on fluctuation of snout and shrinkage in glacier area (past and present) using satellite imageries of landsat MSS (October 1980), landsat TM (September 1989), landsat ETM+ (October 2002) and landsat OLI (December 2014). Topographic map (1962) and GPS was used for snout monitoring during the field visits. Aethalometer was used to measure BC concentration at Tosh (3465 m), Dhundi (3101 m) and Sethan (3536 m) in the foothills of the Parbati, Hamta, and Beas Kund glaciers of H.P., respectively. Aerosol was measured in the form of aerosol optical depth (AOD) using Sunphotometer at 15 min. interval from sunrise to sunset whenever the sky was clear. Ionic component in snow at different altitudes of these glaciers across different depths, i.e., 0–20 cm, 20–70 cm, 70–85 cm and 85–100 cm were analyzed using Ion Chromatograph.

13 CASE STUDY

J.C. Kuniyal, N. Ram, K. Chand, K. S. Rana, N. Kanwar & A. Kumar
GBPIHED, Himachal Unit

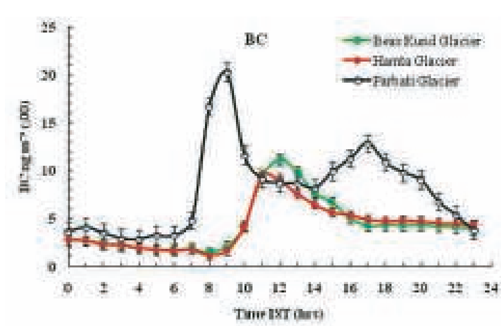


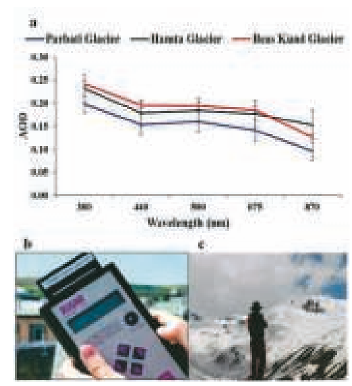
BC Concentration and AOD

Among the three glaciers the highest mean value of diurnal BC was recorded 2026.28 ± 91.29 ng m^{-3} (10:00 hrs IST) at Tosh site at the foothill of Parbati glacier (Fig. 2.20). Also diurnal variations in BC at Tosh were distinct showing two peaks; one during morning (10:00 hrs IST) and other during evening (18:00 hrs IST). High values of BC in the morning could be due to vertical mixing after break-up of the night time stable layer as well as because of increased anthropogenic activities such as biomass burning, forest fire and vehicular emissions (Kuniyal et al., 2004). While at Dhundi and Sethan sites, BC showed only one peak during afternoon (~ 1100–1200 hrs IST) with peak values of 1110.23 ± 55 ng m^{-3} (12: 00 hrs IST) at Dhundi, and 942±46.28 ng m^{-3} (11:00 hrs IST) at Sethan. Single peak of BC has also been reported at Manora Peak, Nainital (Dumka et al., 2010). The mean AOD value at 500 nm (0.16 ±0.01), ranged from 0.08 to 0.25 across the three sampled sites (Fig. 2.21), indicating that AOD decreases with increasing altitude.

Fig. 2.20: BC concentration in the foothill of glaciers.

Fig. 2.21: AOD at all the three glaciers: (a) Microtop-sunphotometer, and (b) & (c) observation of AOD at sampling sites.





Snow Chemistry of the Glaciers

In these glaciers, average amount of all anions was higher for Parbati glacier and ranged from: 0.37–0.39 ppm for chloride (Cl^-),0.04–0.26 ppm for fluoride (F^-), 0.02–0.25 ppm for sulphate (SO_4^{2-}) and 0.10–0.19 ppm for nitrate (NO_3^-). While the cations were found in almost similar concentrations at both the sites except for potassium (K^+), which was found more at Beas Kund glacier (0.27 ppm) as compared to Parbati glacier (0.03 ppm). For other cations it was found ranging from: 0.16–0.18 ppm for ammonium ($NH4^+$) and sodium (Na^+). The dominant anions were found in the following order: $Cl^- > F^- > SO_4^{2-} > NO_3^-$; and the cations: $NH_4^+ > Na^+ > Mg^{2+} > K^+ > Li^+$. The transition metals in the Beas Kund glacier were found as: 0.043 ppm Zn^{+2} > 0.019 ppm Cd^{+2} > 0.014 ppm Cu^{+2}. Whereas, Zn^{+2} 0.07 ppm found as the only transition metal in the Parbati glacier.

Estimates of Glacier Retreat

We recorded a regular shifting of the snouts of all three glaciers since 52 years (between 1962 and 2014), which was computed to be about 32.08 m retreat per year. In case of Beas Kund glacier, using the topographic map of 1978–79 as the base map and landsat satellite imageries of 1989, 2002 and 2014 average snout retreat per year was computed to be 30.04 m. Similarly, in case of Hamta glacier this retreat was computed about 11.04 m per year between 1966 and 2014. As the amount of aerosol loading increases, local temperature also rises and it affects adversely the glaciers and calls for regular monitoring of these glaciers for better insights into glacier dynamics and draw suitable policy implications for water resources management and environmental conservation.

SOCIETAL RELEVANCE OF R&D WORK ON WATER RESOURCES MANAGEMENT

ANNEXURE - II

POLICY RELEVANCE

- Hydrology and watershed management studies led to preparation of guidelines and management plans for Sikkim and Uttarakhand states.
- Environmental and Social Management Framework and Environmental and Social Guidelines were prepared for Watershed Management Directorate, Govt. of Uttarakhand under a World Bank funded project.
- Strategy-cum-Action Plan for Integrated Watershed Development Programme – Hills under a World Bank Project for Siwalik Region was prepared and accepted by Ministry of Agriculture, Govt. of India.
- Bio-engineering practices for spring recharge zone treatment package of practices (Spring Sanctuary Development) was incorporated in drinking water schemes as "Catchment Area Protection Plan" by Jal Nigam in several selected Gram Panchayats in Uttarakhand.
- Village Environment Action Plan was developed for sustainable management of bio-physical resources at Gram Panchayat level and implemented under SWAJAL project across several villages in Uttarakhand.
- Draft Notification Guidelines under Environment (Protection) Act (1986) for rain water harvesting for irrigation and domestic use were prepared.
- Long-term glacier retreat studies enabled to estimate the slower rate of recession of Gangotri glacier, and dispelled the earlier estimates that Himalayan glaciers will vanish by 2035.

CONTRIBUTION TO TECHNOLOGY DEVELOPMENT

- Large Cardamom–Alnus based agroforestry in Mamlay watershed, Sikkim in replacement of traditional agriculture (15–20 year cycle) was popularized for high yield (based on nutrient dynamics studies) and also to achieve soil and water conservation.
- Hydrology of springs and micro-watersheds in Sikkim and Uttarakhand provided insights into role of land use and land cover and other anthropogenic activities in the spring recharge zones and catchment areas and advanced the scientific knowledge for water resources management.
- Application of eco-technology (physical and biological interventions in spring recharge zone) improved spring water yield was a new finding that was demonstrated in an experimental site in Pauri-Garhwal in the IHR.
- Application of stable isotope of oxygen and hydrogen in the spring recharge zone identification in lesser Himalayan watersheds provided insights to construct percolation structures to augment water discharge and water storage tanks based on lean month water discharge.
- Improved kiln for drying large Cardamom in Sikkim was designed that could save fuelwood and labour input due to improved efficiency of drying and also reduced pressure of tree cutting on forests as compared to traditional Bhatti. Natural aroma of the Cardamom capsules was retained that earned more market prices.

OUTREACH

- Training and capacity building programmes on watershed management were conducted for a range of stakeholders both in Sikkim and Uttarakhand. Prominent among these were programmes conducted for 30 NGOs of U.P. and Officials of watershed Management Directorate, Uttarakhand.
- About 50 families in three village of south Sikkim region benefited through improved technologies and raised their income by five times.
- Popularization of improved kiln technology for large cardamom drying in Sikkim was carried out and some improved kiln units were distributed among the cardamom growers.
- Rural Development Department, Govt. of Sikkim replicated our eco-technology to increase spring discharge successfully in several rural areas of the state and improved water discharge of drying springs and streams.
- Demonstrations on spring sanctuary development at Pauri-Garhwal served as training site for many Govt. officials, NGOs and local people in Uttarakhand.
- Spring hydrology work aiming at improving water availability to the rural people attracted two Professors of Free University, Amsterdam and they visited our project site in 2003 and subsequently six overseas students worked under the supervision of GBPIHED faculty for masters work on watershed management.

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3

BIODIVERSITY CONSERVATION AND SUSTAINABLE USE

Linking Knowledge with Bioresource Management

The Himalayan mountains are globally recognized as centers of biological diversity that has sustained people through generations. The ecological and economic importance of mountain biodiversity towards maintaining the environmental balance and achieving goals of socio-economic development has been realized across the globe. Presumably about 40% of the world economy and 80% of the need of the poor are derived from the biological resources. Among the world's mountain ecosystems, the Himalaya holds a special significance by way of supporting representative, rich and unique biodiversity. Therefore, the region is aptly recognized amongst 34 Global Biodiversity Hotspots (HBH). Within the HBH, the IHR, with over two-third geographic coverage of entire hotspot and representation of diverse biomes/climate zones (e.g., tropical, sub-tropical, temperate, sub-alpine, alpine and tundra, etc.), exhibits special conservation and socio-economic values. However, increasing anthropogenic pressure coupled with changing environmental conditions has caused severe threats to biodiversity elements and thereby impacting on sustenance of dependent indigenous communities. The IHR, with geographic coverage of over 5.3 lakh km^2, comprises three biogeographic zones (i.e., Himalaya, Trans Himalaya and North East India) and nine provinces (i.e., 3 in Zone Trans Himalaya - Laddakh Mountains, Tibetan Plateau, and Sikkim Trans Himalaya; 4 in Zone Himalaya - North West, West, Central and East Himalaya; and 2 in Zone Northeast India – Brahmaputra Valley and Northeast Hills), and covers a large altitudinal range (<300 – >8,000 m asl). Biodiversity richness and representativeness of the region is well reflected.

For instance, the IHR represents 26% of India's forest types, 47% of angiosperms, 81% of gymnosperms, 59% of pteridophytes, 61% of bryophytes, 59% of lichens and 63% of fungi. Likewise, in faunal groups, IHR represents about 69% of known mammals in India, 79% of birds, 38% of reptiles, 34% of amphibians and 10% of fishes (Table 3.1) (Palni & Rawal, 2013). Uniqueness (endemism) is yet another important attribute of the region. Amongst floristic elements, besides nearly 32% of species being endemic, IHR represents 71 endemic genera and 5 endemic families. Further, the life support value of biodiversity in the region is well documented. For example, this region has 1748 known species of medicinal (Samant et al., 1998) and 675 species of wild edible plants (Samant & Dhar, 1997). About 118 species of medicinal and aromatic plants (MAPs) of IHR yield essential oils.



Similarly, the ecosystem services, emanating from the region, have far reaching implications. Recognizing the importance of mountain biodiversity for a number of ecological functions and its vital linkages with long-term human welfare, the Institute since its inception has kept conservation and sustainable use of Biological Diversity as core focus of R&D activities, which are on one hand responsive to contemporary global thinking on subject matter and on the other effectively address the specific issues at local/regional scale. The broad guidelines provided under Convention on Biological Diversity (1992), specifically the proposed programme of work on Mountain Biodiversity (UNEP/SBSTTA/9/1, 2003) provided the base for development of framework for activities in IHR. The broad emphasis remained on linking conservation of Himalayan biodiversity with sustainable development goals. Over the years, through detailed investigations, Institute has succeeded in main streaming Himalayan biodiversity aspects in national and global agenda. This section deals with success stories under following broad areas of studies: (i) Understanding Himalayan biodiversity, (ii) Prioritization of biodiversity elements, (iii) Strengthening conservation, and (iv) Promoting outreach. A summary of societal relevance of the R&D work emanated from these studies is summarized in Annexure - III.



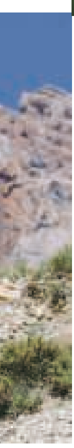
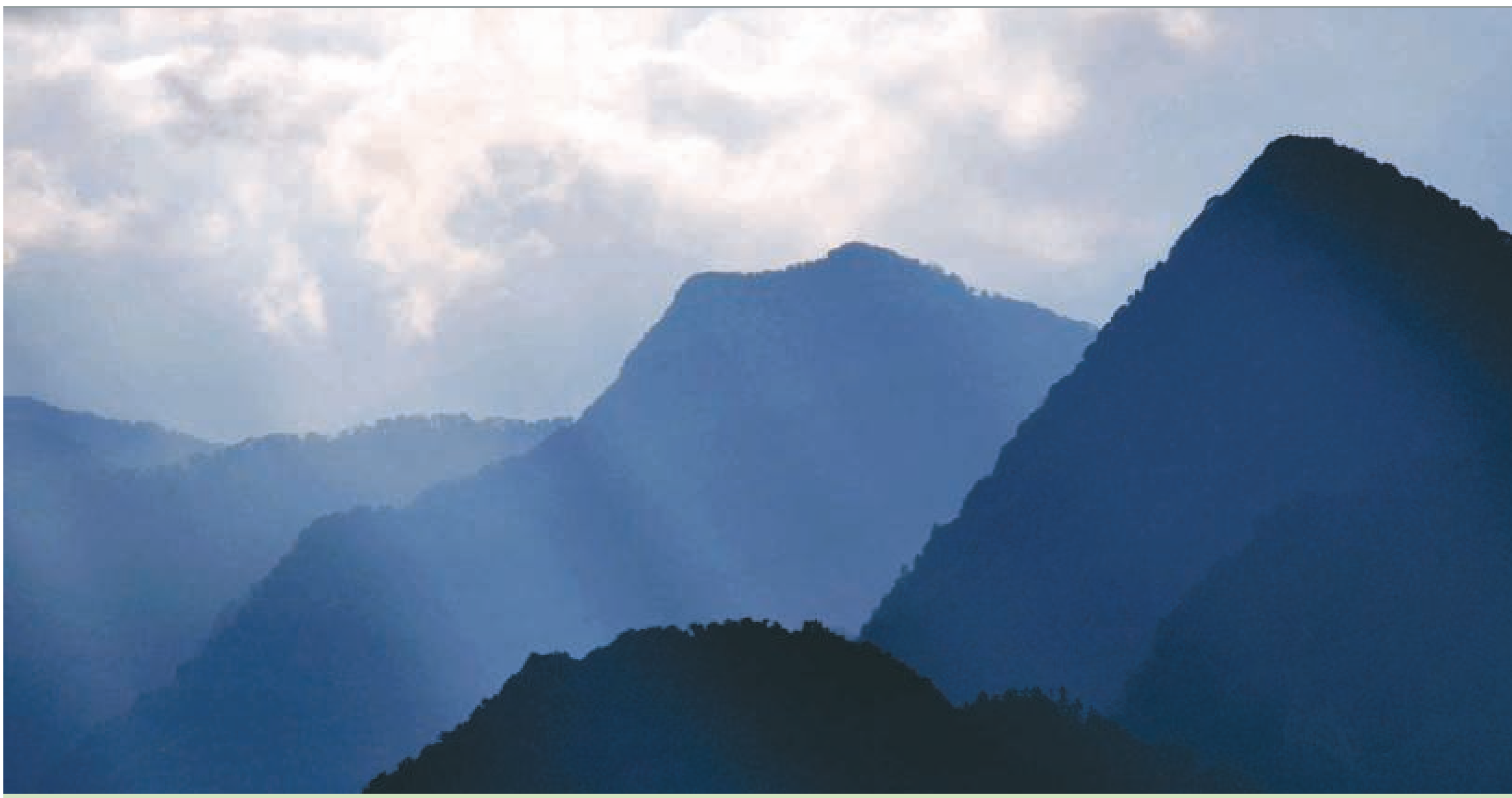



Table 3.1: Richness and endemism in IHR

Group	Total Species	Endemism (%)
Angiosperms	8000	40
Gymnosperms	44	16
Pteridophytes	600	25
Bryophytes	1737	32.5
Lichens	1159	11.2
Fungi	6900	27.4
Fishes	218	25.7
Amphibians	74	47.3
Reptiles	149	19.5
Birds	528	-
Mammals	241	-

UNDERSTANDING HIMALAYAN BIODIVERSITY: STRENGTHENING KNOWLEDGE BASE



Since the beginning GBPIHED laid strong emphasis on building information base so as to better understand patterns and processes of Himalayan biodiversity. Approach remained throughout consultative. For instance, in early nineties the National Workshop "Himalayan Biodiversity: Conservation Strategies", organized by GBPIHED (October 1992), helped in building a broad baseline of information available. The knowledge product of this workshop, a proceedings "Himalayan Biodiversity – Conservation Strategies" provided the direction to the R&D activities in the Institute and to other stakeholders for designing and implementing biodiversity related activities at local and regional level. Following these recommendations, systematic efforts were made to establish inventories on Himalayan bioresources. First of its kind inventories of select plant families, that included detailed assessment of endemism, yielded good results and the findings received global recognition through publication in peer reviewed journals (Dhar, 2002; Mahar et al., 2009). Among others, these studies have highlighted: (i) the distribution patterns of endemic species; (ii) the conservation implications of endemics; and (iii) the usefulness of location specific data in conservation planning. However, efforts were simultaneously made to make the activities more focused towards the National/Regional/Local priorities, and a Brain Storming Session (1996), involving eminent experts on Himalayan biodiversity, resulted in development of "Himalayan Biodiversity – Action Plan", which proved a guiding document for reorienting activities to achieve greater impact. The studies undertaken in representative ecosystems helped in understanding the patterns to explore conservation implication. For example, study on structural diversity and representativeness of forest vegetation in a Protected Area (PA) of Kumaun Himalaya provided first hand information on the nature of forest demography, patterns of changes, and pathways of non-native introduction and proliferation in the area. Based on these patterns conservation and management prescriptions for PA were suggested. Investigations on the biomass extraction trends helped in ranking of plant species in the PA based on extraction pressure for domestic use (Samant et al., 1998). Detailed documentation of plant diversity of climate sensitive timberline zone of west Himalaya has helped in

14
CASE STUDY

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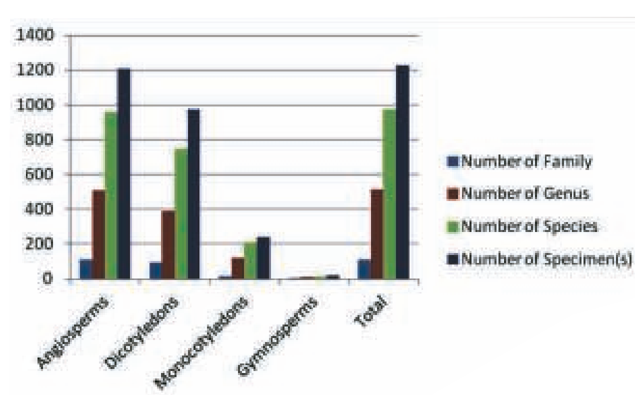
identifying floristic rarities. This documentation subsequently resulted in drawing conservation imperatives for this region (Rawal & Dhar, 1997). Subsequent follow-up studies have generated strong information base w.r.t. (i) structural and compositional features of forests (Gairola et al., 2013), (ii) functional features, and (iii) effects of anthropogenic disturbances on vegetation. Considering the value of medicinal and wild edible plants, the Institute has succeeded in building a strong documentation. The book 'Medicinal Plants of Indian Himalaya' (Samant et al., 1998) is being used by diverse stakeholders as a base for understanding diversity and distribution of Himalayan medicinal plants. Likewise the information compiled and analyzed on diversity, endemism and economic potential of wild edible plants provides a base for harnessing the potential of wild flora. The status (feasibility) document prepared for proposed Cold Desert Biosphere Reserve in India formed the basis of designation of the 16th Biosphere Reserve - the Cold Desert Biosphere Reserve, by the Ministry of Environment and Forests, GoI (20 August 2009). Furthermore, the Compendium on Indian Biosphere Reserves, prepared by the Institute, provides comprehensive information for use by diverse groups of stakeholders, including Biosphere Reserve managers. Based on the information generated over the years and compiled from other studies, the Institute prepared a comprehensive document 'Himalayan Biodiversity – Richness, Representativeness, Uniqueness and Life-support Values', which forms readily available base line information on biodiversity of different Himalayan provinces and under specific groups. More recently, realizing the value of electronic databases, Institute has initiated developing database for vascular plants of western Himalaya (Box - 1). Also, documentation of biodiversity at molecular level (Box - 2), and biodiversity studies in development areas, such as roads, in remote Himalayan localities is being taken-up (Box – 3).

BOX - 1 User-Friendly Data Base of Vascular Plants of the Western Himalaya

A modest beginning has been made in organizing the available information on vascular plants of western Himalaya in the form of electronic databases. In this effort, a total of 1226 GBPIHED herbarium (GBP) specimens have been digitized (Fig. 3.1). The binomials of the digitalized specimens have been carefully checked with the relevant floras and monographs.

