Biological resources and poverty alleviation in the Indian Himalayas

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Abstract. The Indian Himalaya is a vast landscape supporting a wide range of habitat diversity, from alpine meadows to tropical forests and cold deserts. Many plant species serve as important resources for the livelihood of local communities but in recent decades, over-exploitation of fuelwood, fodder, timber, food sources and medicinal plants has threatened their sustainable supply. For centuries, the sustainable use of biodiversity has been a well-proven tool for both biological conservation and the alleviation of poverty. This paper examines the use of wild biodiversity resources such as medicinal plants, edible orchids, rhododendrons and ethnobotanical knowledge packages for reducing poverty in the Indian Himalaya. It further compares biodiversity resources in the northwestern and northeastern parts of India, particularly the Himachal Pradesh and Sikkim states, with a wider interpretation for Himalaya as a whole. The two states are compared in their conservation approaches and use of resources. Various conservation approaches used by local people and/ or governments are examined for their long-term viability. Assessing populations of targeted species is essential before they should be used for reduction of poverty. A case study for one important local plant is the cultivation of Himalayan ginseng (Cordyceps sinensis) and the potential for this to be used for reducing poverty. The role of local communities in providing an essential component of conservation management and with the help of scientific institutions stakeholders can develop the capacity to create bioregion-based entrepreneurship that also meet broader conservation and poverty reduction objectives. The threat of climate change to the availability of biodiversity is discussed and a framework is presented for further action.

Key Words. Biodiversity, Himalayan biodiversity, medicinal plants, biological resources, livelihoods

INTRODUCTION

Himalayan ecosystems have provided biological resources and ecosystem services that have sustained the livelihood of local Himalayan people for centuries (Badola 2009a). Nature-based resources occur in wild and semi-wild areas, in a variety of forests and other habitats (Miller 1999). How these resources are used, whether in a sustainable or non-sustainable manner, not only varies with the people who use them and the nature and location of the bioresources themselves (Bandypadhyay and Parveen 2004, Pradhan and Badola 2008a), but also depends on the extent to which natural capital, which is the foundation on which all ecosystem services depend, varies with the people who use them and the nature and location of the bioresources themselves (Bandypadhyay and Parveen 2004, Pradhan and Badola 2008a).

The availability of resources however, depends to a great extent on the health and vitality of natural ecosystems, while as overharvesting and ecosystem degradation lead to a depletion of valuable resources and ecosystem services.

Horticulture, floriculture and other practices that enhance the cash value of biodiversity have recently become more predominant, alluring many more people in the Indian Himalaya to attempt entrepreneurial ventures that use local biocultural resources to improve their livelihoods (Badola and Aitken 2005; Badola 2009a). Non-timber forest products such as globalization and climate change have brought into question the sustainability of these resources and the services they provide.

The Indian Himalaya is part of Indo-Burma, one of the twenty-five biodiversity hotspots in the world (Myers et al. 2000), and further emerged as a new hot-spot in an expanded list of 34 biodiversity hotspots (Biodiversity International 2005; www.conservation.org accessed 18.7.2010). Yet despite this rich biological wealth, the Himalayan people are among the poorest in the world, primarily as a result of the difficult high altitude terrain they inhabit. This paper examines the use of wild biodiversity resources for poverty alleviation in the Indian Himalaya. It would be an adequate understanding and assessment of use-patterns and dynamics of Himalayan biocultural resources. Coupled with this is the need to be have a long-term strategy for integrated biodiversity conservation and sustainable use of biodiversity (Oli and Gupta 2008; Badola 2009a).

Statutory mechanisms are in place in the various Himalayan countries addressing their specific priorities for biodiversity conservation and sustainable use of biological resources. Encouragingly, India, developed a Biodiversity Act (2002) and Biodiversity Rules (2004), authorizing different states to formulate biodiversity rules to publicize the necessary regulations (Nepal and Weber 1995). Still, with strong legislation in place, it is much more important that a thorough and comprehensive assessment is made to prioritize their conservation and sustainable use, including community level entrepreneurial efforts to alleviate poverty in Himalaya. In this review, we have focused on some of the more important, under-exploited wild resources and their potential for alleviating poverty in the Himalayan people.