Fig. 3.1: Details of digitized plant specimens in GBPIHED herbarium

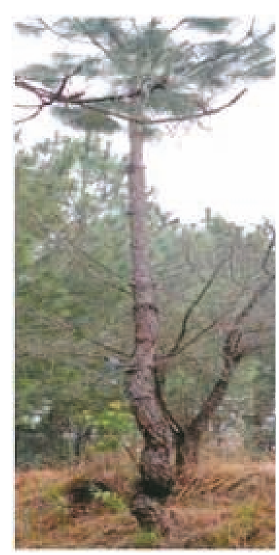


[Contributor: K.C. Sekar, *GBPIHED, Almora*]

BOX - 2 Molecular Marker for Detection of 'Twisted Trait' in Chir Pine at Nursery Stage

Chir pine (Pinus roxburghii) is one of the most useful tree species in the Himalayan region in terms of timber and resin. However, nearly 30% of chir pine trees are reported to be twisted in Garhwal and Kumaun region making them useless for timber purposes and thereby resulting in huge revenue losses (Fig. 3.2). Pine forests in Almora district (Uttarakhand) across five sites (1350–1900 m asl) were surveyed where straight and twisted pine were growing in the ratio of 1:1. Two types of twisted characters were observed: (i) twist in anti-clockwise direction which is initiated at the early stage of trees at an angle of approximately 7°–15°; and (ii) twist in clockwise direction which is initiated at later stages of tree growth. Morphological data were recorded. DNA was isolated and polymerase chain reactions (PCR) were carried out. DNA information obtained from leaf samples of each trait were used to generate differentiating profiles. One RAPD and 5 AFLP primer combinations were observed which were able to segregate the straight and twisted trait; they were re-amplified and similar profiles were observed. When these data were used for construction of graphic phenogram, all straight trees were found falling in one group along with one twisted trees (possessing approximately 7° or lower twist in the tree trunk). Angle of twist was negatively correlated with drum width (–0.84) and number of branches. Morphological parameters such as tree height and angle of twist showed increasing trend with increasing altitude, while drum width, number of branches and number of angles showed decreasing trend with increasing altitude in the twisted trees. This research on eco-morphology and molecular analyses of twisted vs. straight trait of chir pine would prove useful in raising commercial plantations of pine having timber value. The molecular technique can be used for possible segregation of twisted and straight trait in chir pine at an early stage. Therefore, this technique can be gainfully utilized by forest department and other related agencies.

Fig. 3.2: Straight and twisted trees of chir pine growing in Almora forests.



[Contributor: Shilpi Paul, *GBPIHED, Almora*]

BOX - 3 *Biodiversity Documentation in Trans-Arunachal Highway Project, Arunachal Pradesh*

The NE Unit of GBPIHED was assigned to prepare a Biodiversity Conservation and Wildlife Management Plan for the proposed five road segments of Trans-Arunachal Highway (TAH) in Arunachal Pradesh. The study found a total of 859 species of higher plants (trees 251, shrubs 193, herbs 271 and climbers 144), of which 85% species have ethnobotanical importance and in use by tribal groups like Nyishi, Tagin, Apatani, Galo and Adis. Analysis of documented biodiversity revealed existence of 287 species as threatened (RET). Also, 23 species were recorded as endemic to North East India, Indo-China and Arunachal Himalayan region. Of these, Albizia arunachalensis, Schizostayum arunachalensis, Primula subansirica, Begonia aborensis, Capparis pachyphylla, Paphiopedilum wardii and Maesa arunachalensis species were strictly endemic to Arunachal Pradesh. Among the documented RET species, 72 species (25%) fall under various IUCN threat categories (Fig. 3.3). The proposed five road segments of TAH are also rich in faunal diversity such as leopards (Panthera pardus), clouded leopards (Neofelis nebulosa), sambar (Cervus unicolor), barking deer (Muntiacus muntjak), dholes (Cuon alpinus), wild boars (Sus scrofa), jackals (Canis aureus), etc. Based on the field studies, 11 zones were identified as biodiversity rich zones and prioritized areas for wildlife management in Potinto Bame road segment. Four biodiversity rich zones were identified between Nechipu to Bana and Seppa to Passa road segments for taking mitigation measures for conservation of the rich biodiversity.

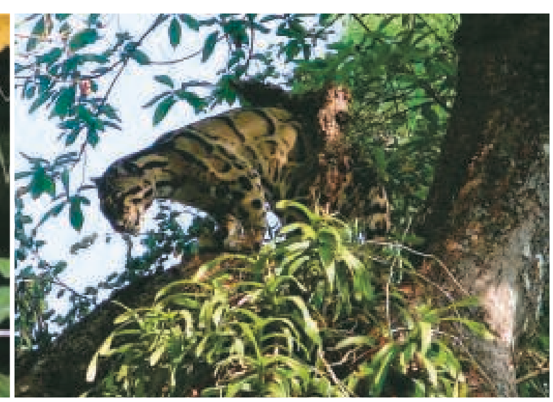
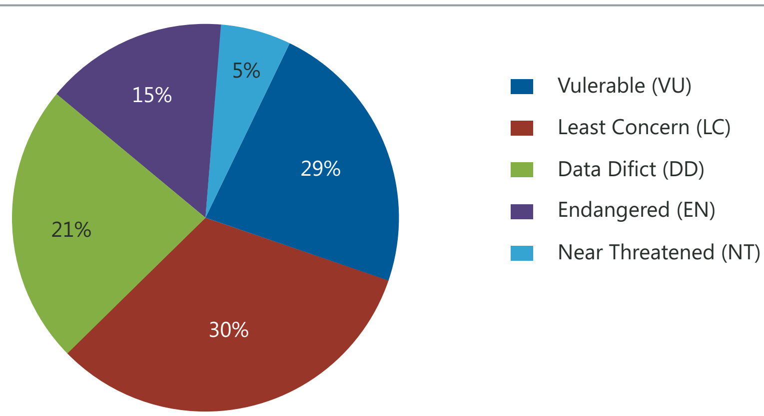


Fig. 3.3: Distribution of plant species in various threat categories of IUCN in TAH.



[Contributor: K.S. Kanwal, P.K. Samal, & M.S. Lodhi, *GBPIHED, NE Unit*]

PRIORITIZING HIMALAYAN BIODIVERSITY – AUGMENTING CONSERVATION AND SUSTAINABLE USE

While attempts were on to strengthen the knowledge base on Himalayan Biodiversity, concurrent analysis of information helped in fixing conservation and development priority of biodiversity elements. The state-of-the art approach developed for setting priorities for medicinal plants utilized in the industry (Dhar et al., 2002) is being followed by diverse groups of stakeholders. This analysis revealed: (I) increased dependence on exclusive wild forms (64.6%), (ii) dominance of destructive harvest trend (69%), and (iii) restricted distribution range of most medicinal plants (MPs) used in industry, which indicates the intensity of threat. Across the life forms top 20 MPs needing conservation attention were thus identified.

The uniqueness (endemism) analysis of documented biodiversity (see Case Study 1) also revealed the conservation priorities (i.e., species and area) in the region. Analysis of the nature and extent of information available on various aspects of plant endemism in the Himalaya has revealed that high altitude Himalaya is rich in plant endemic diversity and in this part the temperate families show higher than expected level of endemicity. Based on this analysis conservation implications of high plant species endemism have been discussed to: (i)

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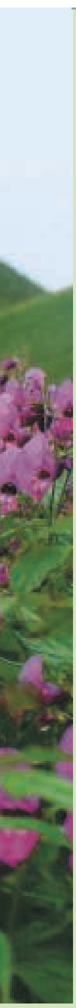

determine extension of boundaries of existing protected areas (PAs) or establishment of new PAs, (ii) identify appropriate sites for establishing trans-frontier parks, (iii) focus on recognizing relative importance of economic and conservation value of anthropogenic endemics, and (iv) recognize the consequences of expected low genetic diversity of narrow endemics. An approach for prioritizing strategies for action has also been proposed considering three important attributes viz., geographic range, ecological amplitude and anthropogenic pressure. Through this approach, specific actions for a particular attribute of an endemic taxon were suggested. Further, a more focused study on diversity and distribution of endemics in selected temperate plant families has helped in identifying the priority sites across IHR (Mahar et al. 2009). The usefulness of location-specific data for assessing patterns of species diversity and endemism based on a data-sets for the 10 temperate flowering plant families from the IHR has been highlighted. Analysis was based on 818 grid cells (15'x15') representing throughout the IHR. Based on the existing information on diverse aspects of the selected plant families four indices, i.e., species richness, weighted endemism, 1–4 cell endemism and corrected weighted endemism were developed and mapped for selected plant families. The outcome enabled identification of potential areas for conservation in the IHR.

Priority assessment across special groups (e.g., medicinal plants, wild edible plants) has helped in identification of species not only having the conservation value but also those with economic significance. Detailed analysis of economically important wild edible species across IHR have resulted in identification of species with income generating potentials (Maikhuri et al., 2004; Samant & Dhar, 1997). Following the outcomes of documentation (Case Study 1) and prioritization (Case Study 2) the medicinal plants of the region have been considered holistically to ensure their conservation and sustainable use (Box- 4). Attempts of cultivating MAPs in the farmers' fields in other parts of west Himalaya also have proved successful (Box - 5 and 6).

BOX - 4 Conservation and Sustainable Utilization of Medicinal Plants of Himachal Pradesh

The Himachal Unit of the Institute considered holistic development of medicinal and aromatic plants (MAPs) sector by way of extensive R&D efforts to: (i) assess, monitor and map the medicinal plant diversity for different threat categories; (ii) prepare strategies and promote ex-situ and in-situ conservation; (iii) develop conventional propagation protocols and agrotechniques for cultivation of important MAPs; and (iv) impart training to different stakeholders on cultivation, conservation and sustainable utilization.

Extensive R&D work was conducted in upper Banjar valley (1500–3600 m asl), Mohal Khad Watershed (1,200–3,000 masl); Parbati Watershed (1,100–6,500 masl), and Upper Beas Valley (2,300–5,000 masl) in Kullu district and Upper Chandra Valley (3,300–5,000) in Lahaul and Spiti district to assess the medicinal plant diversity (Fig. 3.4). A total of 476 species of medicinal plants (307 genera and 101 families) were recorded. Of these documented species, in Parbati Watershed, 244 species; in Chandra Valley, 161; in Upper Beas Valley, 239; in Mohal Khad, 160 and in Banjar Valley, 226 were Himalayan native species. Among these, 19 species in Chandra Valley; 43 in Upper Beas Valley; 29 in Mohal Khad; 44 in Parbati Valley and 43 in Banjar Valley were near-endemic, whereas 2 species in Chandra Valley; 3 in Upper Beas Valley emerged as endemic to the IHR. Some notable endemic and near endemic species include: Aconitum heterophyllum, Allium humile, A. wallichii, Angelica glauca, Berberis aristata, Chaerophyllum villosum, Corydalis melifolia, Delphinium denudatum, Delphinium cashmerianum, Elsholtzia flava, Heracleum candicans, Juglans regia, Jurinella macrocephala, Paeonia emodi, Rhododendron anthopogon, Rhododendron campanulatum, Roscoea alpina, Saussurea heteromalla, Selinum teunifolium, Ulmus wallichaian, Wikstroemia canescens, etc. Based on availability in the wild and use of MAPs, they were put under different threat categories.

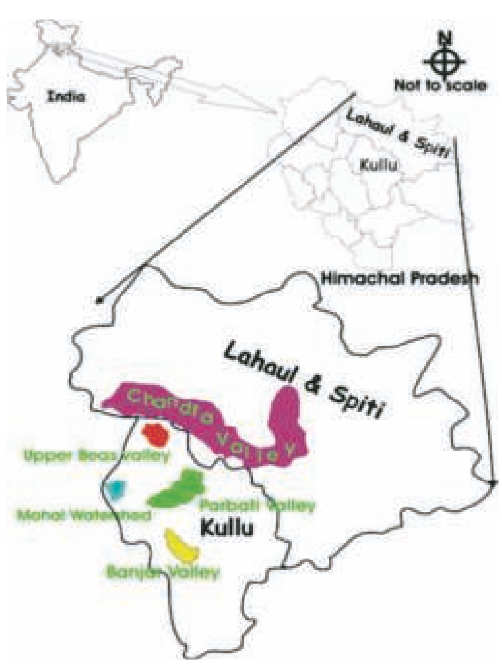

Fig. 3.4: Target study area and medicinal plants cultivation in Kullu and Lahaul & Spiti districts of H.P.

Stakeholders consultations revealed that 6 species - Angelica glauca, Aconitum heterophyllum, Picrorhiza kurrooa, Podophyllum hexandrum, Saussurea costus and Withania somnifera deserve priority for conservation and large scale cultivation. Therefore, efforts were made for their cultivation using R&D based agro-techniques. Agrotechniques, developed for 26 commercially viable medicinal plants (Samant et al., 2008), were disseminated among the stakeholders for promoting cultivation of medicinal plants. Considering farmer's need assessment, capacity of farmers in Kullu and Lahaul valleys was built w.r.t. agrotechniques of A. heterophyllum, A. glauca, P. kurrooa and P. hexandrum, and farmers of Mandi district on the agrotechnique of W. somnifera. These efforts succeeded in study villages. For example, large scale seedlings of A. heterophyllum were raised by 24 farmers at Jana and Khansar village. Amongst the farmers of Jana village, one farmer raised over 3,00,000 seedlings of A. heterophyllum and earned Rs. 2,50,000/- by sale of seeds and seedlings. This success has motivated other farmers in the village for cultivation of A. heterophyllum. Seedlings (+25,000) of W. somnifera raised in Institute's nursery were distributed among the farmers and other stakeholders of Kullu valley and Mandi district. This helped in promoting cultivation of W. somnifera in various parts of Mandi district.

[Contributors: S.S. Samant, M. Lal, & P. Sharma, *GBPIHED, Himachal Unit*]

BOX -5 ***Promoting Medicinal and Aromatic Plants Cultivation and Floriculture for Improved Livelihood***

Three village clusters viz., Dharaunj, Mudiyani and Gumod in Champawat District, Uttarakhand were covered under a project funded by National Agricultural Innovation Project (NAIP) with an aim to promote cultivation of economically important medicinal plants as an alternative option of livelihood through capacity building on cultivation, harvesting, value addition, packaging and marketing. Intensive discussion with stakeholders resulted in identification of five high value medicinal and aromatic plant (MAPs) species viz., Rosmarinus officinalis, Asparagus racemosus, Ocimum basilicum, Valeriana jatamansi and Matricaria chamomila. Following a participatory approach, 5 mother nurseries were developed in identified village clusters. Regular capacity building events led to establishment of small MAPs nurseries by 50 progressive farmers in their fields (Fig. 3.5). Registration of farmers with Herbal Research Development Institute, Govt. of Uttarakhand was facilitated to avail benefits of Government schemes. Medicinal plants cultivation and trade was thus facilitated and a total of 100 farmers (Dharaunj -70; Mudiyani-Banlekh – 20; Gumod – 10) were thus registered. A farmers association 'Gramin Kisan Swarojgar Sangathan, Champawat' was set up so as to promote farmers for cultivation of MAPs in nearby village clusters, and develop an appropriate network for collection, harvesting, packing, value addition and marketing of selected MAPs. The cost-benefit analysis revealed that O. basilicum (Rs. 1970/nali) gives maximum benefits and M. chamomile (Rs. 220/nali) the minimum. This return was encouraging and a total of 120 farmers from identified village clusters adopted MAPs as an option for income generation. Considering the interest of farmers in MAPs cultivation, an oil extraction unit was also established in Dharonj village and technical training for oil extraction was imparted.

Further, realizing that floriculture as one of the major income-generation activities in 2007 under NAIP project and since then over 52 farmers of different village clusters (as mentioned above) are engaged in cultivating different species of flowers, i.e. Gladiolus (Nava Lux-Yellow, White Prosperity-White, Rose Supreme-Pink, Peter Plus-Pinkish, American Beauty-Red) and Lilium (Asiatic Lily-Yellow/Pink and Oriental Redona-Pink/Red) in about 8 ha land (Fig. 3.6). During 2010–11, the return from cut flowers in the project villages was Rs. 5,21,000/ (Table 3.2). A Memorandum of Understanding (MoU) between buyers and farmers under buy back mechanism proved greatly beneficial.

Table 3.2: Income generated from cultivation of flowers by the farmers of Champawat

Name of Cut-Flowers	Beneficiaries/ Farmers	Production (Spike)	Market Price (Rs/spike)	Income/Year (Rs)	Cultivation (Rs)	Net Profit (Rs)
Gladiolus	64	1,50,000	4 / spike	6,00,000	1,40,000	4,60,000
Lilium	06	4,000	17/spike	68,000	7,000	61,000
Total	**70**	**1,54,000**	-	**6,68,000**	**1,47,000**	**5,21,000**

Fig 3.5: Medicinal and aromatic plants growing in Dharonj village.

[Contributors: I.D. Bhatt, P.C. Phondani, V.S. Negi, & B.P. Kothyari, *GBPIHED, Almora*]

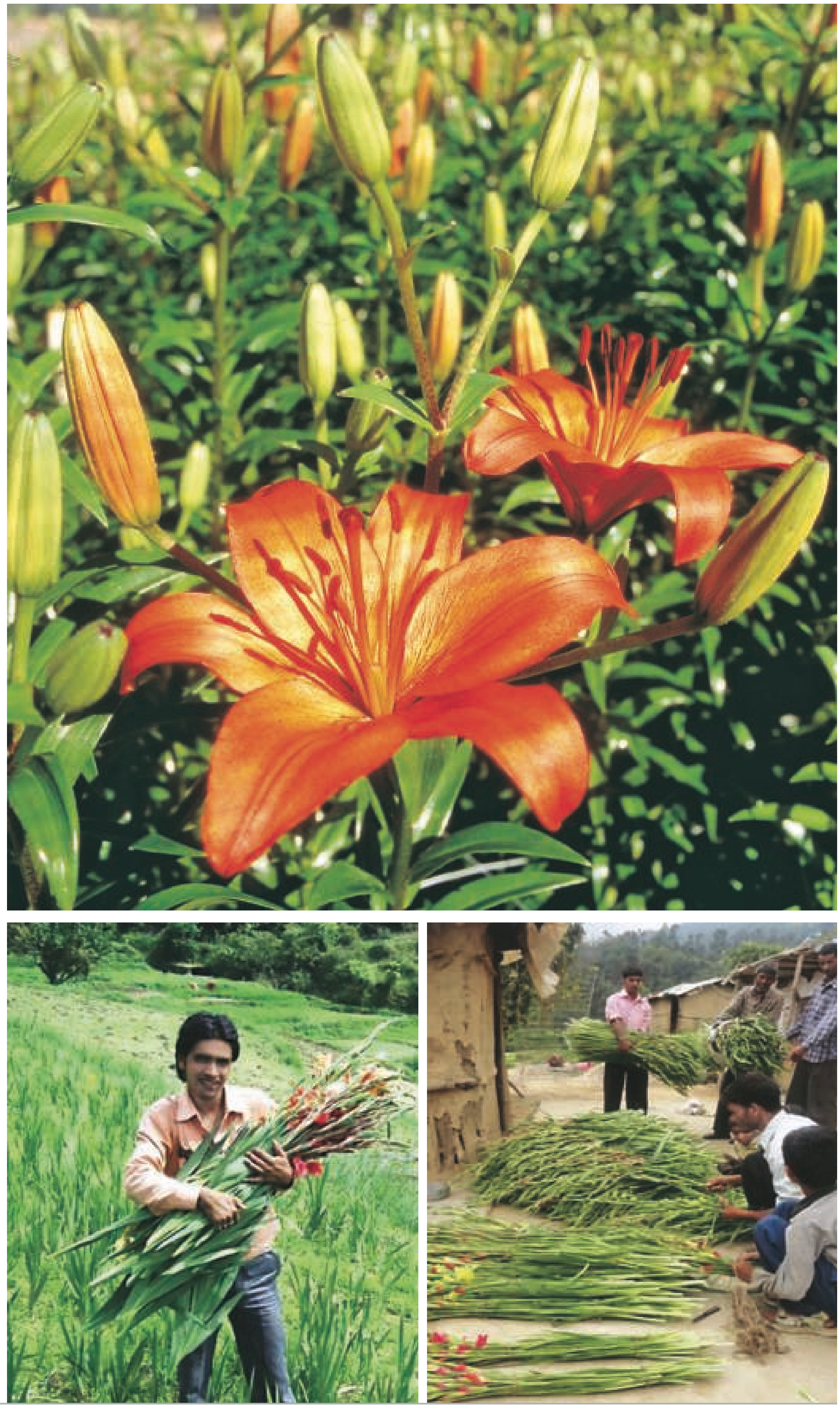

Fig 3.6: Lily flowers growing in Dharonj village.