AREA OF STUDY

Himalachal Pradesh (H.P.), located in northwest India, has a unique physiography and a rich flora that ranges from deciduous mixed forests in the moutainous middle mountains, to scattered alpine and alpine meadows in the drier sites and luxuriant forests of tropical forests and cold deserts. Many plant species serve as important resources for the livelihood of local communities but in recent decades, over-exploitation of fuelwood, fodder, timber, food sources and medicinal plants has threatened their sustainable supply. For centuries, the sustainable use of biodiversity has been a well-proven tool for both biological conservation and the alleviation of poverty. This paper examines the use of wild biodiversity resources such as medicinal plants, edible orchids, rhododendrons and ethnobotanical knowledge packages for reducing poverty in the Indian Himalaya. It further compares biodiversity resources in the northwestern and northeastern parts of India, particularly the Himachal Pradesh and Sikkim states, with a wider interpretation for Himalaya as a whole. The two states are compared in their conservation approaches and use of resources. Various conservation approaches used by local people and/ or governments are examined for their long-term viability. Assessing populations of targeted species is essential before they should be used for reduction of poverty. A case study for one important local plant is the cultivation of Himalayan ginseng (Cordyceps sinensis) and the potential for this to be used for reducing poverty.

Studies on the cultivation of Himalayan ginseng (Cordyceps sinensis) began as early as 1984 (Verma and Pradhan 1984) and it was cultivated at various locations in Himachal Pradesh and Sikkim. It was noted that the cultivation of Cordyceps sinensis was a viable source of cash for community development and it could be used as an alternative source of livelihood (Verma and Pradhan 1998). The cultivation of this species was championed by Pratap Singh Chauhan, who initially worked in a village near Shimla. In his efforts to promote the cultivation of Cordyceps sinensis, Pratap Singh Chauhan identified several communities in Himachal Pradesh and Sikkim with traditional knowledge that intrinsically links them to the natural resources of the area (Pradhan and Badola 2008a). The strength of the rural inhabitants of Sikkim is the blinding of agriculture and cash crops supported by strong socio-political and environmentally-friendly governmental policies (Badola 2009a) such as a complete ban on green felling (no live tree cutting in the wild). Sikkim has a Biosphere Reserve (with a national park as the core-zone) and 7 wildlife sanctuaries comprising 46.93% of the geographical area of the state. Both states contain ecologically sensitive habitats, particularly due to the presence of specialized high-altitude niches. In recent decades, non-timber forest resources have been targeted by commercial ventures including medicinal plants, wild edibles, orchids, and bamboo as well as adventure tourism, all of which contrasts markedly with the traditional subsistence living of the local people. However, if properly managed, the rich biodiversity and relatively untapped potential of both states could offer many entrepreneurial opportunities to supplement the low incomes of the local people.

WILD BIOLOGICAL RESOURCES

Edible plants, high-value medicinal plants, ethnobotanical knowledge packages, orchids, rhododendrons, and bamboo are some of the wild biological resources that offer entrepreneurial opportunities in the Indian Himalaya. Well-timed initiatives and government policies addressing biodiversity conservation and promoting agro-based entrepreneurship may result in greater awareness in the general public and particularly in forward looking farmers with an eye for commercial ventures.

MEDICINAL PLANTS

Herbal medicines have a global market value of about US$ 43 billion a year (Christie 2001). Out of 1759 medicinal plant species in the Indian Himalaya (Samant et al. 1998), the Sikkim-Darjeeling hills contain 707 species and H.P. harbours 548 species. Examples of high market demand are:

• Aconitum napellus (Pashu/Bikhma - used in body-ache, fever, cold, cough, and nose discharge);
• Angelica gueu (Chora - used in constipation and vomiitng and as cardioactive, carminative and diaphoretic);
• Cordyceps sinensis (Keera-Jhar/Yar - used in making a drug for treating cancer;
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Key Words. Indian Himalaya, alpine meadows, medicinal plants, biological resources, livelihoods

INTRODUCTION

Himalayan ecosystems have provided biological resources and ecosystem services that have sustained the livelihood of local Himalayan people for centuries (Badola 2009a). Natural-resource-based activities are prevalent in wild and semi-wild areas, in a variety of forest types and other habitats (Miller 1999). How these resources are used, whether in a sustainable manner or not, varies with the people who use them and the nature and location of the biore sources themselves (Bandopadhyay and Parveen 2004, Pradhan and Badola 2008a). The availability of resources, however, depends to a great extent on the health and vitality of natural ecosystems, while as overharvesting and ecosystem degradation lead to a depleting value of resources and ecosystem services.

Horticulture, floriculture and other practices that enhance the value of biodiversity are being pursued more vigorously in the Indian Himalaya to attempt entrepreneurial ventures that use local biore sources to improve their livelihoods (Badola and Aitken 2005; Badola 2006). The local ecosystem is a large potential for globalizarion and climate change have brought into question the sustainability of these resources and the services they provide.

The Indian Himalaya is part of Indo-Burma, one of the twenty-five biodiversity hotspots in the world (Myers et al. 2000), and further emerged as a new hotspot in an expanded list of 34 biodiversity-hotspots (Biodiversity International 2007; www.conservation.org accessed: 18.7.2010). Yet despite this rich biological wealth, the Himalayan people are among the poorest in the world, partially as a result of the difficult high-altitude terrain they inhabit. Thus, it is important that a good basis for an evaluation of poverty alleviation in the Indian Himalaya would be an adequate understanding and assessment of use-patterns and dynamics of Himalayan biore sources. Coupled with this will be the requirement of land-use sustainable use and appropriate conservation planning of Himalayan biodiversity (Oli and Gupta 2008; Badola 2009a).

Statutory mechanisms are in place in the various Himalayan countries addressing the specific priorities for biodiversity conservation and sustainable use of biological resources. Encouragingly, India, developed a Biodiversity Act (2002) and Biodiversity Rules (2004), authorizing different states to formulate biodiversity bounds to publicize the necessary regulations (Nepal and Weber 1995). Still, with strong legislation in place, it is much more important for a thorough and forethought is made to prioritize their conservation and sustainable use, including community level enterprises to alleviate poverty in Himalayas. In this review, we have focused on some of the more important, under-exploited wild resources and their potential for alleviating poverty in the Himalayan people.

AREA OF STUDY

Himalach Pradesh (H.P.), located in northwest India, has a unique physiography and a rich flora that ranges from deciduous mixed forests in the mountains, to scattered alpine and meadow-type vegetation at higher altitudes. The region supports luxuriant forests of Pinus roxburghii and Abies nuda in drier sites and Quercus leucotrichophora, Rhododendron arborvorn, on moister slopes. (Curtisia semenopappina, Q. floribunda, and Pinus wallichiana forests are characteristic of the high altitudes; the timber-line and sub-alpine zones consist of Abies sp., Betula utilis, Rhododendron campanulatum, and Juniperus communis. Rich alpine meadows and grasslands are located above the tree line (~ 3600 m). Two national parks and 32 wildlife sanctuaries have been developed in H.P.

Sikkim, has a relatively small geographic area (7,096 km2) located in the northeastern Indian Himalaya and supporting a population of just over half a million. The world’s 3rd highest peak, Mt. Kanchendzonga (8,586 m), is located here along with rich natural resources. Over 80% of the people live in rural areas of Sikkim, the main ethnic groups consisting of Nepalese, Bhutia, Lepcha, Limbu and Sherpa. Lepchas are the local tribe of Sikkim and they have traditional knowledge that intricately links them to the natural resources of the area (Pradhan and Badola 2008a). The strength of the rural inhabitants of Sikkim is the blending of agriculture and cash crops supported by strong socio-political and environmentally-friendly governmental policies (Badola 2009a) such as a complete ban on green killing (no live tree cutting in the wild). Sikkim has a Biosphere Reserve (with a national park as the core-zone) and 7 wildlife sanctuaries comprising 46.93% of the geographical area of the state. Both states contain ecologically sensitive habitats, particularly due to the presence of specialized high-altitude niches. In recent decades, non-timber forest resources have been targeted by commercial ventures including medicinal plants, wild edibles, orchids, and bamboo as well as adventure tourism, all of which contrasts markedly with the traditional subsistence living of the local people. However, if properly managed, the rich biodiversity and relatively untapped potential of both states could offer many entrepreneurial opportunities to supplement the low incomes of the local people.