BOX - 6 **Indian Olive Tree Yields High and Good Quality Olive Oil**

Among various multipurpose tree (MPT) species, Olea ferruginea Royle, generally known as Indian olive, is an important plant for socio-economic development in the western Himalaya (Fig. 3.7A). This MPT is used for quality fodder, firewood, timber, edible fruits and treatment of various ailments (Joshi, 2012). Edible fruits of this species are mainly valuable for its oleic acid which is used in typhoid, jaundice, biliousness, scabies, burning of the eyes, toothache and caries of the teeth. The oil is useful in cooking, rheumatism, joints pains, malaria, gonorrhea, skin diseases and cosmetics.

Fig. 3.7 A: Olive oil tree growing in Himachal Pradesh

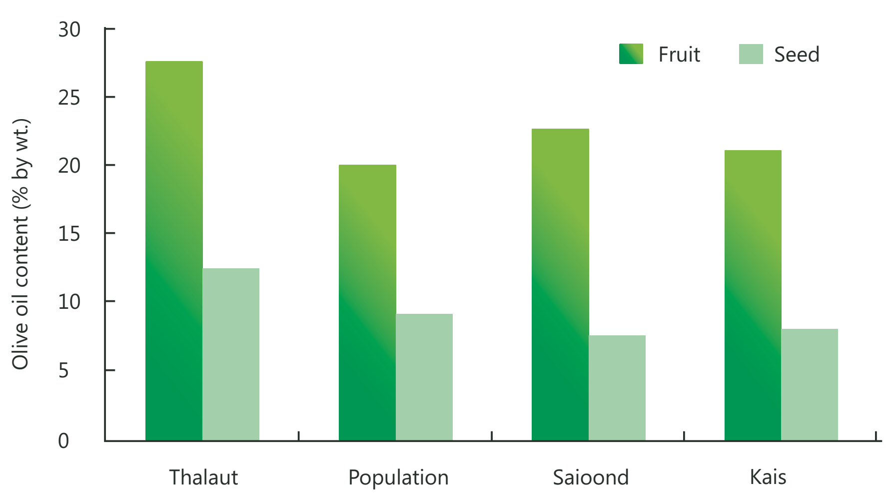

Fig. 3.7 B: Olive oil content in the fruits of O. ferruginea

Four populations of O. ferruginea (Kullu and Mandi districts of H.P.) were explored to determine the content of olive oil and their fatty acid composition in the fruits. The oil of O. ferruginea fruits, like many O. europaea cultivars was found rich in monounsaturated fatty acids, which are known to reduce harmful low-density lipoprotein and total cholesterol without changing the levels of beneficial high-density lipoprotein cholesterol. The olive oil contents in the fruits varied from 20.67% to 27.40%, across the four populations (Fig. 3.7B), which is at par with the world's most prominent olive oil varieties (13% to 28%). This species was also found to be best for its ability to withstand drought based on eco-physiological observations (e.g., lower specific leaf area, lower leaf water potential, lower relative water content and lower water content at saturation), indicating its greater tolerance to drought hence can be planted in rain-fed areas. Thus sustainable use of this potential native MPT holds promise for the socio-economic development and conservation of this important plant.

[Contributor: S.C. Joshi, GBPIHED, *Sikkim Unit]*

ACHIEVING TARGETS OF BIODIVERSITY CONSERVATION – PROGRESSION OF 'SURYA-KUNJ'

On account of richness, uniqueness and changing sensitivity of biodiversity elements, the Himalayan region has been recognized one amongst the 34 global biodiversity hotspots. High degree of endemism in the region implies occurrence of various critical habitats and eco-regions having global importance. However, the extreme vulnerability of Himalayan biodiversity elements towards natural and human induced disturbances has also been well established. This calls for extensive conservation efforts at different levels. In this context, *in-situ* efforts of conservation in the region are reported to be at satisfactory level.

Recognizing the above, and considering that the conservation of threatened and sensitive biodiversity elements, especially the plants, would require adequate *ex-situ* conservation support, the GBPIHED, in early nineties initiated establishment of a functional arboretum – 'Surya-Kunj', at the Institute headquarters in Kosi-Katarmal, Almora. The immediate aim was to ensure *ex-situ* maintenance of representative sub-tropical and temperate woody species of the western Himalaya. However, the envisaged long-term goal was to develop an on-site demonstration and learning site on conservation of Himalayan plant diversity, especially the threatened species. Towards achieving these short-and-long term goals, various objectives were drawn (Box – 7).

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BOX - 7 An Ex - Situ Conservation Site "Surya-Kunj" Established at GBPIHED, Almora

- ***Ensure ex-situ maintenance of representative threatened and otherwise important plant species.***
- ***Develop adequate facilities (research and infrastructure) for plantation and growth of plants.***
- ***Establish and enrich germplasm and investigate trends of growth and survival of species.***
- ***Develop propagation packages of selected species; monitor and analyze performance, and support reintroduction of highly threatened species.***
- ***Meet growing demand of planting material by diverse stakeholders.***
- ***Serve as a centre for on-site training and extension on conservation of Himalayan plant diversity.***
- ***Act as referral centre for identification of Himalayan endemic, threatened, and otherwise important species.***

Approach

Since the beginning all interventions for *ex situ* conservation followed a systematic approach for achieving both short-and-long term goals. A degraded hill slope (approximately 71 acres, within altitude range of 1100–1250 m asl) in close proximity of the Institute premises was identified for the intervention. Idea was to meet the dual objectives of *ex-situ* plant conservation and restoration of degraded hill slopes. The identified area was mapped and grouped under various habitat types. Also, an inventory of existing plants across identified habitats was prepared (Samant et al., 1998). It was followed by systematic interventions, considering habitat suitability, by way of plantation of representative species. Consequently, adequate research support and infrastructure was developed. Nursery, glass-house, net-house facility along with fully functional tissue culture and analytical laboratories were created, and intensive research back-up was provided through development of conventional and in-vitro propagation protocols of sensitive and high value species.

Since the inception, it was well understood that the plantations and other interventions will bring in changes in site conditions. Therefore, the approach of interventions was kept flexible so as to accommodate these changes. Also, the conceptual framework remained evolving over time. The basic thinking was not to keep the interventions static, as happens for most of the *ex-situ* conservation sites (e.g., botanical gardens), rather to follow a dynamic path of natural growth. Our special efforts were to synchronize development of different plantation patches with natural systems. While considering the above, equal attention was paid to make the site attractive and informative to various stakeholder groups. Therefore, integration of special components, like medicinal plants, wild edibles, and orchids, was made. More importantly, nature-friendly walkways and interpretation spots were developed. The interactive boards and signage, along with creation of accommodation and interaction facility in the form of Nature Interpretation and Learning Centre (NILC) within the site helped in promoting outreach.

The Functional Arboretum

As envisaged, the beginning was made with an exclusive focus on ex-situ maintenance of representative woody species. As a result of this focus the 'Surya-Kunj' currently harbours over 110 tree species. The representation ranges from species of common societal interest, like the representative 5 Oaks of west Himalaya (*Quercus glauca, Q. leucotrichophora, Q. lanuginosa, Q. floribunda* and *Q. semecarpifolia*), to the ones with high research interest, such as Kumaun- Palm (*Trachycarpus takil*); economic value species, e.g. Kaiphal (*Myrica esculenta*), to evolutionary importance taxa (*Ginkgo biloba)* (Fig. 3.8). More importantly, various species introduced about 15–20 years back have now started producing seeds thereby ensuring the progeny. Some of the woodlots, thus developed, have now emerged as sites for interpreting patterns of nature's diversity.

Fig 3.8: Ginkgo biloba tree

Research Support and Infrastructure

Realizing the need for providing adequate research back-up to achieve successful conservation of target species, 'Surya-Kunj' has proved an excellent research infrastructure. The propagation protocols developed for over 30 plant species; using experimental sites, the nurseries and the tissue culture facilities, have secured space in reputed scientific journals and act as reference material for further research as well as for mass scale production of planting material (Joshi et al., 2007). For example, the protocols developed (conventional and in vitro) for *Pittosporum eriocarpum*, an Indian Red Data Book species, not only got published in reputed journals but have been effectively utilized for mass multiplication and subsequent plantation of this rarely occurring species.

Conservation through Habitat Enrichment

While the site was being enriched with upcoming woodlots, the 'Surya-Kunj' has witnessed a gradual progression of natural succession. As a result it has got enriched with numerous indigenous floristic elements. Increasing diversity of ground flora, including terrestrial orchids, ferns and herbaceous climbers can be experienced frequently. The diversity of lichens is yet another testimony of site being biologically enriched. The established woodlots have emerged as an excellent habitat for diverse faunal elements, which range from minor invertebrates to several migratory birds. Presently, 'Surya-Kunj' attracts more than hundred birds in different times of the year including some threatened species of the region which were not recorded /documented earlier from the region. The diversity of birds increased considerably over last one decade or so (Palita et al., 2011). More recent survey (2014–15) reports 149 spp. (Pathak et al., 2015, unpublished report). This even includes occurrence of threatened species including Bengal Vulture (*Gyps bengalensis*), Indian Scavenger Vulture (*Neophoron perinopterus*) and King Vulture (*Sarcogyps calvus*), etc.

The positive impacts of increasing floristic diversity are also reflected in the butterfly composition. The site now holds more than 60 species of butterflies belonging to the 6 different families. Among all, Nymphalids are the most dominant, which comprises of more than 20 species. Some notable species are Common Mormon (*Priceps polytes*), Brimstone (*Gonepteryx rhamni*), Common Tiger (*Danaus genutia*), Common Punch (*Dodona durga),* etc.

Dynamic Demonstration and Learning Site

Over the years with evolving thoughts and interventions, the Institute has succeeded in upgrading 'Surya-Kunj' from a mere arboretum to a more dynamic demonstration on (i) restoration of degraded hill slopes, and (ii) multiple approaches of plant conservation. The wider potential of this site has been aptly recognized by the Ministry of Environment, Forests & Climate Change, GoI, by way of identifying it as a lead garden for ex-situ conservation and knowledge dissemination. With this recognition, the existing garden is being strengthened as 'Nature Interpretation and Learning Centre-NILC', which on one hand ensures *ex-situ* conservation of representative species (especially known threatened and endangered, T&E species) of the region and on the other acts as a site for research and learning for diverse groups of stakeholders. For instance, it serves as an excellent site for organizing Nature Camps for young students, the farmers groups benefit from the on-site exposure of high value medicinal herbs in the herbal garden within the site, and students on biology study tours find the site effective for interactive learning (Fig. 3.9). The remarks of diverse groups of visitors are the testimony of increasing value and recognition of 'Surya-Kunj' (Box - 8).

Fig 3.9: Nature Camps for young students.

BOX - 8 **The Increasing Value and Recognition of "Surya-Kunj"**

... you have been doing research, writing papers and conducting many projects but at Surya-Kunj you have created and developed different life forms. It is really great.

- Prof. Sekhar Pathak, Padmashree, Nainital 20 Aug 2009

...Beautifully done and arranged. Students and teachers learned and experienced the Himalayan flora & fauna. In time it will turn out to be a great place.

- Leader, Students Tour, GIC Dwarsoon, Almora 16 Feb 2012

... It clearly shows what vegetation can do to a mountain slope. It does not look like a plantation, it is close to a natural forest, with several species coming in their own...I am sure the team has applied its mind continuously to develop it...GBPIHED must talk about this success more.

- Prof. S.P. Singh, FNA Dehradun 7 Aug 2014

(Excerpts of remarks made on Surya-Kunj visitor's book)

More importantly, realizing the new challenges and responsibilities of *ex-situ* conservation sites (e.g., Botanical Gardens) towards meeting the goals of research and development programmes on documentation, bio-prospecting and sustainable use of biodiversity, as reflected in the action programme associated with the implementation of Convention on Biological Diversity, the 'Surya Kunj' has made necessary shifts in its focus so as to provide leadership support to other botanical gardens and facilitate further research on T&E species in the region by way of: (i) conducting researches to understand bottlenecks and developing technology packages for propagation, multiplication and rehabilitation of selected T&E species, (ii) designing and organizing promotional activities for wider popularization amongst diverse stakeholders so as to promote environmental awareness and inculcating sense of responsibility for nature protection amongst masses, (iii) forging sustainable partnerships with other arboreta/botanical gardens in the region/country/world for exchange of knowledge/expertise and collaborative researches (Box :9-12).

BOX - 9 Promoting Ex-Situ Conservation of Medicinal Plants in Himachal Pradesh

The Himachal Unit of GBPIHED initiated establishment of a Herbal Garden in 1.33 ha land at Doharanala (1465 m asl) in 2004 and an Arboretum in 2 ha land in November 2006 at Mohal Khad watershed, Kullu (1155 m asl) (Fig. 3.10). The aim was to: (i) conserve and maintain the germplasm of rare, endangered, threatened and endemic plant species; (ii) conduct research on their propagation and morpho-genetic variability; (iii) meet the demand of planting material by different stakeholders; and (vi) serve as a centre for on-site training and extension programmes for various stakeholders.

In Dohranala Herbal Garden, over 80 species of medicinal plants have been established and maintained. Whereas, at Mohal Arboretum, about 1200 individuals of 40 species of trees and shrubs have been introduced and maintained along with a Medicinal Plant Nursery. These conservatories/germplasm banks are proving excellent educational centres for students, teachers, farmers, mahila mandals, line departments and other stakeholders from Himachal Pradesh and other parts of the Country. Over 1000 stakeholders have visited these Arboretum, Herbal Garden and Medicinal Plant Nursery also serve as a centre for on-site training and extension programmes.

The most interesting part of the capacity building programmes is the strong research based backup provided by the Institute. For example, extensive seed germination experiments on diverse species of medicinal value provide data-sets to convince people and subsequently develop agro-technologies. Among the propagation trials on the MPs, seed-germination protocol was developed for Angelica glauca using pre-sowing chemical treatments, achieving 50% germination by soaking seeds for 30 minute in Sodium hypochlorite ($NaHClO_3$), compared to 24.4% germination in control. Seed germination was also improved for Hedychium spicatum, Heracleum candicans, H. wallichii, Polygonatum cirrhifolium, Saussurea costus, Swertia chirayita, etc. In field condition, seed germination varied from 30% (Podophyllum hexandrum) to 84% (H. candicans). Vegetative propagation, using root/rhizome segments and identifying suitable substrates (soil + vermi-compost, and soil + farm yard manure + vermi-compost + forest humus, etc.) and growing conditions in field, responded to 100, 96, 92 and 76, 88 and 82% rooting, respectively for A. glauca, H. spicatum, A. heterophyllum, P. hexandrum, V. Jatamansi and P. Kurrooa etc.

Fig 3.10: An Arboretum at Mohal Khad watershed and a Herbal Garden at Doharanala, Kullu

[Contributors: S.S. Samant & H.K. Badola, *GBPIHED, Himachal and Sikkim Units]*

BOX - 10 Pangthang Arboretum in Sikkim: A Platform for Biodiversity Conservation, Education and Innovation

With the establishment of Sikkim Unit of GBPIHED at Gangtok in 1992, an Arboretum was formally instituted in 10 acre land (Fig. 3.11). This Arboretum largely accommodates temperate and sub-alpine species. With various R&D interventions, over the years, the entire Arboretum has turned into natural woodland offering very suitable habitat niches to a large variety of native flora, fauna including birds. Over 2500 adult trees were recently recorded, representing Edgeworthia gardneri, Prunus nepalensis, Hovenia dulcis, Casearia glomerata, Elaecarpus lancaefolium, Quercus lamellose, Meliosma wallichii, Ficus nemoralis, Magnolia campbelli, Saurauia napaulensis, Rhododendron arboreum, R. dalhousiae, Eurya accuminata, Acer campbelli, Castanopsis tribuloides, Ficus clavata, Symplocos theifolia, Machilus sp, Symplocos glomerata, Spondias axillaries, Glochidion acuminatum, Engelhardtia populnea, Michelia excelsa, Betula cylindrostachys, etc. Dawn Redwood (Metasequoa glyptostrobioides), considered as rare fossil tree, other than the more common Ginkgo biloba is the unique element. Entire Arboretum is interspersed with large Cardamom (Amomum subulatum) cultivars such as Bharlangay, Sawanay, Ramsai, and Sawanay, representing the local cardamom land races along with exclusive collection of its wild forms, viz. Amomum dealbatum, A. kingii, etc. The threatened species Podocarpus brought from Darjeeling hills is also conserved (Butola & Badola, 2004). Among others, the Arboretum holds a live collection of over 20 Rhododendron species including already established Rhododendron arboreum, R. dalhousiae and R. griffithianum. The tissue culture raised and conventionally produced R. maddenii plantlets are growing well. This site now serves as an important platform for outreach to a wide array of people. Training and exposures to masses, especially students and teachers, for biodiversity conservation is most attracting events for the school children.

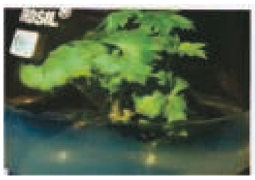
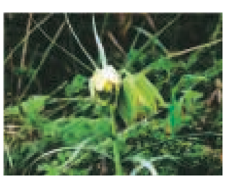
Fig. 3.11:
An Arboretum at Pangthang Sikkim and interactive learning by school children (Below)

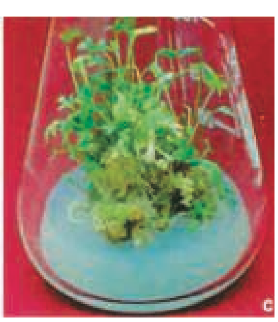
[Contributors: H.K. Badola & L.K. Rai, *GBPIHED, Sikkim Unit*]

BOX - 11 **Tissue Culture Protocols for Conservation of Selected Himalayan Medicinal Plants**

Conservation of medicinal plants has emerged as one of the priority agenda of R&D as many of the species are facing the risk of extinction due to growing demand for health care products. Unscientific and illegal exploitation from the nature and deforestation and habitat destruction have further exacerbated this situation. As per IUCN, so far a total of 8321 plant species have been added to the Red List of threatened species. This situation calls for immediate conservation action, especially with regard to the Himalayan medicinal plants, which harbours 1700 species (out of a total of 3000 species reported from India), and nearly 47% of them are endemic and 62 species fall under different categories of threat. GBPIHED took this responsibility in a big way right from its early years of establishment and researchers developed propagation protocols (seed germination, vegetative propagation and plant tissue culture) of some of the most important medicinal plants of RET&E category and devised appropriate strategies for their conservation those could be taken up by extension agencies for mass cultivation (Table 3.3).

Table 3.3: Medicinal importance and propagation protocols for some important medicinal plants of IHR.

Species	Medicinal Importance	Propagation Protocol
 *Aconitum balfourii* Stapf. (Meetha vish) (3000–4300 m asl)	The tuberous roots is used for curing rheumatism, fever, etc. due to presence of several diterpenoid alkaloids, mainly balfourine, bikhaconitine, aconitine and pseudoaconitine.	Callus was induced from small leaf segments/auxiliary buds developed on MS medium containing 4.5 µM BA and 26.9 µM NAA. The highest shoot induction were recorded in MS medium supplemented with the 4.5 µM of BA and a lower concentration of NAA (1.4 µM).
 *Arnebia benthamii* (Royle) Jonst. (Baalchadi) (3700–4200 m asl)	The major compound of this species is shikonin, that possesses antibacterial, antifungal, anti-inflammatory, and wound healing properties. Also used in tongue and throat as well as fever and cardiac disorders and exhibits potent anti-HIV activity.	Organogenesis was optimal (12.2 shoots/culture) in 1 mM IBA combined with 2.5 mM BA and induction of somatic embryogenesis (16.3 embryos/culture) occurred in 2.5 mM IBA combined with 2.5 mM BA. 100% shoots rooted in half strength MS medium supplemented with 2.0 mM IBA. Also, encapsulation of early cotyledonary-stage embryos with 3% sodium alginate and calcium nitrate (100 mM for 25 min) produced 60.6% germination in MS medium (Manjkhola et al., 2005).
 *Fritillaria roylei* Hook. (Kshir Kakoli) (2500–3500 m asl)	This species forms one of the eight components of the polyherbal Ayurvedic formulation – Astavarga, an important ingredient of Chyavanprash.	Best regeneration (95.8%) with maximum number of bulblet (10.1±0.63) were obtained in 5.0 µM kinetin with 2.0 µM NAA after 8 weeks of culture. Gas chromatographic profiles of diethyl ether extract of in vitro raised bulblets showed patterns similar to naturally grown mother bulbs.
 *H. edgeworthii* Hook. f. ex. Collett (Virdhi) (1500–3000 m asl)	This 'Ashtvarga' species is used in tonics like 'Chyavanprash'. Tubers has refrigerant, intellect promoting, aphrodisiac, appetizer, anthelmintic and rejuvenating properties, and used in fever, cough, asthma, insanity, cataplexy, leprosy, anorexia, helminthiasis, haematemesis, gout and general debility.	Seeds cultured in MS and ½ MS medium with 1.0 µM NAA showed 94.7% germination and induced callus. Subcultured calli produced 11.9 shoots/ explant in MS medium supplemented with 0.1 µM BA and 0.01 µM NAA. Shoots when transferred to ½ strength MS medium with different auxin concentrations induced roots and tubers. Maximum (87.5%) rooting was found in free MS medium. Callus grown on medium supplemented with 3.0 µM BA contain high phenolic content along with increased antioxidant activity, however, callus growth was higher in medium containing 1.0 µM BA.
 *Heracleum candicans* Wall. (Gandhrayan) (2000–4300 m asl)	Roots rich in furocoumarin, xanthotoxin, xanthotoxol and sphondin are widely used in the treatment of leucoderma and as a component of suntan lotion.	In vitro propagation protocol using cotyledonary leaf explants produced 29 shoots/explant in MS medium supplemented with 10 µM 6-benzyladenine. Of the harvested shoots, 74% rooted in medium supplemented with 4 µM IBA. Rooted shoots transferred to sterile soil, sand and peat mixture (1:1:1 by volume) showed 70% survival ex vitro (Joshi et al., 2004).