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- Acronemum philippinum (Pattish/Bikhma - used in body-ache, fever, cold, cough, and nose discharge);
- Angelica glauca (Chora - used in constipation and vomiting, and as cardiovascular, carminative and diaphoretic);
- Cordyceps sinensis (Keera-Jhun/Yar Tsangmura - used for immunologic, antineoplastic, antiarrhythmic, hypoglycemic and erythropoietic effects);
- Dactylorhiza incarnata (Kamar-bodo-ungri - used to treat dysentery, diarrhoea, chronic fever, cough, stomach-ache, wounds, cuts, burns, fractures, and general weakness);
- Nordracthiza jatamansi (Jatamansi - used in cases of high blood pressure, heart disease and insomnia, and as a tonic and stimulant);
- Picrocita furrowo (Kakhi, Kava - used for fever and cough); Panax pseudoginseng (Ginseng - used in treating wounds, soft tissue injuries, and bleeding cases such as haematuria, haematemesis, uterine bleeding, and coronary heart disease);
- Podophyllum hexandrum (Bankioki - used in making a drug for treating cancer;
Swertia chirayita (Chirayita - used for fever, cough, diarhoea, stomach-ache, etc., and Tatas baccata (Rakhal Dhungre-salla - used in making drugs for cancer treatments, etc.

In addition, there is high market demand for Swertia chirayita, a critically endangered and globally marketed herb. This wild genetic resource has potential, in terms of length and success of seed viability under storage, for cultivation in Sikkim, thereby providing a means of avoiding over-harvesting in the wild and promoting the conservation of the species (Pradhan and Badola 2008b). Hedychium spicatum is traditionally used in indigenous medical practice and in Tibetan medicine. Its rhizome contains an ingredient used in the preparation of an anticancer drug, PADMA-28, and offers great potential for local entrepreneurship in both regions (Badola 2009b). Similarly, Picrorhiza kurrooa has a high international market demand. Marginal land farmers in high altitude regions in the northwest and northeast can earn a lucrative income through cultivation of this species. Innovative agro-practices with Heracleum candicans and Dactylorhiza hatagirea domestication have provided good economic returns in H.P. as shown by scientific demonstrations in farmers' fields (Badola and Butola 2005; Butola and Badola 2006). Ten high-value threatened taxa were successfully adopted by over five dozen households for ex-situ cultivation in H.P., though commercial cultivation is yet to come (Badola and Butola 2004). Community-based cultivation entrepreneurship need further support to develop their full potential.

Yar Tsagumba (Corydendron sitaxnotum) is a fungus parasite that feeds on moth larvae of the genus Thitarodes and is considered to be an aphrodisiac. It is found in alpine and sub-alpine zones (3,000-4,200 m asl) in the north-east India, amongst other locations. It is one of the top globally marketed species with prices at an average rate of 60 to 100,000 Indian Rupees ($130-210 USD) per kg. Saussurea costus (Kuth), an endangered plant listed under the Convention on International Trade in Endangered Species (CITES), has been under community-based local cultivation for over 40 years in the high Himalayas of Lahaul (H.P.). It is grown at 2500-3500m asl, and farmers have developed strong cooperative-based marketing systems (Badola and Pokhiyal 2001). Also, local cultivation has taken place for other high value endangered medicinal species, Inula racemosa (Mama) and Bantum periculum (Kala zira), the former, has been successful in the Lahaul area, and the latter in Kinnaur district of H.P (Badola and Pokhiyal 2001).

Species that have potential for successful local entrepreneurship include Saussurea costus which has good market demand (Badola and Pal 2002) and cultivation demonstrations have been successfully established both in Parvati valley H.P. (Badola and Butola 2004) and Sikkim (Badola; unpublished). Expanding the commercial cultivation of S. costus could provide great economic gain for native people in high altitude and Himalayan cold desert zones. Better conservation planning may contribute to the commercial opportunities for poor people of the Himalaya.