Species	Medicinal Importance	Propagation Protocol
 *Picrorhiza kurrooa* Royle ex Benth (Kutaki) (2800–4800 m asl)	The extract of runners and roots of this plant is used in stomach-ache, purgative, and antiperiodic agent, as a brain tonic and in dyspepsia and fever. It is known to contain picroside I, II, III and kutkoside as major bioactive compounds.	Juvenile explants (cotyledonary nodes and shoot tips) produced 12 shoots/explant in MS medium supplemented with 1.0 µM BA or Kn. Cent per cent and callus-free rooting of microshoots was obtained on MS medium supplemented with 0.5–2.5 µM NAA, IBA or IAA.
 *Pittosporum nepaulensis* (DC.) Rehder & Wilson (Raduthia) (1000–2400 m asl)	The bark of the species is bitter, aromatic and valued as a medicine. The local inhabitants apply the paste of the bark to inflamed and rheumatic swellings. The bark is reported to possess expectorant, febrifuge and narcotic properties and is used as a remedy for chronic bronchitis.	The best bud proliferation (83.1%), shoot number (21 auxiliary shoots/ explant) and shoot length (5.5 cm) was achieved in MS medium supplemented with 5.0 mM BA and 0.1 mM NAA. Of the three cytokinins tested, BA proved to be the best for shoot induction. Regenerated shoots rooted after 48 hours treatment on half-strength MS liquid medium supplemented with 20 mM IBA.
 *Saussurea obvallata* (Brahmkamal) (3800–4800 m asl)	Treatments of bone-ache, intestinal ailments, urinary track problems and coughs.	Epicotyl explants of this perennial herb on MS medium supplemented with 1.0 µM kinetin and 0.25 µM NAA produced 5 shoot/explant and 100% in vitro rooting was obtained in half strength MS supplemented with 2.5 µM IBA. The rooted plants were acclimatized in nursery resulted in 66.7% survival (Joshi & Dhar, 2003).
 *Selinum wallichianum* (DC.) Raizada & H. O. Saxena (Bhootkeshi) (2400–2800 m asl)	Whole plant or roots are used as a nervine sedative and act as substitute of *Nardostachys jatamansi*. Three furanocumarin i.e. bergapten, heraclenol, heraclenin along with other coumarin selinedin, vagenidin, angelicin, oroselol and lomatin have been isolated from the root. The oil obtained from roots has been reported to possess antibacterial property.	Maximum number of leaf explants (67%) produced callus on 3.0µM 2,4-D. Significantly higher percentage of explants producing shoots (100%), shoot (14 shoots/ explant) and shoot length (5.7 cm) was obtained in MS medium supplemented with 0.5 µM BA and 0.5 µM GA3. Regenerated shoots produced 93% rooting in MS medium fortified with 2 µM IBA produced after 4 weeks of incubation. About 79% plantlets survived after 60 days of transfer in autoclaved sand and soil (1:1 ratio).

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Box - 12 **Conservation of Sikkim Himalayan Rhododendrons Using Biotechnological Tools**

Rhododendron is an important genus occurring in the high altitudes and known for its beautiful flowers. In India this genus is represented by 50 species and about 98% of them are found in the IHR. In the Sikkim Himalaya (the Sikkim Hills and Darjeeling Hills combined, ~10000 km^2) 36 species, with 45 different forms (including subspecies and varieties) of Rhododendrons are found between 1600–3600 m asl (Pradhan & Lachungpa, 1990). The author and his group at GBPIHED, Sikkim developed propagation protocols for some of the threatened Rhododendrons using both conventional and biotechnological methods (Kumar et al., 2004; Singh & Gurung, 2009) and large scale multiplication and subsequent field plantation was carried out (Fig. 3.12).

Fig. 3.12: Tissue culture raised R. maddeni plants and flower

Fig. 3.13: Conventional methods for propagation in Rhododendron dalhousie through seeds

Experiments on seed germination carried out over 7 sets of soils resulted into improved germination in garden soil : actinorhizal soil of 25:75 composition, followed by forest floor soil and 50:50 composition of garden soil : actinorhizal soil. At present, over 5,000 plantlets are growing at the Rhododendron nursery section (Fig. 3.13). Following air-wet method (Fig. 3.14 A, B, C) we obtained initiation of rooting in 40% cuttings after six weeks in *R. griffithianum*, 80% in *R. arboreum* and 50% in *R. dalhousiae*. All rooted stem cutting survived under green house conditions. This method has the advantage of "true-to-type" propagation of elite or specific clones for mass multiplication and regeneration.

Propagation protocols of *R. maddeni, R. griffithianum, R. dalhousie* and *R. niveum* have been developed through tissue culture. *R. maddeni*, the largely localized in north Sikkim with fragrant flowers is important tree. Well-developed complete plantlets were transferred to plastic cups containing Silrite. The rooted plantlets were hardened and successfully established in greenhouse and were successfully transferred to field sites at Pangthang Arboretum of the Institute. In general, the Institute had established an exclusive Rhododendron plants section in its Pangthang Arboretum to establish regional Rhododendron germplasm pool. Further, under a collaborative programme of the GBPIHED with Department of Forest, Government of Sikkim, a unique kind of rare and threatened plant Conservation Park in 2 ha area has been established in the Himalayan Zoological Park, Bulbulay-Gangtok in which a large number of high quality, tissue culture and nursery raised rare and threatened plants (including Rhododendrons) have been planted and surviving well.

A

B

C

Fig. 3.14: The stem cuttings of R. griffi thianum using air-wet technique.

(A) The stem cuttings with moistened absorbent paper,

(B) Rooted stem cutting,

© Growth performance of rooted stem cutting developed form air-wet technique

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COMMUNITY BASED NATURAL RESOURCE MANAGEMENT FOR BIODIVERSITY CONSERVATION

Fig. 3.15: Paddy-cum-fish cultivation

Arunachal Pradesh with a geographical area of 83,743 km^2 (2.5% of India and 15.76% of the IHR) is biodiversity rich state with a representation of 23.5% of flowering plants reported in Indian sub-continent (Samal et al., 2013). This biodiversity rich state has 11 Sanctuaries, 2 National Parks and 1 Biosphere Reserve. Culturally, the state is also quite rich being home to 26 major and more than 110 minor tribal communities. To conserve the rich biodiversity of the state, there are formal laws in place enacted both by the state and Central Government. However, in recent years, the rich biodiversity of the state is facing varied threats warranting its conservation on priority. With this in view, GBPIHED, NE Unit is engaged with the local communities to conserve the rich biodiversity of the state focusing on local human resource development through formation of community institutions and livelihood development activities. In this endeavour partnership was forged with SFRI, Itanagar, NERIST, Nirjuli (Itanagar), NCADMS, Ziro (Itanagar) and WWF India, Tezpur (Assam).

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CASE STUDY

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Approach

Our R&D activities covered (i) Tawang-West Kameng (proposed) Biosphere Reserve (TWKBR), (ii) Apatani plateau in Arunachal Pradesh spreading over three districts, five development blocks and 32 villages. The approach for conservation, included promotion of innovative livelihood options, taking into cognizance the cultural and historic values and being sensitive to needs of the local communities. The initiatives undertaken included formation of Biodiversity Management Committee (BMC) following National Biodiversity Authority norms, 2013. Also, creation of Community Conserved Area (CCA; Box - 13) and Sacred Groves for *in-situ* and *ex-situ* conservation of biodiversity. Among others, major livelihood intervention pertained to strengthening of traditional paddy-cum-fish cultivation (Fig. 3.15), piggery, beekeeping (Fig. 3.16), capacity building on appropriate low-cost technologies (Fig. 3.17) and gender focused entrepreneurship development. In addition, community based tourism (CBT) was also promoted. The conservation initiatives were carried out through BMC. Organization of awareness camps/workshops on conservation of natural resources and prohibition of hunting, environmental education programmes in schools were regular activities. Conservation attitude and awareness was further inculcated amongst the villagers involving them in patrolling of forests jointly with State Forest Department and BMC on regular intervals. RS & GIS were used for resource database generation and mapping. Development of Peoples' Biodiversity Register (PBR) and training locals as village botanists were other activities. In these initiatives support from various officials like Deputy Commissioner, Divisional Forest officer, District Agricultural and Horticultural Officers, etc. was sought by the BMCs. These activities were monitored at various levels by State Level Steering Committee, headed by the PCCF and Principal Secretary, Dept. of Environment and Forests, Govt. of Arunachal Pradesh.

Fig. 3.16: Bee-keeping by local people in Arunachal Pradesh

Fig. 3.17: Capacity building on low-cost technologies

Outcomes: Major livelihood benefits for communities

The main livelihood benefits for stakeholder communities from the project included - Fruit/cash crop plantation (60 ha land brought under *Cardamom* cultivation), promotion of paddy-cum-fish cultivation (3 lakh fish seedlings; beneficiaries, 460 households), promotion of piggery (190 piglets amongst households from BPL group identified by BMCs in 18 villages), SHG focused livelihood (16 SHGs), Community Based Tourism (CBT) was promoted in TWKBR and a model for culture based tourism was developed in Apatani plateau), Capacity building (jobs such as tailoring, weaving and handicrafts, beekeeping and training on low-cost rural technologies, etc.). Thus our efforts and initiatives helped address Goal 7 of the Millennium Development Goals (MDGs, 2000).

Biodiversity outcomes of the project

The major challenges of biodiversity management addressed through our initiatives included reduction in hunting, habitat destruction and biodiversity loss, shifting cultivation and natural resource degradation, and improved livelihood. Focused attention was also given to (i) conservation of ecologically and socially valued wild flora and fauna, (ii) restriction on unsustainable extraction of timber and NTFPs, (iii) prohibition of hunting excluding hunting for ritualistic purpose, (iv) revival of threatened wild flora and fauna through *in-situ* or *ex-situ* conservation, and (v) revenue generation and livelihood promotion.

BOX - 13 **Establishing Community Conserved Area**

In Arunachal Pradesh, the communities living in the margin of forests have limited options available for their socio-economic development, thereby continually increasing pressure on the forest and threatening wild flora and fauna. Considering this scenario, under the GOI-UNDP CCF-II funded project a series of community conserved Areas (CCAs) are formed in line with Indigenous Peoples' and CCAs. The approach included (i) declaration and institutionalization of a series of CCA, (ii) ensure participation of local communities in conservation and resource management, and (iii) enhancing community's knowledge on conservation using PBR and help the communities capitalize on its indigenous knowledge.

The CCAs thus declared include: 'Mihin-Radhe' CCA (5000 ha) and 'Siikhe-Bo' CCA (18-20 ha) in Apatani plateau, 'Ritosa Ree-Mainarang Ree' CCA (100 ha), 'Hugore Sewaphu' CCA (50 ha) and 'Thembang Bapu' CCA (300 sq km) in Tawang and West Kameng (proposed) BR in Arunachal Pradesh. Thembang Bapu CCA formed by WWF-India was also strengthened under this initiative. The major issues addressed through the CCAs are: (i) conservation of ecologically and socially valued wild flora and fauna; (ii) restriction on unsustainable extraction of timber and NTFPs; (iii) prohibition of hunting with exception for ritualistic purpose; (iv) revival of threatened wild flora and fauna through in-situ and ex-situ conservation, (v) revenue generation and livelihood promotion, (vi) sustained benefits from ecosystem functions such as *protecting hydrological benefits of forests for irrigation and drinking water, and (iv) sustained religious, social identity or cultural needs through protection of sacred floral and faunal species. For example, the 'Siikhe-Bo' CCA formed by the villagers of Hong Niichii and Hong Niitii villages in Apatani plateau is conserving the forest thereby helping in recharging of the Siikhe stream that feeds the irrigation canals of rice-cum-fish cultivation fields of the villages, and is also used for drinking water. The CCA is also promoting conservation of biodiversity, particularly Schizothorax, a fish species (local name Ngilyang-Nyige), which is culturally valuable and whose population has been gradually declining in the Siikhe stream due to water shortages. The BMCs/CCAMCs, that are managing CCAs have evolved mechanisms to generate their own corpus fund through membership fee, royalty from resources extraction from CCAs, community based tourism conducted within the CCAs, and also are generating funds from schemes and programmes. CCAs, with this generated funds will be able to exist even after the exit of the project functioning (Fig. 3.18).*

Fig. 3.18: Observation of World Environment Week by the people of project village in NE region

The major outcomes included: (1) Development of Guidelines for Promotion of Home stays, Promotion and Management of Community Conserved Areas (CCA), and Arunachal Pradesh Ecotourism Policy. (2) Constitution of 22 BMCs, which are now adopted by Arunachal Pradesh Biodiversity Board (APBB). The BMCs have framed regulations for (i) prohibition of illegal hunting and marketing of wild faunal species, (ii) prohibition of electrocution and use of bleaching powder and chemicals for fishing, and (iii) non-judicious and unauthorized extraction of natural resources such as felling of tress, collection of firewood, collection of sand, etc. The decisions in all project villages are taken by the BMCs in a participatory manner. Maintaining of Peoples' Biodiversity Register (PBR) and training locals as village botanists are other activities ensured by BMC. The BMCs have developed their corpus fund and started generating fund from sources like APBB and Compensatory Afforestation and Fund Management Planning Authority (CAMPA) to become self sustaining. (3). A number of CCAs declared by the communities themselves has promoted conservation of ecologically and socially valued wild flora and fauna and also accruing other benefits from ecosystems. (4). Plantation of 36,000 saplings of *Taxus wallichiana* (142 ha), *Alnus nepalensis* (40 ha), *Michelia champaca* (28 ha) and another 15 ha of land was brought under species like *Phoebe goalparensis*, *Terminalia myriocarpa, Castanopsis* sp., etc. (5). 130 LPG Sets were distributed among 130 households from BPL group identified by BMCs in 19 project villages which reduced fuel wood consumption by about 9.5 kg of fuel wood/day/household. (6). Improved awareness and informed village community by installing about one hundred biodiversity conservation notice boards, joint patrolling of forests by villagers and State Forest Department and maintaining of PBR, etc.

The Way Forward

The interface developed through this initiative is generating new opportunities for various project activities to sustain themselves even after exit of the project simultaneously helping the Govt. departments. The APBB is now in the process of replicating formation of BMCs in villages across Arunachal Pradesh. The Homestay, Ecotourism and Manageme CCA Guidelines are now under consideration to be adopted by Govt. of Arunachal Pradesh. Development of PBRs, promoting village botanists, etc. are some other scalability of the present case study.

PROMOTING OUTREACH THROUGH CONSERVATION EDUCATION

Environmental Education (EE), which has emerged as a broad concept across the globe, attempts to develop a sense of responsibility among people for conservation and management of the environment. EE also provides an opportunity to understand complexities and values of the nature. Therefore, dissemination of EE among masses has been recommended as a life-long process to attain sustainable development. The international agreements emanated as a result of UN Conference on Human Environment, Stockholm (1972); the first Intergovernmental Conference on Environment Education, Tbilisi (1977); and the UN Conference on Environment and Development, Rio de Janerio (1992) have been instrumental in bringing EE on global agenda. Among various leading centers, which are promoting this concept in India, GBPIHED has made significant strides towards dissemination of this concept in the region.

While considering environmental issues in the country, the Himalaya has remained focus of attention for centuries due to its vastness, uniqueness and fragility. More importantly, under changing global climate scenario, perhaps for the first time, the Himalayan issues have been appropriately included in the national work agenda in the form of provisioning for an area specific National Mission on 'Sustaining the Himalayan Ecosystem' under National Action Plan on Climate Change (NAPCC). All these features qualify the region for special consideration under various initiatives, including EE programmes. Unfortunately, remoteness, inaccessibility and political marginality of

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CASE STUDY

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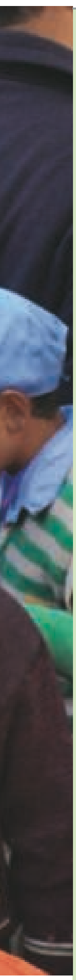

the region have caused severe hindrances in progress of such programmes. In spite of this, in recent decades, a few initiatives have registered significant popularity in the region which includes Conservation Education (CE) initiative of GBPIHED. The programme attempts to provide outreach through informal CE activities.

APPROACH

With a modest beginning of an activity known as "People's participation in Himalaya biodiversity conservation", in 1995 (Dhar et al., 2002), reo-orientation of approach under Planning- Process- Product evaluation model was attempted, and the activity was made an integral part of education system through as specially designed CE programme, which targets high school/college level Institutions. The programme contains following major events: (i) Training Workshops; (ii) Orientation Courses; (iii). Nature camps, etc. The participant's feedback based re-orientation of programme components form the strongest part of these events to keep them dynamic and evolving.

Training Workshops

Series of training workshops for sensitizing students and teachers on issues pertaining to Himalayan biodiversity conservation forms the main content of programme. The training modules include: (i) Definition and dimensions of biodiversity, (ii) Status assessment and monitoring, (iii) Value and value addition, (iv) Maintenance (in-situ and ex-situ), (v) Modern tools of biodiversity assessment and conservation, and (vi) Linking biodiversity with weather, soil and water components. The on-site practical sessions organized at remote schools of the region from the most important part of these workshops. Over the years, organization of 17 training workshops across seven districts of Uttarakhand (i.e. Pithoragarh, Champawat, Almora, Bageshwar, Nainital, Chamoli and Pauri Garhwal) have resulted in training of 1346 participants (i.e. students and teachers) of 370 schools. Analysis of the responses (pre and post workshop) of participants has established that the approach followed in the programme can serve as a model for replication in other areas of Indian Himalaya. Moreover, the trained workforce has also proved instrumental in: (i) collection of area specific information on biodiversity especially the traditional crop diversity; and (ii) establishment of school conservation models (till date 10 Nos.).

Orientation Courses and Nature Camps

Realizing the need for speedy extension of activities across the region, Orientation Courses (7 days) for trained teachers have been designed. The idea is to groom them as Resource Persons to independently impart training on identified modules. Five such courses have been organized to cover five districts (i.e. Almora, Bageshwar, Nainital, Pithoragarh and Chamoli) of Uttarakhand state. The Institute has, therefore, recognized 152 schools teachers (representing 147 schools) as Resource Persons for promoting CE programme.

Realizing that the current education system does not promote motivation among school children towards nature learning, the Institute has made a beginning with new initiative called "Himalayan students' 'Nature Awareness Campaign". The 'Nature camps' have been conceptualized as an uninterrupted cyclic process of visiting the nature, observing, learning, understanding and teaching. Broadly it targets to: (i) Connect students with the nature and develop their affection for it; (ii) make them learn from the nature and understand its complexity and linkages, (ii) sensitize students about life support values of the nature and make them responsive for natural perturbations. In year 2014–15, a total of seven nature camps were organized wherein 327 students from 53 schools participated. Likewise, for year 2015–16 a total of 5 camps are scheduled of which one was organized during 20–22 May 2015 and attended by 55 students and 11 teachers of 11 schools. Through on-site learning experiences, these camps have proved very effective in developing affection amongst students for the nature and its components.

The Way Forward

Recognizing that for wider outreach on this subject, we feel there is a need to strengthen process to increase number of Resource Persons. Institute under its ongoing programmes, especially under the National Mission on Sustaining the Himalayan Ecosystem, has planned to strengthen such initiatives and consider for replication across the Himalayan states with area/location specific modifications. Effective synergy between CE programme of the Institute and programmes of Ministry of Environment, Forests and Climate Change (e.g., National Green Corps and National Nature Camping programme) would help immensely in achieving the objectives.

SOCIETAL RELEVANCE OF R&D WORK ON BIODIVERSITY CONSERVATION & SUSTAINABLE USE

ANNEXURE - III

POLICY RELEVANCE

- Himalayan Biodiversity documentation and prioritization helped in identification of sites and species of conservation importance, which may be used in redefining and redesigning Protected Area Network in IHR and the species needing ex-situ and in-situ backup.
- Threat assessment (IUCN categories) and documentation of use value of MAPs is an effective input for formulating conservation strategies, cultivation and development plans.
- Showcasing of comprehensive *ex-situ* plant conservation across IHR has great relevance to be promoted as a policy programme for restoration of degraded lands by way of strengthening ex- situ conservation efforts.
- In Sikkim, a 'Rare and threatened Plant Conservation Park' at Bulbulay-Gangtok established in collaboration with state forest department, Govt. of Sikkim provides an example as to how science can be brought to practice.
- Registration of farmers with Herbal Research Development Institute, Uttarakhand for buy-back mechanism and formation of a farmers association 'Gramin Kisan Swarojgar Sangathan, Champawat' for cultivation of MAPs.
- Formation of Biodiversity Management Committees (22 nos.) and development of Peoples' Biodiversity Register and training of village botanists to achieve the mandate of National Biodiversity Authority in compliance of CBD Act (2005).
- In Tawang-West Kameng (proposed) Biosphere Reserve, Institute's activities with communities have helped address MDGs (2000) Goal 7.

CONTRIBUTION TO TECHNOLOGY DEVELOPMENT

- A new plant species, *Arnebia nandadeviensis* (Boraginaceae) and three new fish species viz., *Erethistoides senkhiensis, Glyptothorax dikrongensis* and *Garra magnidiscus* have been discovered by the Institute researchers, which forms great contribution to science.
- Identification of high value MAPs that deserve large scale cultivation (e.g., Aconitum heterophyllum in H.P.) following agro-climatic and socio-economic considerations can be easily promoted for commercial gains through effective policy backup.
- Development of molecular marker for early detection of 'twisted' trait in chir pine at the nursery stage was identified using DNA isolation and polymerase chain reactions.
- Development of electronic database of the Institute herbarium (1226 herbarium specimens).
- Development of propagation protocols for selected high value plants, including multipurpose trees and medicinal plants, involving conventional and tissue culture approaches have contributed significantly for commercial gains through mass propagation.
- Adoption of "Citizen Science" approach by involving volunteers from many parts of the world to generate field data is an innovative approach for participatory research leading to enhanced efficiency of researchers to obtain first-hand datasets.
- The state-of-the-art approach developed for promotion of Conservation Education has relevance for replication across the region through programmatic approach.

OUTREACH

- Documentation of Himalayan biodiversity elements, especially analysis of endemic plant species and priority ranking, has emerged as strong outreach material for Himalayan biodiversity research.
- Comprehensive documents such as "The Himalayan Biodiversity – richness, representativeness, uniqueness and life-support value", "Medicinal Plants of the Himalaya", "Wild Edible Plants of the Himalaya", "Himalayan Biodiversity Action Plan", and "Compendium on Indian Biosphere Reserves" are important outreach material.
- Establishment of ex-situ conservation sites, by way of restoring degraded lands at diverse locations in the Himalaya (i.e., Pangthan-Sikkim; Kosi-Katarmal, Uttarakhand; Mohal-Kullu, Himachal Pradesh), along with herbal gardens, have proved important outreach facility on-site training and capacity building programmes.
- With strong biodiversity information backup on Himalaya and recognizing the needs, a protocol was designed for promoting conservation education among school students and teachers. The programme acts as one of the most popular outreach events of the Institute.
- The Community Conservation Areas approach as established and implemented in Arunachal Pradesh has proved effective in participatory resource management and improving peoples' livelihoods.
- Development of Guidelines for Promotion of Home stays in Arunachal Pradesh.
- Formation of Community Conserved Area for in-situ conservation of biodiversity and community based tourism promotion in tribal villages of NE region can be replicated across IHR.

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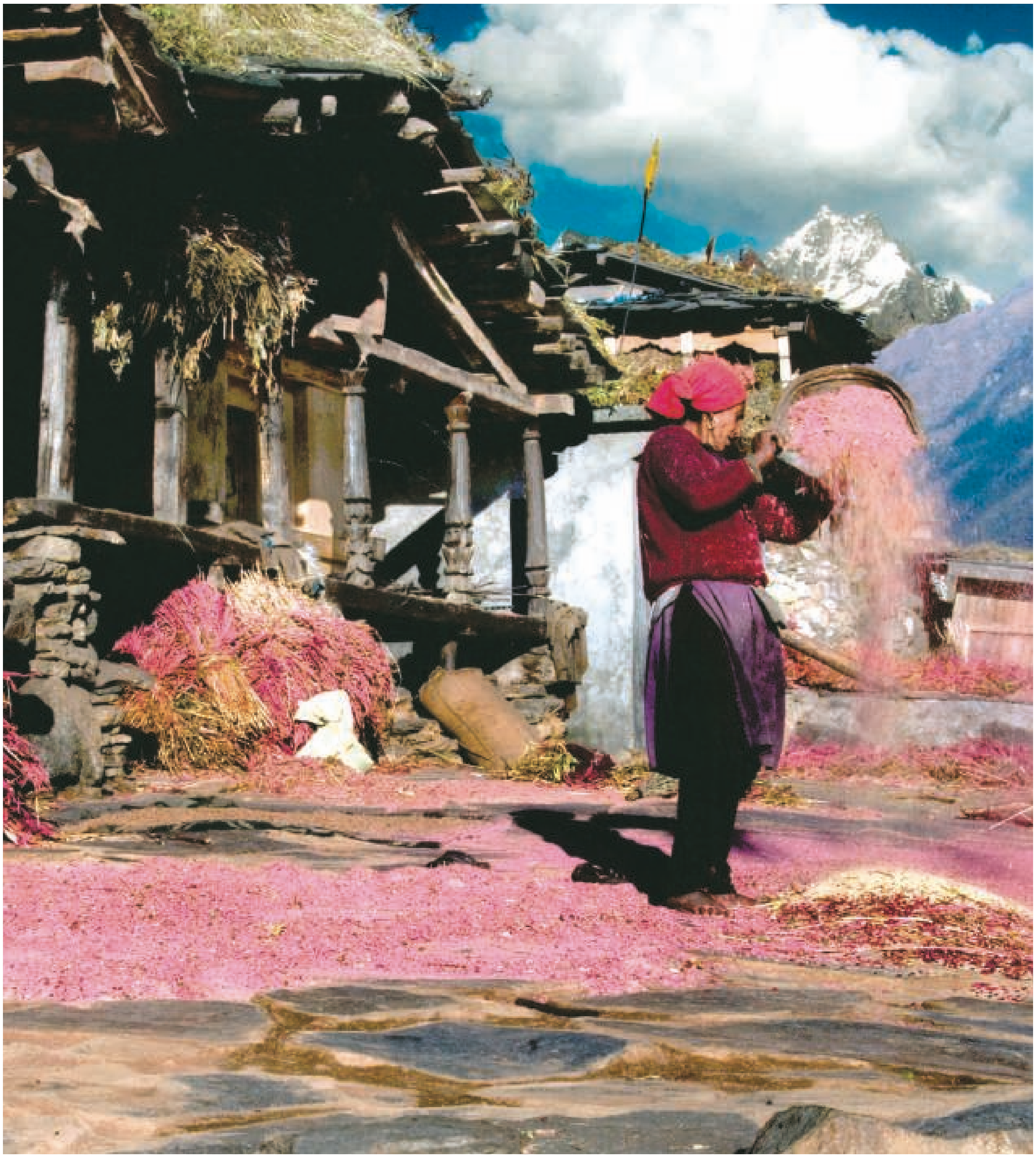
4

LIVELIHOODS & CAPACITY BUILDING

Demonstrating & Up-scaling Innovative Approaches

The Himalaya constitutes a unique geographical and geological entity comprising a diverse social, cultural, agro-economic and environmental setup. In this region, due to topographic constraints land is a finite and precious resource and livelihood options are limited to subsistence level. Majority of the population (about 70% of the total workers) is engaged in agricultural and allied activities, and women constitute over 85% of this work force (Rawat & Kumar, 1996). Involvement in various household and agricultural operations from the childhood is a major bottleneck for educational/ technical advancement of rural women in the hills leading to economic backwardness and ecological poverty. To overcome some of these problems related to the livelihood, a number of on-farm and off-farm R&D based natural resource management (NRM) and mountain-specific package of practices are available. These technologies are not only simple, cost-effective and eco-friendly but also helpful in reducing the drudgery of women, out-



migration and environmental degradation (Rawat et al., 1996; Joshi et al.,1998). However, location-specific package of practices and their effective implementation for NRM is still a need of the hour in the IHR. In this context, capacity building of rural people, particularly women is urgently required for sustainable utilization of available resources to provide alternatives for livelihoods and employment and help reducing drudgery and out migration. Therefore, keeping into consideration the complexity of bio-physical set-up and socio-economic dimensions the process of technology transfer need to be accomplished in systematic steps (Fig. 4.1): (i) site selection, (ii) resource survey, (iii) development of an operational framework, (iv) establishment of demonstration, (v) consideration of the specificities of peoples' participation, (vi) capacity building and skill development, (vii) implementation/adoption, (viii) monitoring and evaluation, and (ix) feedback for further up scaling and improvement of the technology.

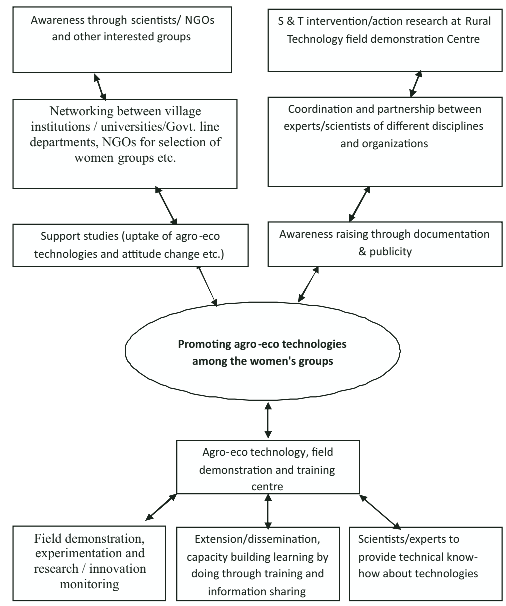


Fig. 4.1: Promoting adoption of agro-eco technologies among the women groups through capacity building, participatory research and demonstration

It may be pointed out here that there are many constraints still faced by the farmers while implementing these technologies: These include (i) inadequate package of practices, capacity building and training programme, (ii) lack of facilities, funds and resources, (iii) lack of overall communication and coordination between government programmes, NGOs and farmers, and (iv) insufficient field testing and trial of rural technologies at grass root level, etc. It is hoped that efforts made by GBPIHED will lead to reduce the gap between R&D institutions and policy planners, extension workers, NGOs, GOs and the implementers (local people). As majority of the farmers are marginal (< 1 ha holdings), they would prefer adopting technology already undergone location-specific modifications with proven potential to minimize risks and achieve food security (Negi, 1994).

Also, in the recent decades tourism is rapidly becoming an important economic activity for livelihood option across the IHR owing to rich natural and cultural heritage. The tourism industry is increasingly having an ecological impact on the Himalayan environment and increasingly confronted with arguments about its compatibility with environmental management. Ecotourism, with its focus on environmentally sound practices also offers an opportunity to improve local livelihoods and protect unique heritage.

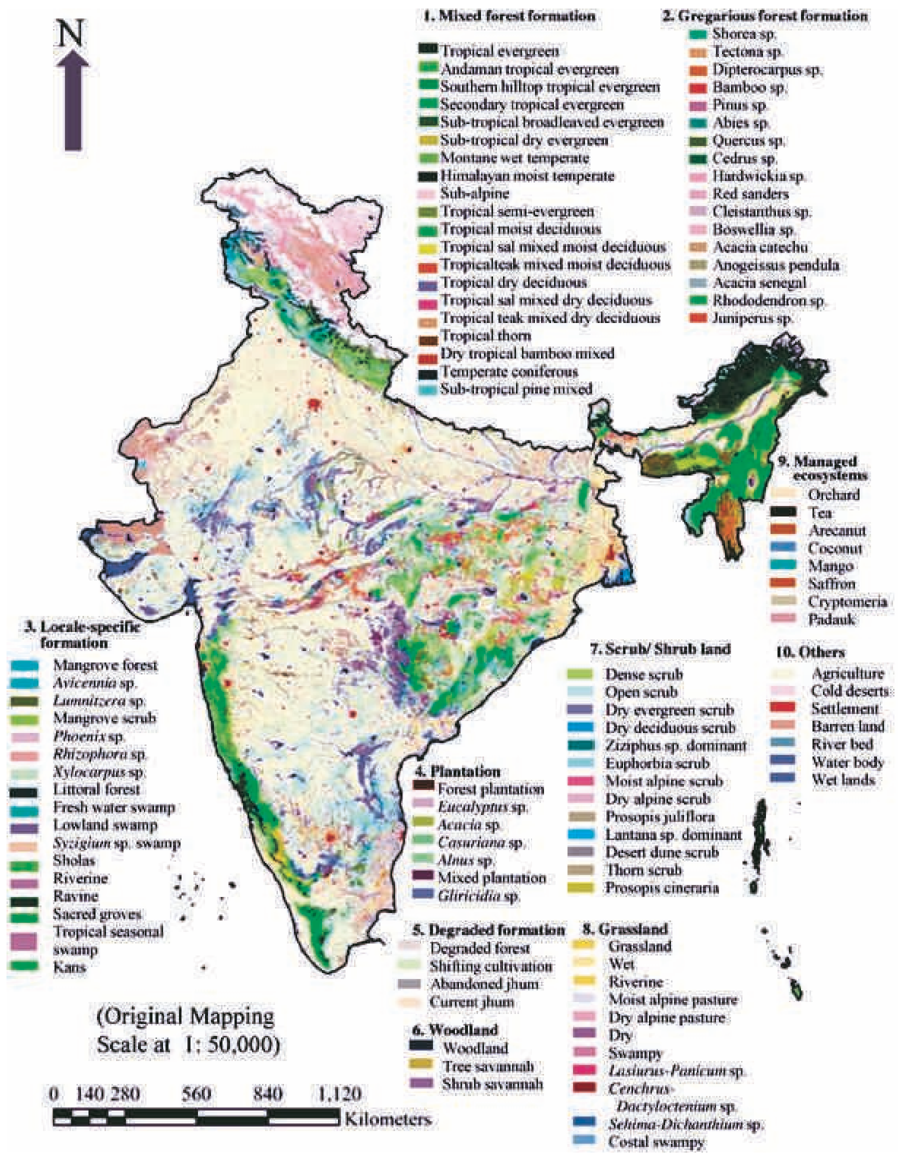
A network of farmers, extension workers, scientists, institutional experts' financial institutions (bank, etc.) and NGOs thus need to be developed for effective communication among all stakeholders for large scale adoption of these R&D based technologies and approaches in the mountains along with appropriate capacity building programmes. In this direction, GBPIHED has evolved and tested quite a few approaches of eco-tourism. Apart form focussing on rural people, a major emphasis is also given to build the capacity of researchers, govt. officials, NGOs, etc. for use of modern technologies such as remote sensing and GIS. Through these tools, GBPIHED has built the capacity of stakeholders and increased its outreach (Box – 1).

BOX - 1 **Himalayan Environmental Management Using Space Technologies**

At GBPIHED use of space technologies (RS & GIS) were aimed at to facilitate the R&D adding new dimensions of exploration, monitoring, modelling, and integration for decision support system. RS and GIS facilities at the Institute were initially developed (with the support of ICIMOD, Kathmandu in early 1990s), and strengthened subsequently through various externally funded research projects and contributed immensely to the R&D activities both within and outside the IHR. We provided hands-on training to a range of stakeholders including Academicians/Scientists/ Young Researchers/Students (167 individuals) of various organizations to intensify use of this technology (Fig. 4.2). Partnership in Satellite based distance learning courses through IIRS EDUSAT program (Department of Space, Govt. of India) was also executed for the benefit of researchers. Such awareness and adoption of space techniques has been able to attract financial support to GBPIHED that further strengthened this facility and various research activities.

Fig. 4.2: Hands on by the officers of Line Departments of Uttarakhand on RS&GIS technology

Fig. 4.3:
New vegetation type map of India.



Use of space technology has proved to improve the quality of R&D work in the field of hydrology and snow cover mapping including glacier retreat, land use and land cover change and forest/ habitat fragmentation, vegetation response to climate change, and also refinement in methodology. The recent scientific contribution of Institute using this technology has appeared in a collaborative approach as "New Vegetation Type Map of India" (Fig. 4.3) (Roy et al., 2015). RS & GIS expertise so developed at GBPIHED has been contributing in space technologies based programmes of the country viz., Glacier mapping of the Himalayan region (Space Application Centre, Ahmedabad), Biodiversity characterization at landscape level for the country (Indian Institute of Remote Sensing, Dehradun), Monitoring of Himalayan alpines (Space Application Centre, Ahmedabad) and timberline (Indian Institute of Remote Sensing, Dehradun), inventorization of all the Biosphere Reserves of the country (National Remote Sensing Agency, Hyderabad; Forests Survey of India, Dehradun; MS Swaminathan Foundation, Chennai). Thus human resource development through capacity building on use of space technologies has been an important activity of GBPIHED to spread these technologies for better management of Himalayan resources and environment.

[Contributor: S. Sharma, *GBPIHED, Almora*]

SCIENCE AND SOCIETY INTERFACE: R&D EXTENSION THROUGH RURAL TECHNOLOGY COMPLEX

Fig. 4.4: Demonstration of different technologies at RTC (Kosi-Katarmal, Almora).

In keeping with the mandate, GBPIHED established Rural Technology Complex (RTC; Box – 2) in its early years of establishment with the following objectives: (i) To provide a basket of hill-specific and environment-friendly rural technologies; (ii) Capacity building of stakeholders and training of trainers (TOTs) through trainings/ live demonstrations/ field exercises; (iii) Guidance and support for field implementation of technology packages to the stakeholders and subsequent monitoring; (iv) Reduce out-migration by providing self employment options; and (v) Develop a framework towards achieving resource self-sufficiency within the rural eco-systems.

BOX - 2 **Key Features of RTC Set-Up at GBPIHED, Almora**

- *Collection of useful low cost and eco-friendly hill-specific technologies developed by different institutions / organizations.*
- *Live demonstrations/working models of useful technologies through live specimens, functional models, distribution materials, posters, pamphlets, etc.,*
- *Lecture rooms and a central hall with a seating/ staying capacity of about 150 persons and audio-visual and related facilities.*
- *Lodging, boarding and transport arrangements for about 30 out-station trainees.*
- *Trained, skilled and user friendly trainers and experts.*

19
CASE STUDY

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GBPIHED, Almora; [1]GBPIHED, Garhwal Unit

In view of the above mountain specificities, eco-friendly and relevant technologies were collected, tested and demonstrated for hands-on training and dissemination at RTC, Kosi-Katarmal, Almora (Table 4.1; Fig. 4.4). In addition, similar approach was followed in Maletha village (Tehri Garhwal), Triyuginarayan (Rudraprayag) and Tapovan (Chamoli), covering a wide range of altitude and agro-ecological conditions of Uttarakhand (Figs. 4.5). Keeping in mind educational level of the trainees, trainings manuals/folders/pamphlets were developed and training was imparted in Hindi or in local dialect and feed-back and suggestions from trainees are also sought to further improve our training programme.

Table 4.1: Selected technologies for training and demonstrations at RTC, GBPIHED, Almora

A. Yield Increasing

- Bio-composting and organic farming/ Bio-fertilizers
- Vermi composting/Vermi wash
- Biodynamic compost/Liquid manure
- Cow pit pat/Nadep composting
- Protected cultivation: Polyhouse, Polypit, Polytrench

B. Land-based Income Generating

- Integrated fish farming
- Vegetables and cash crops cultivation
- Mushroom cultivation
- Horticulture/Floriculture
- Apiculture/Organic farming
- Fruit & vegetable processing
- Medicinal plant cultivation
- Bamboo propagation

C. Life Supporting

- Watershed management
- Silvi pasture development
- Multipurpose tree plantation
- Agro forestry
- Bio fencing
- Traditional art/Handicraft and decorative items
- Nursery development
- Management & improvement of waste land

D. Other Supporting Activities

- Water harvesting
- Zero energy cool chamber
- Bio-briquetting
- Biomass briquetting
- Drip irrigation
- Sprinkler
- SHGs formulation
- Traditional food items
- D.P.R. Preparation
- P.R.A technique

Fig. 4.5: Demonstration and on-site training of stakeholders on simple rural technologies in Maletha village of Tehri-Garhwal.

At the RTC, Kosi-Katarmal, Almora for the last 15 years (since 2001) training and capacity building (1–3 days training capsules as per requirement) programmes were conducted for different user groups i.e., farmers, GOs, NGOs, students, army persons, etc. So far we have conducted a total of 424 training programmes (201 one day, 26 two days and 197 three and more days) and a total of 16396 persons (7217 female and 9179 male) were trained (Table 4.2), covering various Govt. and voluntary agencies (Table 4.3). Also ToT (training of the trainer's) programmes were conducted at the RTC established by the Garwhal Unit for wider implementation of these eco-friendly technologies. Among these, highly rewarding technologies such as integrated fish farming was also adopted by a few stakeholders in spite of high cost involved initially.

Table 4.2:
Stakeholders' capacity building activities at RTC, Almora

Stakeholders	Total	Male	Female
• ToTs	100	80	20
• Farmers and NGOs	3096	1185	1911
• Farmers & officials selected by Govt. organizations	7166	5055	2111
• GBPIHED R&D programmes	1629	549	1080
• Students	4152	2061	2091
• Army Personnel	253	249	04
Total	**16396**	**9179**	**7217**

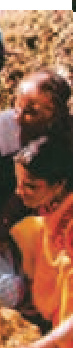

Table 4.3:
Persons trained under various Govt Programmes at RTC, Almora

Govt. Organizations/ Programmes	No. of Beneficiaries
• Watershed management (DPAP, BARANI, etc.)	1720
• Soil Conservation Department	357
• Agriculture Department	529
• Decentralized Watershed Management Directorate	180
• Integrated Watershed Management	138
• Block Development Programme (Hariyali)	629
• National Bank for Agriculture and Rural Development	137
• Mahila Dairy Vikash	164
• Horticulture Department	179
• State Biotechnology Programme	581
• SWAJAL	79
• Centre for Development Studies, Nainital	164
• Livelihood Improvement Programme	670
• Army Personnel	303
• Forest Department	68
• Council for Advancement of Peoples Action and Rural Development	24
• Bal Vikas Vibhag (ICDS)	125
• GBPIHED programmes	1629
Total	**7676**

Table 4.4:
Capacity building and on-site trainings at RTC, Garhwal (values in paranthesis are exposure visits)

Category of Participants	Total
• Farmers	1086 (589)
• NGOs	213 (146)
• Students (Senior level)	723 (608)
• Students (Junior level)	713 (791)
• Ex-Army Personnel	63 (120)
• Officials of Govt. line departments	67 (102)
• Academicians/policy planners/ and officials from financial institutions	51 (75)
Total	**2916 (2431)**

The Way Forward

The RTC has been powerful vehicle of R&D carried out by GBPIHED so far that aims at bringing changes over a period of time, leading to improvement in the economic status of the inhabitants, generation of employment opportunities, and reduction of environmental degradation and sustainable use of the available resources. Location-specific technology packages based on ecological, social, economic and cultural considerations have been demonstrated and implemented through participatory approaches are readily accepted by the people. Training and capacity building programmes conducted by us has gained much popularity (particularly among women) and made sufficient impact among the society. A number of farmers, NGOs, Govt. Departments, etc. have adopted various technologies as evident from the continued demand for conducting trainings and setting up of various demonstrations on nominal fee-basis making the RTC self-sustaining. This should, slowly but surely, lead to human resource development, women empowerment, and improve yield of crops and overall enhancement in the quality of life and environmental regeneration of IHR.

TECHNOLOGY BACKSTOPPING FOR ENTREPRENEURSHIP DEVELOPMENT IN NORTH EAST REGION

Economic development and improvement in livelihood condition of tribal communities of north east India is grossly dependent on the agricultural sustainability and efficient use of available natural resources. In the NE region, shifting cultivation continues to be a predominant agricultural practice and poses a potential threat to the rich biodiversity. Therefore suitable approach and technological measures need to be adopted based on the principles of low external input, user-friendly, low-cost as well as local appropriateness so as to enhance agricultural production and generate employment opportunity (Box -3). Technology backstopping was therefore carried out across Assam, Manipur, Meghalaya, Mizoram and Tripura with the help of seven Partner NGOs (PNGOs) covering 8 districts, 12 development blocks, 47 villages and more than 11 tribal communities (Table 4.5). The tribes covered in the project were Boros, Hmars and Biete of Assam; Mao Naga/Liangmei Naga and Tangkhuls (Naga) of Manipur; Mizos of Mizoram; Garos, Reangs, Debbarmas and Darlongs (Kukis) of Tripura and Jaintias of Meghalaya. The PNGOs had selected technologies based on the specific need of their region for agriculture and entrepreneurship development. The process involved networking with institutions and credible NGOs, capacity building of selected PNGOs to set up Demonstration Centres for capacity enhancement of tribal farmers – particularly that of shifting cultivators. Dissemination of technology material/information in local languages was made through PNGOs for effective adoption (Samal, 2012).

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CASE STUDY

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GBPIHED, NE Unit; [1]GBPIHED, Almora

BOX - 3 *Simple and Low-cost Technologies Popularized in NE Region*

- *Yield Improving Technologies: Weed/Bio-composting, Vermi composting, Liquid manuring, Polyfilm technology, Polyhouse, Legume intercropping/Mixed cropping, Multi-tier cropping system and Trellises.*
- *Soil Erosion Control Technologies: Contour hedgerow technology (CHT), Modified Jhum.*
- *Water Management Technologies: Haandi (pitcher) irrigation system.*
- *Post Harvest Technologies: Zero-energy cool chamber*
- *Energy/Fuel Saving Technology: Bio-briquetting technology*
- *Nursery Techniques: Bamboo propagation, cutting and grafting*

Project Design for Capacity Building/Adoption of Technologies

The PNGOs, trained by the GBPIHED established technology demonstration parks in their respective areas, which became technology dissemination centers for the user groups. Identification of technologies was need based and selected through survey and PRA exercises. The envisaged project design was a three-tiered structure that function as a chain with a feedback loop. It established an institutional network, where GBPIHED served as a 'Single Window' Technology Dissemination and Up-gradation Centre or a 'Technology Hub'. This was linked at the next level to local NGOs, who have established Demonstration Centers, which served as 'Rural Technology Colleges'. These were linked to Lead Farmers and On-Farm Demonstration sites, which served as 'Farmer Schools' (Fig. 4.6).

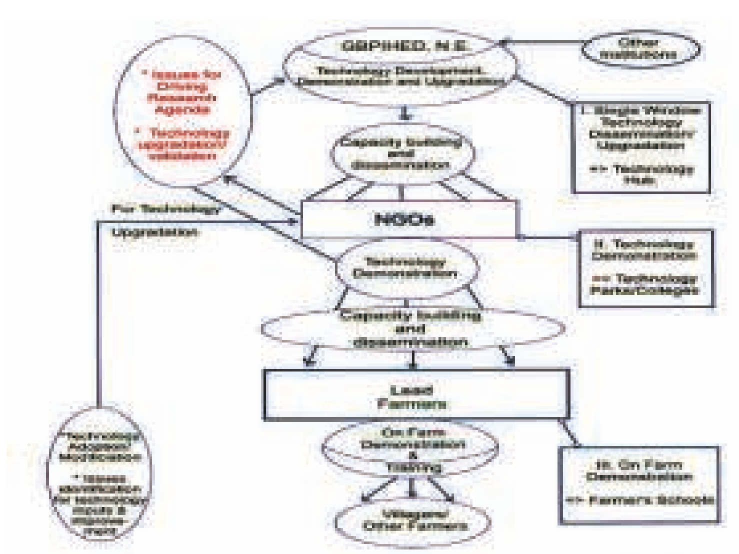


Fig. 4.6:
Flow diagram of institutionalization of technology backstopping

In the process of project implementation, capacity enhancement of more than 3670 tribal framers was accomplished through hands-on-training on fifteen low-cost and simple technologies (Table 4.5). To ensure sustained community participation, PNGOs have formed SHGs and cooperatives like farmers club and women were given adequate preference. As many as 69 SHGs and 3 Farmers Clubs, 1 Marketing Committee were formed by the PNGOs and number of entrepreneurships were developed. The level of adoption of various technologies at household level across the NE region reveals the practical application and impact of the case. More than 1500 households had adopted one or the other technology for enhancing crop yield in Jhum farming and developing entrepreneurship. They also modified some of the technologies such as bio-briquetting, weed composting, liquid manuring, zero-energy cool chamber and haandi technology (pitcher irrigation) as per their needs and requirements.

Table 4.5: Capacity enhancement of farmers through hands-on training in NE region

S. No.	Name of PNGOs	People's Participation/Coverage			No. of Farmers Trained		
		Districts	Villages	Communities	2006-07	2007-08	2008-09
1.	IIRM, Assam	Sonitpur	10	Boro	–	323	120
2.	CEP, Mizoram	Aizwal/Kolasib	5	Mizo	250	916	115
3.	SSRD, Manipur	Senapati	3	Tangkhuls	35	47	167
4.	NIDA, Manipur	Dhalai	6	Mao Naga/ Liangmei Naga	155	323	120
5.	St. VWS, Tripura	Jaintia Hills	10	Garos, Reangs, Debbarmas, Darlongs (Kukis)	20	79	270
6.	NAM-RHEN, Meghalaya		8	Jaintias	103	266	113
7.	NCHHCO, Assam	NC Hills	5	Hmar, Biete	189	–	65
Total	**7 PNGOs**	**8 Districts**	**47**	**11 Communities**	**752**	**1954**	**970**

Entrepreneurship Development

Couple of technologies like vermi-composting, bio-briquetting and weed-composting were taken up by farmers towards entrepreneurship development all across the project area. Bio-briquetting also has been taken up for entrepreneurship in the project villages in Assam and Mizoram. In project villages, use of bio-briquettes for fish roasting has increased income by Rs. 8000 to Rs. 10,000 annually for a few entrepreneurs, mostly women. In the project villages in Assam, use of both bio-composting and vermi-composting enhanced crop yield, where surplus products are now sold in the market. The farmers are also selling the compost in the nearby market and supplying to the nearby tea gardens. In project villages in the state of Manipur farmers could increase their income by Rs. 10,000 per annum from mix-cropping in the home gardens through application of bio-composting and vermi-composting. This collaboration with PNGOs therefore proved successful in technology dissemination and livelihoods improvement of the tribal people of the NE region.

Apart from the PNGOs imparting training on technologies to farmers in various parts of NE India, hands-on-trainings on technologies are regularly imparted to diverse stakeholders by us at Multi Technology Demonstration Centre located at Doimukh, Arunachal Pradesh. These technologies are also promoted by Krishi Vigyan Kendra, Papumpare, Govt. of Arunachal Pradesh, CAPART, Guwahati, IFAD-MRDS, Meghalaya; Watershed Development Programme of Govt. of Arunachal Pradesh. These technologies were also recommended for rehabilitation of jhum lands by the Inter-Ministerial National Task Force of MoEF & CC on rehabilitation of shifting cultivation areas, etc. (Box - 4).

BOX - 4	Integrated Agro-Horti-Silviculture Model – An Alternative to Shifting Cultivation

In the northeast India, shifting agriculture (commonly known as Jhum), which was once considered to be sustainable, has become unsustainable owing to massive damage to forests and associated soil erosion and biodiversity loss (Samal et al., 2009). To address the issue of Jhum, GBPIHED, North-East Unit in collaboration with Dept. of Environment & Forest, Govt. of Arunachal Pradesh developed an "Integrated Agro-Horti-Silvicultural Model", which envisages conservation of forests, planting of MPTs in the Jhum land and its integration with horticulture and pisciculture. The model is divided into 5 different layers/strata (S_1 to S_5) (Fig. 4.7). The top most strata (S_1) is represented by trees/forests in which suitable species such as Artocarpus spp., Celtis australis, Erythrina indica, Garuga pinnata, Gmelina arborea, Kydia calycina, Lagerstroemia spp., Lannea coramandalica, Michelia champaca, Morus laevigata, Terminalia spp., etc., in moderate altitudinal zones and Alnus nepalensis, Aesculus indica, Robinia pseudoacacia, etc. be planted combined with other local species for providing fodder, fuelwood, etc. In the S_2 strata, horticulture species such as Apple, Banana, Guava, Kiwi, Large Cardamom, Litchi and Orange are planted based on agro-climatic conditions. The S_3 strata is represented by agricultural crops grown locally. By mixing pulses/legumes with cereals and vegetables the soil fertility of the land and crop yield can be improved. In the S_4 strata, the crops get sufficient soil nutrients to support good yield. In case of S_3 and S_4, techniques like modified jhum, trellis, pitcher irrigation, etc. can be applied to enhance crop yield. With availability of suitable land, the S_5 strata consisting of paddy-cum-fish cultivation can be practised. This devised model is being adopted under "Rehabilitation of Jhum area through integrated agro-horti-silviculture cultivation" scheme of Govt. of Arunachal Pradesh under State Compensatory Afforestation Fund Management Planning Authority (CAMPA).

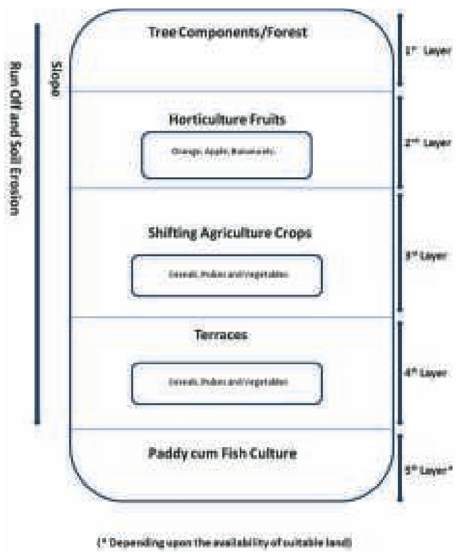
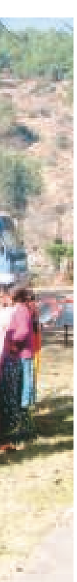


Fig. 4.7: Integrated Agro-Horti-Silvicultural Cultivation Model for sustainable agriculture in North East India.

[Contributors: P.K. Samal, S.C. Arya, R.C. Sundriyal[1], & P.P. Dhyani[1], *GBPIHED, NE Unit; [1]GBPIHED, Almora*]



BOX - 5	Award for the Case Study

This project work has been awarded "SCHOLL Research Challenge 2010 Award" in the category "Technology for Development" by National Foundation for India and North East Development Foundation sponsored by IDRC, Canada "for capturing the knowledge of various technologies that are relevant for the Indian rural socio-economic ecosystem. It tells about key steps very relevant to deploy technology tools and solutions to address growth and development within communities".

The case study is also an excellent example of collaboration between GOs and NGOs and multi-disciplinary approach in addressing technology development and governance in the NE India and given SCHOLL Research Challenge 2010 Award to GBPIHED team (Box - 5).

ECOTOURISM FOR LIVELIHOODS IMPROVEMENT AND BIODIVERSITY CONSERVATION

This case study on ecotourism deals with strengthening the capacity of villagers on community based tourism (CBT) in Thembang village and Thembang Bapu Community Conserved Areas (CCA) (TBCCA), and bringing Namshu and Sangte villages for developing ecotourism through a GOI-UNDP-CCF-II funded project support and partnering with WWF-India in the proposed Tawang & West Kameng BR (TWKBR) of Arunachal Pradesh. Capacity building of village people was done through training workshops for cook, guide and camp site and financial management, Home Stay and Home Based Restaurant, and orientation programme for youths for management of tourists. CBT and Coordination Committee and Community Conserved Area Management Committee (CCAMC) were constituted among the villages and benefit sharing mechanism was developed. Tourism infrastructure in the project villages was supported by providing 12 Jungle Safari Tents, development of camp sites with construction of platforms, buildings for kitchen and toilet facilities in all the three villages, and training to villagers on managing CBT. Earning scope for villagers included home stay, pack animal, porter, guide, cultural program, local handicraft, etc. Earning scope for CCAMC included CCA entry fee, camera fee, trekking camping site charge, camp site accommodation charge and, CCA conservation fee (15% and 10% of total service cost for International and domestic tourist, respectively).

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CASE STUDY

P.K. Samal, R.C. Sundriyal[1] & P.P. Dhyani[1]
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Fig. 4.8:
Ecotourism model developed in Apatani plateau.

Partnering with North Eastern Regional Institute of Science and Technology (NERIST), we developed a culture based ecotourism model at Apatani Plateau in Suluya village (Fig. 4.8) involving Achukuru Welfare Society. Efforts were made to interlink the cultural heritage with natural heritage through CBT. The model comprised kitchen garden, nursery, community based sales counter, museum, duckery unit and pisciculture, fishing, etc. Two traditional cottages with standard living facilities were also created over a pond in the model site. Community based sales counter was developed, which acts as a platform to exhibit and sell the locally made products such as bamboo based handicrafts, wood carvings, beads, ornamental items, etc. The CBT activities have helped in engaging the villagers from the two fringe villages (Namshu & Sangte) of Thembang Bapu CCA for support to villagers of Thembang in conserving the rare and threatened flora and fauna of the Thembang Bapu CCA including the black-necked crane (*Grus nigricollis*). The village camp sites of Thembang, Namshu and Sangti are operational and the villages have been receiving more tourists. Total income in the project sites since 2008 and till December 2012 was about Rs. 9.71 lakh out of which total income by villagers was Rs. 7.93 lakh and corpus saved by constituted village level committees was about Rs.1.77 lakh (Table 4.6).

The project also helped in strengthening CBT facilities in the area which in turn is providing multiple choices for the visitors coming to the area, thereby ensuring economic promotion in project villages. In Namshu and Sangte Village Camp Sites, developed facilities can accommodate a group of 8–9 persons at a time.

Table 4.6: Income generation in the project villages

Income	TBCCAMC	Sangte	Namshu	Total
Villagers	Rs. 7,75,911	Rs. 17,300	Nill	Rs. 7,93,211
management Committee	Rs. 1,27,197	Rs. 42,300	Rs. 8,500	Rs. 1,77,997
Total	**Rs. 9,03,108**	**Rs. 59,600**	**Rs. 8,500**	**Rs. 9,71,208**

In the CBT Model developed in Apatani plateau, the museum displays a number of cultural and natural items of Apatani tribes such as traditional dress, tools, cloths, beads, ornaments, etc. The traditional hut developed is being used for lodging facilities for the tourists. The community based sales counter developed in this model provides a market linkage to the villagers who doesn't have a market or sale counter for selling their products. The SHG plays a significant role in selling of the products wherein they incorporate 5% to 10% commission on each product to generate corpus fund. The CBT model depicts the cultural heritage and natural heritage of the Apatani tribe viz., their natural resource management practices, ethnobotanical knowledge, etc. Kitchen garden developed provides valuable information to tourists on medicinal plants as well as the cultivars of agricultural crops, which are traditionally used by the Apatani community. Through the nursery developed in the project site trainings were provided to the local people on nursery management as well as raising nursery stock (tree and ornamental plants species), etc. Also, through up scaling of the skill of artisans of handicraft and wood carving through capacity building programme, a number of villagers have been benefited (Fig. 4.9).

Fig. 4.9: Capacity building of local youth in bamboo handicrafts

The model promotes plantation of the medicinal plants, seasonal agricultural cultivars and vegetables used by the communities as major components of agri-diversity in the kitchen garden. The practice of agro-tourism, which is being promoted through the model is helping in maintaining the agro biodiversity. It has reduced the existing pressure on the natural resource by promoting CBT as an alternative livelihood. Based on these experiences Guidelines for Promotion of Homestays in Arunachal Pradesh and Arunachal Pradesh Ecotourism Policy were developed and submitted to Government of Arunachal Pradesh.

Biodiversity Conservation and Ecotourism in Sikkim

In Sikkim state with over 90,000 domestic and 6,000 international tourists in 1995, tourism has rapidly become an important economic activity (Joshi & Dhyani, 2009). Under the Sikkim biodiversity and ecotourism project, a collaborative initiative was designed by GBPIHED-Sikkim Unit to conserve the biological diversity of Khangchendzonga National Park in participation with communities, private sector and government and planned community based enterprise to minimize the impact of tourism on biodiversity and other natural resources (Rai & Sundriyal, 1997). Within the National Park is Sikkim's major trekking route, the Yuksam-Dzongri-Goechba La Trail-an exhilarating climb through dense forests and impressive mountain views. The spiritual and physical focus of the area is Khangchendzonga, the world's third highest mountain peak (8,548 m asl), and revered as the protective deity of Sikkim. At the trail head is Sikkim's first capital, Yuksam. From Yuksam, visitors can take short walks to several archeological ruins and to Dubde, Sikkim's oldest monastery. A number of different groups, including Lepchas, Bhutias and Nepalis, as well as Tibetan refugees, live in this culturally and historically rich area. Most pursue traditional agricultural livelihoods, while some have added tourism in recent years. Other project sites include Khechopalri Lake, one of Sikkim's most sacred and popular lakes and Pelling, a settlement near Pemayangtse Monastery. The forests and alpine meadows of this area are some of the most biologically diverse in India, and contain over 36 species of Rhododendrons, 400 species of Orchids and many other flowering plants. This Park also contain 81 mammals, over 300 bird species, and about 400 butterflies.

Project Partners and Activities

The major partners in the project comprised GBPIHED, The Mountain Institute (TMI) USA, The Travel Agents Association of Sikkim (TAAS), The Green Circle (local NGO) and the local community. The Process involved collection of baseline information using participatory tools, identification of issues related to micro-enterprise (i.e. ecotourism), formulation of conceptual models, and devising strategic plans with time frame and responsibilities of each stakeholders. The major areas of interventions comprised enforcement of Code of Conduct, promoting community ecotourism plans, such as trail and site maintenance, NRM; conservation education; fuelwood consumption reduction measures by trek operators and local lodges; and built capacity of local NGOs and people engaged in ecotourism.

The Salient Impacts

The main success pillars for this project comprised participatory approach, strong local institutions, expertise inputs and income sharing. As the direct impact of the project was formulation of Khagchendzunga Conservation Committee (KCC), a local NGOs that voluntarily monitored the tourism activities at trekking route along the Yuksam-Dzongri-Goechba La Trail. The Ecotourism and Conservation Society of Sikkim (ECOSS) was also formed as an outcome of this project which is now a dedicated NGO to promote ecotourism and conservation. Thus GBPIHED played a key role in developing tourism related policies in the state of Sikkim. The project also brought a policy change in alternative fuel (LPG/kerosene) in place of firewood that the tourist used during treks. The project also provided substantial inputs in developing the 'Tourism Master Plan' for Sikkim state. Similar efforts were made in Uttarakhand (Box - 6).

Box - 6 *Promoting Eco Tourism in Nanda Devi Biosphere Reserve*

The Nanda Devi Biosphere Reserve (NDBR), a World Heritage Site is one of the unique tourist destination in Chamoli district of Uttarakhand with high ecological, cultural, religious and spiritual values (Fig 4.10). However, establishment of the National Park in 1982 and the Biosphere Reserve in 1988 under the UNESCO's Man and Biosphere (MAB) programme resulted in ban on tourism to the core zone besides restriction on many traditional rights enjoyed by the local inhabitants to support their livelihoods without having provided with adequate alternative options. This situation had created "park-people conflict" in NDBR defeating the envisaged conservation goals. Thus promoting eco-tourism in buffer zone villages of NDBR was thought an appropriate intervention to address the livelihood of local inhabitants. Efforts were made to create awareness and empower the local people and tour operators in the field of nature guides, medicinal plant cultivation, bioprospecting and value addition in farm produce and wild edibles, serving traditional local meals in homestay and trekking, conservation education, use of alternative fuel, safety, hygiene and sanitation, cultural events organization, etc. so as to improve local economy by organizing workshops and exposure visit of locals to homestays elsewhere in the region. Based on the experiences we prepared guidelines for eco-tourism promotion so as to meet twin goals of socio-economic development and conservation.

Fig. 4.10:
A view of NDBR (left) Training to local people on eco-tourism (right).

[Contributor: R.K. Maikhuri GBPIHED, Garhwal Unit]

BIO-FERTILIZERS FOR BOOSTING GROWTH AND PRODUCTION OF IMPORTANT PLANTS

In the Himalayan mountains growth and productivity of plants is often limited due to cold temperature. Also, use of chemicals to boost the plant growth is undesirable from the standpoint of environmental pollution. Therefore, how to enhance survival, growth and productivity of food crops and other economically important plants is a major challenge that has direct public concern. In the recent times, enhanced global preference for the naturals (organics) food products and the need to cut down on the use of chemical fertilizers has catalyzed research on the development of biological fertilizers. Twin benefits of the eco-friendly, microbe-based bio-fertilizers are: (1) improved plant nutrition, and (2) biocontrol of a range of pathogens. Isolation of microorganisms, screening for desirable characters, selection of efficient strains, production of inocula, and easy to store and transport commercial formulations are important steps of this bio-fertilizer technology.

Understanding this challenge, systematic experiments were conducted for the development of microbial inoculants, specifically across different altitudes in the cold areas of the IHR. The initial on-farm experiments indicated (i) the importance of ecological suitability of microorganisms used, and (ii) the need for using native microorganisms as inoculants for field applications.
This was followed by subsequent lab and field based screenings, which resulted in the final selection and development of desired bioformulations those were found effective for agriculture, forestry and tissue culture raised (TCR) plants of the IHR. In addition, endophytic microorganisms were also used for propagation and conservation of medicinally important tree species, such as *Ginkgo biloba* and *Taxus baccata*.

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CASE STUDY

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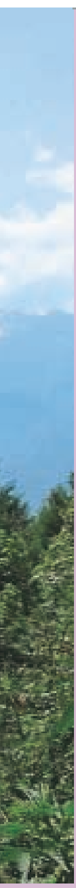
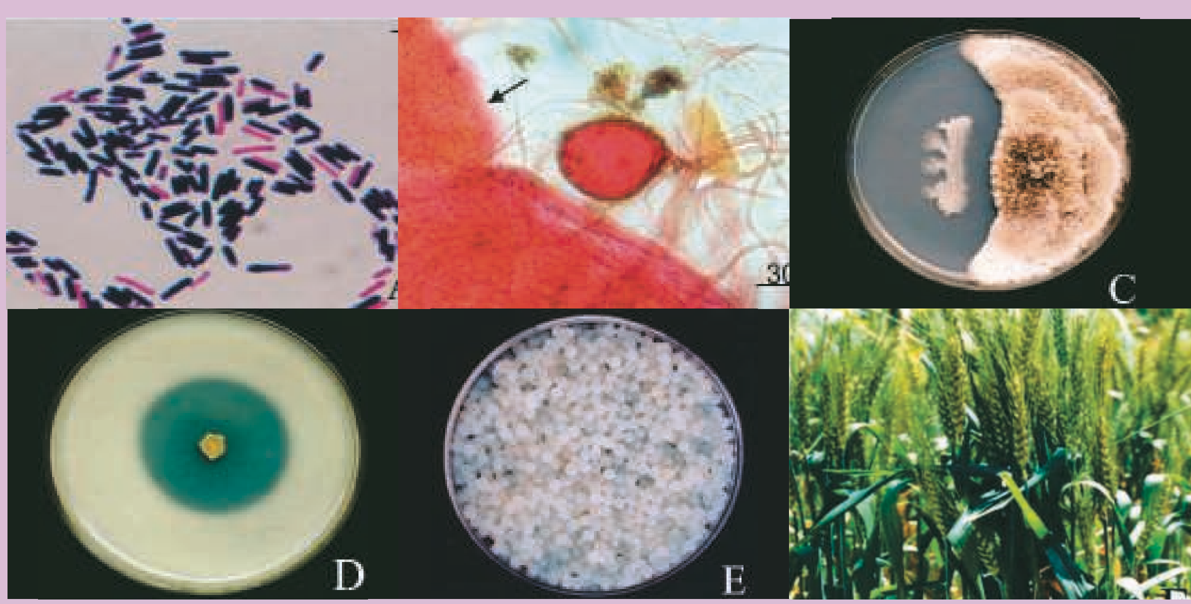


Laboratory Techniques

For the isolation of microbial inoculants, soil samples were collected from various temperate and alpine locations of the IHR, and a culture collection of native "high altitude microbes" was established. Effective strains of bacteria as well as fungi could thus be selected from the native isolates. The purified isolates were evaluated for desirable traits, such as atmospheric nitrogen fixation, solubilization of locked phosphates in soil, production of antimicrobial substances, and the ability to colonize the roots of target plants, along with their ability to survive and proliferate under low temperature conditions. Important systematic steps in the development of microbe based bioinoculants are depicted in Fig. 4.11 A–F. Inoculation trials on agricultural crops, forest, plantation and TCR species were initially conducted in GBPIHED under green house conditions, and subsequently in tea gardens and forest nurseries.

Fig. 4.11: A. Bacillus subtilis - a suitable plant growth promoting and biocontrol bacterial agent (Bar = 2mm), B. Ectomycorhizae in the root tissues of Taxus baccata, C. Antifungal property of B. subtilis, D. Phosphate solubilization by Pseudomonas sp. (a cold tolerant plant growth promoting rhizobacterium), E. Carrier-based bioformulation of a bacterial inoculant in alginate beads (for storage and commercialization), F. Bacterial inoculation of wheat for growth enhancement



Novel Bioinoculants for Application in Cold Regions

Species of *Bacillus* and *Pseudomonas*, namely *B. subtilis, P. corrugata* and *P. putida* gave best results in terms of biocontrol and plant growth promotion (Pandey et al., 2006). Likewise, selected species of arbuscular mycorrhizal fungi, mostly belonging to the genus *Glomus*, were also found to have the ability of growth promotion. Positive effects of bioinoculation were recorded on a range of agricultural crops, forest (*Cedrus deodara*) and plantation species (*Camellia sinensis*), as well as on the TCR plants (Table 4.7).

Table 4.7: Benefits of microbial inoculation on various plant species

1. Microbial inoculants

Strains of *Bacillus subtilis, B. megaterium, Pseudomonas corrugata, P. putida, Trichoderma* sp. and arbuscular mycorrhizae

2. Benefits on plant growth

2.1. Agricultural crops (cereals, e.g. rice, wheat, maize; millet, e.g. finger millet, barnyard millet; legumes, e.g. lentil; vegetables, e.g. *Amaranthus*)

a. Increase in biomass and yield
b. Increased mineral content
c. Disease control
d. Stimulation of native beneficial rhizosphere microflora
e. Increased colonization of mycorrhizae and endophytes
f. Enhanced nitrogen fixing efficiency of legumes

2.2. Forest/plantation species (*Cedrus, Pinus, Taxus, Ginkgo*, oaks, tea)

a. Control of fungal (mainly *Fusarium* wilt) and insect attacks (cutworms)
b. Improved seed germination, seedling survival and growth
c. Increased mineral content
d. Increase in colonization of mycorrhizae and endophytes
e. Production of healthy seedlings for plantation programmes

2.3. Tissue culture raised plants

a. Increased survival during lab to field transfer, and subsequent growth
b. Increased mineral content
c. Increased mycorrhizal colonization

Benefits to Agricultural Crops, Tree Species and Medicinal Plants

A range of agricultural crops were benefited by the use of this microbe based technology in respect of stimulation of the native rhizosphere microflora (mainly plant growth promoting rhizobacteria), increased mycorrhizal colonization, improved germination, overall nutritional status of the plant biomass as well as yield as compared to control. In case of legumes, inoculation resulted in increased nodulation in addition to other plant growth related attributes (Kumar et al., 2007). Similarly, the benefits of inoculations were seen on seed, cutting, and tissue culture raised tea plants (Pandey et al., 2013). Bacterial inoculation of TCR plants, namely tea, resulted in significant increase in the survival following field transfer (Pandey et al., 2000). Microbial inoculation in *Cedrus deodara*, at the time of seed sowing resulted in significant enhancement in germination, along with nutrient uptake, mycorrhizal colonization and overall biomass of seedlings (Bisht et al. 2003).

Ginkgo biloba L. (Maiden hair tree, family Ginkgoaceae, often referred as the living fossil), is a rare tree that contains pharmaceutically important flavonoids, glycosides and ginkgolides which improve blood flow, act as antioxidants, and also used as memory enhancers and anti-vertigo agents. It is a slow growing tree and its regeneration through seeds is poor. Clonal propagation using stem cuttings is a

Fig. 4.12: Inoculated plants of Ginkgo biloba and Taxus baccata under net house conditions, ready for fi eld transfer.

practical option for this species. An endophytic bacterium isolated from the mycorrhizae infected cortical cells in the roots of this plant has been used to develop a bioformulation for the initial establishment of *G. biloba* stem cuttings; cutting raised plants so developed have been successfully transferred to the field conditions (Pandey et al., 2014; Fig. 4.12). Similarly, *Taxus baccata*, an important tree (Box - 7), was studied for its rhizosphere colonization; variously designed soil amendments significantly increased its seed germination along with reduction in germination time (Pandey et al., 2002). In addition, stem cuttings, inoculated with bioformulations have been successfully planted at different locations. To further popularize this eco-friendly technology on-farm demonstrations in collaboration with the local farmers it is desirable to establish 'production units', as cottage industries for large-scale production of bioinoculants for its use by the farmers. This research was patented by the authors (Box - 8).

Box - 7 **Conservation of Himalayan Yew**

Taxus baccata L. supbsp. wallichiana (Zucc.) Pilger (Hindi- Thuner; the only species of genus Taxus from India; Fig. 4.13) has come into prominence in recent times due to its uncontrolled harvesting from the Himalayan wilds for the extraction of taxol@ (paclitaxel), an anticancer drug. It is very slow growing tree with poor regeneration, and canopy damage is likely to have serious consequences on biomass yield, plant survival and natural regeneration by affecting 'seed' output. A study by GBPIHED in the Jageshwar area of the Central Himalaya (1770 to 1920 m amsl) revealed that of the total of 57.4% canopy volume have been removed, representing about 8% of the total area under T. baccata habitat. Therefore, it was considered relevant to develop a simple and efficient clonal (vegetative) multiplication protocol for mass propagation of this species through chemical (auxins, phenolic compounds and a systemic fungicide Bavistin) treatment of stem cuttings and growing them in polyhouse (Fig. 4.14). In general, lower concentration (0.25 mM) of IBA or NAA (both auxins), and Bavistin (0.05%, w/v) were highly effective in inducing adventitious rooting (> 80%); the phenolics were somewhat less effective. A seasonal effect of root induction in these cuttings was also observed with best results in monsoon season (Nandi et al. 1996). Survival of vegetatively propagated plants following transfer in their natural habitat was about 50% even after 8 years. In addition, seed germination was also enhanced (>70%) using soil treatments. In view of above results, some urgent steps and strategies for multiplication, conservation, afforestation and even cultivation of T. baccata clones containing high level of taxol have been proposed (Nandi et al. 1998). The above mentioned studies and investigations on tissue culture resulted in Cash Award by ICFRE, Dehradun to GBPIHED scientists in the field of Forest Conservation for 1996-97. Using this technological know-how the Forest Department, Govt. of Uttarakhand mass multiplied this species in their nurseries. As a step towards conservation and afforestation, cutting-raised plants of T. baccata have been planted in several places in Kumaun region, namely Munisyari, Dhauladevi and Jageshwar. Non-governmental organizations, State Forest Departments, village committees, and voluntary bodies need to be mobilized form undertaking conservation by planting clonally propagated as well as plants of seed origin in their natural habitat to conserve this rare and threatened species.

Fig. 4.13: A mature tree of T. baccata growing in Jageshwar forest

Fig. 4.14: Rooting in one-year-old stem cuttings of T. baccata treated with chemicals; (a) untreated control.

[Contributor: S.K. Nandi, *GBPIHED, Almora*]

Box - 8 **Beneficial Microbes under IPR**

Native microorganisms isolated from the soil samples, collected from various locations spread across the IHR, were screened for desirable traits such as nitrogen fixation, phosphate solubilization and biocontrol. Selected bacteria and arbuscular mycorrhizal fungi, raised in carrier based formulations, have been demonstrated for their benefits on plant growth on a range of agricultural, forest and plantation species, as well as on the tissue culture raised plants. The promising bacteria have been deposited in Agricultural Research Service (ARS) Patent Culture Collection, United States Department of Agriculture, Illinois, under Budapest treaty (Accession nos.: NRRL B-30408 and NRRL B-30408/ Patent no. KE 303).

REDUCED TILLAGE AND MULCHING FOR SUSTAINABLE RAINFED AGRICULTURE

Fig. 4.15:
Large areas of landscapes in middle mountains are invaded by Lantana camara (Inset: A close view Lantana twig and flower).

Poor soil fertility and soil moisture in the sloping rainfed crop fields in the Central Himalayan mountains are the two major limiting factors that affect germination, growth and yield of agricultural crops. Traditionally, the crop fields are tilled twice and a huge quantity ($\approx$1.7 t ha^{-1}) of farm yard manure (FYM) is applied every year to restore soil fertility. The FYM mostly contains poor quality and slow decomposing leaf litter of Oak and Pine forests that hardly builds up soil fertility adequately, and results in low crop yield (0.6–1.3 t ha^{-1}yr^{-1}). Soil nutrients are also washed away from these crop fields due to monsoon rains. Reduced tillage and mulching with high quality *Lantana camara* leaves (a weed that has invaded crop fields and most part of the landscape in the warm valleys of Central Himalaya; Fig. 4.15) in combination with Oak and Pine leaf litter was therefore considered to be useful to improve soil fertility, SWC and crop yield as has been proved beneficial for wheat and rice crops in rainfed condition in this region (Bhusan & Sharma, 2005). Researchers have proved that mulches modify soil physical properties, regulate soil temperature, increases soil permeability, aeration and root penetration, reduce water run-off and soil moisture evaporation, soil erosion thus resulting into better yield (e.g., Acharya and Kapur, 1993; Kundu et al., 2007).

Fig. 4.16
An overview of experimental plots established in Kosi-Almora.

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CASE STUDY

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This success story based on a long-term experiment on reduced tillage and mulching by mixing high quality Lantana leaves with Oak and Pine leaf litter suggests that this technology could be useful for conservation of soil moisture, soil fertility and crop yield in the mountain rainfed farming and will also prove useful in eradication of this obnoxious weed (Kumar et al., 2009). In this experiment on abandoned crop fields of Almora district (Uttarakhand) (Fig. 4.16) three types of mulch materials (leaf litter): Lantana (*Lantana camara* L.), Oak (*Quercus leucotrichophora* L.) and Pine (*Pinus roxburghii* Sarg.) were mixed under four different combinations, L_1–L_4 (L_1= Lantana, 50%, Oak= 25% and Pine= 25%; L_2= Lantana, 33%, Oak= 33% and Pine= 33%; L_3= Lantana, 75%, Oak= 12.5% and Pine= 12.5% and L_4= Lantana= 100%) and three tillage frequencies (no-tillage, once and twice) and applied in the experimental plots just after sowing wheat and rice crops. The soil of the experimental plots was sandy loam in texture (sand = 19.7%, silt = 61.4% and clay = 17.1%), well drained (bulk density = 1.19 g cm^{-3} and water holding capacity = 51.5%), dry (soil moisture = 17.2% and soil temperature = 16.6°C) and low in available soil nutrients.

Lantana Mulching Improves Soil Fertility and Crop Yield

The Lantana dominated litter bags (L_4; 100% Lantana and L_3; 75% Lantana) decomposed much faster as compared to the litter bags with low proportion of Lantana leaves (L_2 and L_1 combinations) and took around 500 days to accomplish >80% decomposition, thus supplied nitrogen and phosphorus to soil uninterruptedly (Kandpal & Negi, 2003). Lantana having a greater nutrient concentration in leaf litter (N= 1.3%, P= 0.26%, K= 1.23%), low C:N ratio (30.9) and low lignin (6.3%) as compared to Oak and Pine leaf litter realized faster decomposition. A net increase ($P<0.05$) in concentration of soil OC (0.16%), total N (0.05%), total P (0.28%) and total K (0.53%) and the available forms of N were recorded at the end of the experiment over the initial status of soil nutrients. However, the soil moisture and other soil fertility parameters decreased markedly with increasing tillage frequency.

The 100% Lantana-mulched plots recorded distinctly high seed germination and grain yield of wheat (1309 kg ha^{-1}) as compared to the traditional practice (620 kg ha^{-1}). Similarly, grain yield for the rice crop for 100% Lantana mulch with twice tillage treatment (1110 kg ha^{-1}) was recorded about 1.8 times higher as compared to traditional practice (633 kg ha^{-1}). Thus, results of this study suggest that Lantana mulching with reduced tillage proved beneficial in rainfed crop fields for improved soil fertility and crop yield over the traditional practice (Kumar et al. 2009). Results of this study were subsequently spread over four villages among the farmer's fields in this region under a DST women scientist project. The scope of replication of the research results is immense as use of Lantana leaves for sustainable rainfed farming will also contribute to its eradication which is otherwise a huge challenge for environment of this region. Notably fertilizer / pesticides application can not be recommended to increase crop yield from environmental safety standpoint as it has been found to contaminate the food crops (Box – 9).

Box - 9 Pesticide Residue Contamination in Vegetables in Kullu Valley, H.P.

Pesticides are repeatedly applied during the entire period of growth and even sometime at fruiting stage for the better yield and quality of crops. In Himachal Pradesh and Kullu Valley in particular, pesticides are used to protect the food crops such as apple, tomato and cauliflower from pests that could cause health risks to consumers (Sharma et al. 2008). This study on pesticide residue levels in soil, water and food crops in Kullu Valley during August–September 2011 revealed that concentration of residues of chlopyrifos, endosulfan, cypermethrin and malathion were not detected in bore well water, whereas river water samples were found contaminated. Concentrations of pesticide residues in all the test crops were found markedly higher at field sites as compared to that of market sites, however, the concentrations was found below their maximum residue limit set by the National and International agencies except for cauliflower. The pesticide residue load have exceeded by one unit in soil, water and food chain which indicates that application of pesticides in the study area is not judicious and may pose risks to aquatic organisms, soil flora and fauna as well as human health in long run.

[Contributors: R.K. Sharma & S.S. Samant, *GBPIHED, Himachal Unit*]

BIO-COMPOSTING: A SUSTAINABLE WAY TO MANAGE SOLID WASTE

In the mountain towns municipal waste has emerged as a serious environmental problem in the recent decades. With the ever increasing native residents as well as floating populations, hill towns, trekking and expedition locations (Kuniyal et al., 1998; Kuniyal, 2002) have grown as godowns of garbage posing hazards to the ecology and life of the area and pollution of air and water. Realizing this a serious environmental issue, GBPIHED conducted fourteen in-depth case studies in western Himalaya (i.e., six hill urban towns- Bilaspur, Kangra, Mandi, Hamirpur, Chamba and Keylong; five tourist spots- Kullu, Rewalsar, Manali, Tabo and Kibber, two trekking areas- Chandratal and Valley of Flowers - Hemkund Sahib and one expedition region - Pindari Valley, Uttarakhand) to quantify and classify the waste as well as its management (Kuniyal & Thakur, 2013–14). The composition of collected waste from these sites was categorized as: Readily biodegradable waste (RBW), biodegradable waste (BW) and non-biodegradable waste (NBW). The RBW was found highest in Manali (65.5%) and lowest in Chandratal (4.5%) of the total sampled and segregated waste. In case of BW, it was found between 30.5% in Kangra and 3.3% in the Valley of Flowers. The NBW was found highest in Chandratal (90.1%) and lowest in Manali (16.9%). It was observed that the urban towns and tourist spots were dominated by biodegradable waste (RBW and BW), while the trekking and expedition regions with NBW (Fig. 4.17).

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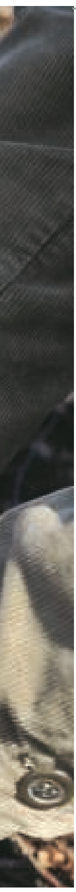
CASE STUDY

J.C. Kuniyal & H.K. Thakur
GBPIHED, Himachal Unit



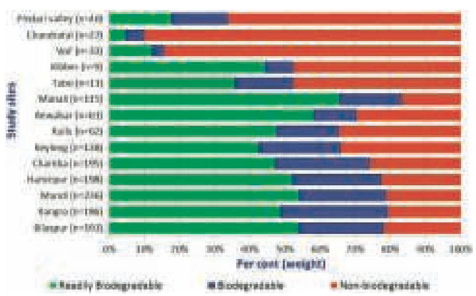


Fig. 4.17: Solid-waste composition in fourteen study sites of the Himalaya ('n' indicates number of 1 m3 samples analysed)

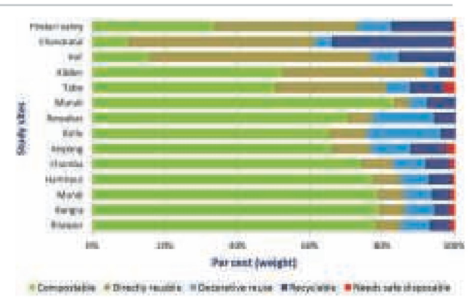


Fig. 4.18: Solid-waste management (SWM) options based on segregated and sampled waste.

Fig. 4.19: MBC pit designed by GBPIHED, Himachal Unit, Kullu.

Solid Waste Composition in Towns of HP

The RBW category consists of leftover food, vegetables, fruits, plant residues, etc. and decomposes in a couple of weeks under controlled temperature (25±5°C) and humidity (40-60%). The BW category of waste requires about a month time to decompose under the same temperature and humidity and consists of fruits (seeds, shells and peels), wet papers, old clothes (jute and cotton), rags, fuel wood residues, etc. While the NBW consisting of polythene, plastic, nylon, glass, metals, broken crockery, synthetic clothes, hairs, bones, stones, bricks, etc. is a non-decomposable waste category under normal conditions and needs other options of management. Looking at biodegradable nature, RBW and BW can be combined together from management point of view. Overall ~75% of the total waste could be converted into useful compost (Fig. 4.18). However, the remaining 25% NBW can be either reused or recycled. The medical/ toxic/ hazardous waste needs a separate treatment and safe disposal.

Bio-compost Enhances Yield of Crops

Bio-composting is an aerobic process under which the RBW and BW waste disintegrates and decomposes to nutrient rich compost useful for crops and orchards. We designed a microbial biomass compost (MBC) pit having following specifications (Fig. 4.19): (i) It should be sun facing and away from water bodies, (ii) The size of pit should preferably be 3 m×1 m× 1 m and can be reduced up to 1 m×1 m×1 m; (iii) The base of the pit should have at least one feet vertical soling of stones to avoid water logging; (iv) Put one to two PVC pipes across the pit from its base for aeration purpose; (v) The roof of the pit should be covered with multi-layered ultraviolet (UV) resistant polyethylene sheet to create a green house effect for regulating temperature; (v) Turning waste material in an interval of about 15 days and sprinkling a bucket of water over it to maintain 40–60% moisture would be required for better decomposition and composting; (vi) The hazardous, medical waste, non-biodegradable or any other waste deteriorating raw material quality needs to be treated separately. The compost thus prepared from this MBC was used in garlic crop and recorded 44.5 quintal/ha yield as compared to FYM with only 28.5 quintal/ha. Thus by using bio-compost after 5 years one can earn Rs. 17,352 per pit. This study has a significant contribution not only for making microbial composting from solid waste successfully and improve crop yield, but also has awakened many of the stakeholders such as municipal committees, villagers, urban dwellers, school children, hoteliers, hydropower project authorities, policy makers, etc. for adopting this MBC pit technology.

PROMOTION OF CITIZEN SCIENCE IN THE INDIAN HIMALAYAN REGION

Citizen Science has been defined as "the systematic collection and analysis of data; testing of natural phenomena; development of technology; and the dissemination of these activities of researchers primarily on a vocational basis". In this approach the volunteers collect experimental data for researchers, raise new questions and co-create a new scientific culture. As a result of this open, networked and trans-disciplinary scenario, science–society–policy interactions are improved leading to a more democratic research and informed decision making.

Keeping in view the limited scientific manpower for achieving R&D mandate, GBPIHED thought it pertinent to involve the volunteers in collaboration with Earthwatch Institute India, under a project on "Assessment and Quantification of Forest Ecosystem Services with Special Emphasis on Pollination in the Indian Himalayan Agro-ecosystems" which aims at achieving ecological and economic security by enhancing flow of Ecosystem Services (ES) through biodiversity conservation and management including bee flora and pollinator services in selected agricultural landscapes in representative agro-ecosystems in the IHR (upper Kullu watershed in HP, Khul Gad Watershed in Almora and Mamlay Watershed in Sikkim). Volunteers were roped in this project from across the globe by Earthwatch Institute and so far 11 field programmes have been conducted. Volunteer's participation was efficiently utilized under the supervision of GBPIHED scientists and research staff in various lab/field R&D activities following the study modules developed by us. Marked plots in forests and Apple orchards were used for the repeated surveys to collect the long-term data set.

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CASE STUDY

S.S. Samant, A. Sharma, G.C.S. Negi[1], R.S. Rawal[1], S. Sharma[1],
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P. Mehta, & R. Saxena, *Earthwatch Institute, India*

These Volunteer Groups collected data on 650 plant species and phytosociologocal details in 5 forest communities (i.e., *Alnus nitida, Cedrus deodara, Pinus wallichiana, Picea smithiana* and *Pinus wallichiana–Cedrus deodara* mixed forest) (Fig. 4.20). They conducted household questionnaire surveys and PRA exercises to collected data on ecosystem services and collected information on medicinal plants (108 spp.), wild edibles (86 spp.), fuel wood (66 spp.), and fodder plants (71 spp.) and phenological monitoring in various apple orchards. In addition, 3 forest communities (i.e., *Alnus nitida, Cedrus deodara* and *Pinus roxburghii*) were studied for pollinators diversity. Scan Sampling revealed that maximum number of Butterflies, followed by Ants, Grasshoppers & Beetles (Fig. 4.21). In Nashala village 13 species of insect pollinators were recorded and maximum density of Syrphids and butterflies was observed. Similarly, in Bashkola and Raugi villages 12 species of insect pollinators were recorded and maximum density of wild bees and butterflies observed. In all the apple orchards amongst pollinators, Drone/Hobber flies, Indian Honey bees, European Honey bees and syrphids were found common visitors.

Thus it is evident from this case study that involvement of about 100 volunteers drawn from across the globe in the project activities helped us in first hand data collection which was otherwise difficult through the limited project team within the scheduled time. Therefore, involvement of volunteers should be encouraged in all R&D projects across the IHR. It would also help in creating interest of citizens towards science, ultimately promoting Citizen Science in the IHR as well as outside the region and help conservation goals.

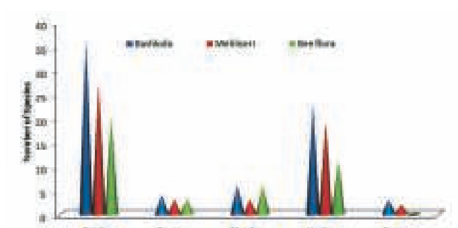

Fig. 4.20: Qualitative assessment of vegetation at Bashkola and Mehliseri orchards in Kullu valley, HP

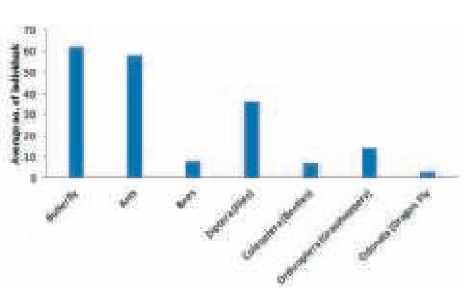

Fig. 4.21: Diversity of insects through Scan /Visual Sampling

SOCIETAL RELEVANCE OF R&D WORK ON LIVELIHOODS & CAPACITY BUILDING

ANNEXURE - IV

POLICY RELEVANCE

- Development of prototypes on environment friendly, low-cost and hill specific technologies for natural resource management (NRM), livelihood enhancement and employment generation at GBPIHED HQs.
- NE Unit of GBPIHED served as a single window for technology dissemination and up-gradation centre (Technology Hub) linked with local NGOs, which served as "Rural Technology Colleges", and further linked with local farmers and on-farm demonstration sites, which served as 'Farmer Schools'.
- Manuals developed in local language for effective dissemination of technology were utilized by several state Govt. agencies.
- Sikkim Unit played a key role in developing eco-tourism related policies in Sikkim and brought a policy change in alternative fuel (LPG/Kerosene) in place of firewood that tourists use during trekking. Substantial inputs were given in developing Tourism Master Plan for Sikkim State.
- Community based tourism (CBT) was developed as a new approach for biodiversity conservation along with tourism/ home stays in R&D project sites in north-east.
- Guidelines for promotion of Homestays in Arunanchal Pradesh and Arunanchal Pradesh Ecotourism policy were developed. Also ecotourism guidelines were prepared for NDBR in Uttarakhand.
- Integrated agro-horti-silvicultural model is adopted by Govt. of Arunachal Pradesh under CAMPA.

CONTRIBUTION TO TECHNOLOGY DEVELOPMENT

- Site - specific and stakeholders feedback based modifications in R&D based technologies in water management, irrigation, bio-composting were made that improved NRM.
- Demonstration trials on protected cultivation, organic farming, biofertlizer application, off-farm and other supporting technologies were maintained to show that additional income can be earned as compared to traditional methods of cultivation and livelihood options.
- Integrated agro-horti-silviculture model was developed as an alternative to conceptual Jhum cultivation in NE India. This model has been adopted under Compensatory Afforestation Fund Management Planning Authority (CAMPA) scheme of Govt. of Arunanchal Pradesh.
- Integrated fish farming with poultry using cattle shed dung for small holder farmers of Uttarakhand.
- Selection of novel microorganisms based on extensive laboratory and field screening and development of eco-friendly technology of bio fertilizer for improving growth and yield of important food crops and tree species.
- Improvement in soil fertility, soil and water conservation and crop yield through Lantana mulching and reduced tillage was demonstrated among the farmers fields in Almora district.

OUTREACH

- 459 training programmes conducted so far for capacity building of 19,312 persons (particularly women farmers) belonging to 18 different Govt. Line Depts./ NGOs, Army personnel, local people, students, etc.
- Technologies adopted by 547 households and earned Rs. 8214/ HH/yr due to improved farming and livelihood supporting practices.
- Up scaling of technologies back stopping in Assam, Manipur, Meghalaya, Mizoram and Tripura with the help of partner NGOs covering 8 districts, 12 Block, 49 villages and 11 tribal communities. Thus capacity of over 3670 tribal farmers through hands-on training on 15 low-cost environment-friendly technologies was built.
- 69 SHGs, 3 farmers club and 1 market committee was formed by the PNGOs. Over 1500 HH adopted 13 technologies for enhancing crop yield in Jhum cultivation of NE region.
- Sikkim ecotourism and biodiversity conservation project was implemented in partnership of the Mountain Institute, USA; Travel Agents Association of Sikkim. The Green Circle NGO and local people.
- Eco-tourism and conservation society of Sikkim was formed as an outcome of the project which is now a dedicated NGO to promote eco-tourism and biodiversity conservation.
- RS & GIS training to a range of stakeholders (Govt. officials, NGOs, etc.).

TRANSLATING RESEARCH INTO ACTION

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ACTION PLAN
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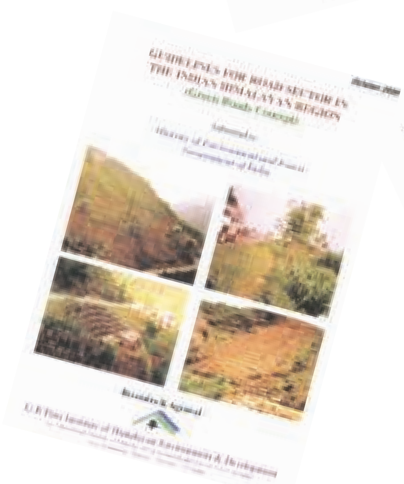
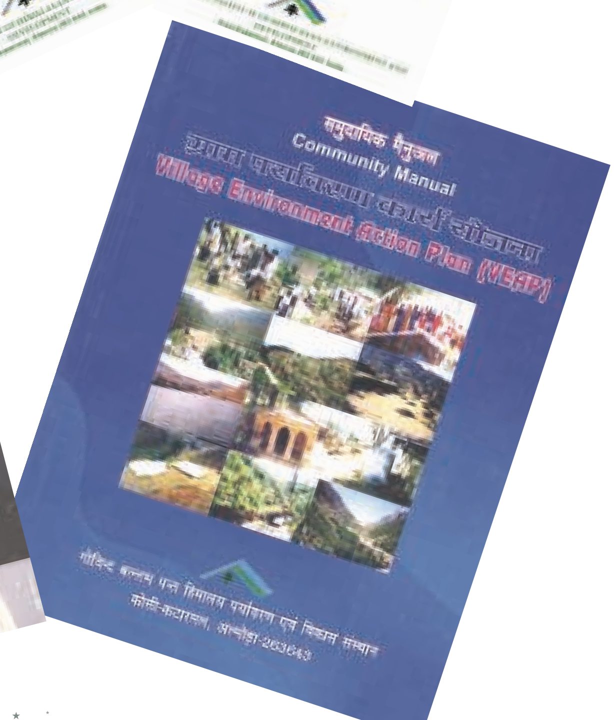
GBPIHED
Over the years


GUIDELINES FOR ROAD SECTOR IN
THE INDIAN HIMALAYAN REGION


RAIN WATER HARVESTING FOR
IRRIGATION AND DOMESTIC USE


FOR RESIDENTIAL BUILDINGS, TOURIST/
COMMERCIAL COMPLEXES IN HILL
TOWNS


Governance
G-SHE
for Sustaining
Himalayan Ecosystem
GUIDELINES & BEST PRACTICES


Community Manual
Village Environment Action Plan (VEAP)

Human Resource Development Over the Years at GBPIHED

One of the important outcomes of R&D work at GBPIHED is human resource development. A variety of stakeholders including researchers, project staff engaged in lab. and filed work, farmers, Govt. employees gain expertise in the process of their engagement with the R&D projects of the Institute. Research scholars drawn from across the country working under different R&D projects of the Institute are encouraged to pursue Ph.D. for which MoU were signed with various Regional/National Universities. So far, 100 Ph.D theses in different subjects have been produced by the Institute since its inception (Plate 1), and the alumni are placed in reputed national and international organizations (http://gbpihed.gov.in).

As an outcome of R&D work pursued by scientific and technical staff, since 1989, a total of 584 research papers have been published in impact factor journals and 576 research papers in non-impact factor journals (Plate 2). Also, 611 chapters and 667 popular articles have been published in various books, newsletters, bulletins and conference/workshop proceedings. The Institute faculty has authored/edited 56 books and 56 booklets and 5 monographs on different aspects. Further, 24 books have been written/compiled by the Institute staffs which have been published by the outer agencies. Electronic version of some of these books/booklets, monographs and regular publications such as Hima-Paryavaran, Himprabha (Hindi Magazine), ENVIS Newsletter/Bulletin on Himalayan Ecology are accessible through the institute website. Apart from a centralized IT lab. at GBPIHED HQs at Almora to provide internet services, the regional Units are connected through 512 kbps bandwidth through VSAT for video conferencing.

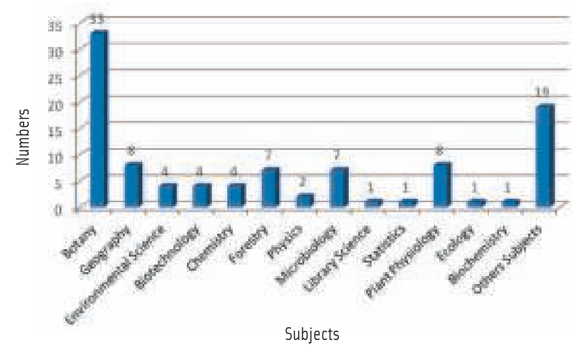


Plate 1. *Ph.D. thesis completed in various subjects at GBPIHED*

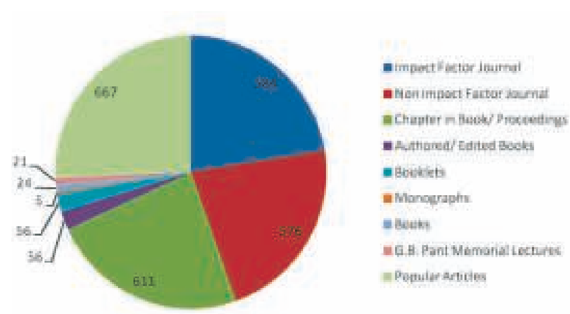


Plate 2. *Institute publications between 1989 and 2015.*

The core R&D activities of the Institute mainly run through in-house funding. But significant stride has been made by the GBPIHED scientists in generating external funding. So far, over 150 R&D projects with a total outlay of Rs. 17.21 crore funded by the National agencies, and 29 projects (with a total outlay of Rs. 89.7 lakh) funded by the International agencies have been successfully completed by the Institute faculty. Currently 61 such projects with a total outlay of Rs. 5.54 crore are on-going (Plate 3).

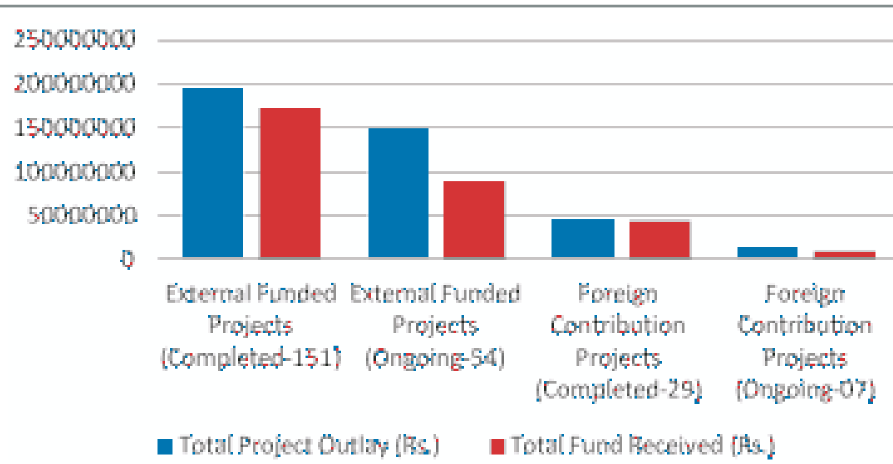


Plate 3. *Project funding pattern to GBPIHED by external agencies*

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GBPIHED, Almora]

Eight New Initiatives of GBPIHED

- *Initiative 1: Himalayan Research Fellowships*
- *Initiative 2: Himalayan Young Researchers' Forum*
- *Initiative 3: Himalayan Research Mentors' Forum*
- *Initiative 4: Himalayan Popular Lecture Series*
- *Initiative 5: Himalayan Peoples' Representatives Meet*
- *Initiative 6: Himalayan Students' Nature Awareness Campaign*
- *Initiative 7: Himalayan Farmers' Livelihoods Enhancement Drive*
- *Initiative 8: Mountains Environmental Policies Repository*

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