Several other taxa with high entrepreneurship potential (Table 1) can be introduced for ex-situ cultivation in Himalayan terrains. However, propagation and cultivation prospects may be constrained as shown in some studies (Butola and Badola 2008).
Swertia chirayita (Chirayita - used for fever, cough, diarrhoea, stomach-ache, etc.), and Taxus baccata (Rakhal Dhungre-salla - used in making drugs for cancer treatments, etc.).

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Similarly, Picrorhiza kurrooa has a high international market demand. Marginal land farmers in high altitude regions in the northwest and northeast can earn a lucrative income through cultivation of this species. Innovative agro-practices with Hura canariensis and Dactyloctenium aegrotere domestication have provided good economic returns in HP as shown by scientific demonstrations in farmers' fields (Badola and Butola 2005; Butola and Badola 2006). Ten high-value threatened taxa were successfully adopted by over five dozen households for ex situ cultivation in HP, though commercial cultivation is yet to come (Badola and Butola 2004). Community-based cultivation enterprises need further support to develop their full potential.

Yar Tagumba (Cordeya sinensis) is a fungus parasite that feeds on moth larvae of the genus Thitarodes and is considered to be an aphrodisiac. It is found in alpine and sub-alpine zones (3,000-4,200 m asl) in north-east India, amongst other locations. It is one of the top globally marketed species with prices at an average rate of 60 to 100,000 Indian Rupees ($130-210 USD) per kg. Saussurea costus (Kuth), an endangered plant listed under the Convention on International Trade in Endangered Species (CITES), has been under community based local cultivation for over 40 years in the high Himalayas of Lahaul (H.P.). It is grown at 2500-3500 m asl, and farmers have developed strong cooperative-based marketing systems (Badola and Pokhriyal 2001). Also, local cultivation has taken place for other high value endangered medicinal species, Inula racemosa (Manu) and Bumium pericium (Kala zira), the former, has been successful in the Lahaul area, and the latter in Kinnaur district of HP (Badola and Pokhriyal 2001).

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Table 1. Medicinal plants with potential for entrepreneurship, including their prior origin in mountain areas, major uses in each hold, the Table shows the approximate market potential for cultivation in Sikkim and HP (Pradhan and Badola 2008a).

- **Species**: Name of the plant
- **Conservation status**: Status of the species as per IUCN
- **Marketing potential**: Current market potential
- **Potential altitude**: Potential altitude for cultivation
- **Use in Tibetan medicine**: Uses in Tibetan medicine
- **Cultivation opportunities**: Opportunities for cultivation
- **Innovative agro-practices**: Innovative agro-practices for cultivation
ETHNOBIOLOGICAL RESOURCES

Indian tribal populations in rural Himalayan areas possess vast ethnobotanical knowledge (Pradhan and Badola 2008a). Over 7500 species are used by Indian tribal communities in primary health care, often as much as 50% of the plant species of a given ecosystem (Badola and Aitken 2003). Ethnic use of biodiversity and industrial sub-sectors are highly related ventures. It is important to understand the diversity of practices among communities inhabiting similar agro-climatic and cultural settings in such regions as the Indian Himalayas and to ensure that Access and Benefit Sharing (ABS) practices are maintained for local communities (Pradhan and Badola 2006a; Uneyal et al. 2006).

The Lepcha tribe of Dzongri in Khangchendzonga Biosphere Reserve-Sikkim uses over 116 ethnobotanical plant species to treat 66 ailments under 14 broad categories (Figure 1). Pandanus nepalensis in the north-east is another taxon that exhibits multiple utility (Badola et al. 2009). Such examples offer many opportunities for poor people of the region if standardized ex-situ cultivation protocols are practiced. The under-exploited potential of individual taxa coupled with ethnobotanical knowledge can lead to socio-economic gains for the local people. However, this ethnobotanical knowledge, resting largely with the older generations, is in need of documentation and protection before it is lost.

WILD EDIBLES – AN UNTAPPED RESOURCE

Traditionally, wild edibles are used as supplementary foods in Himalaya (Sundriyal and Sundriyal 2003; Badola 2010a). However, marketing wild edibles can provide an economic boost for the local people - as shown by the commercial success in the north-east. In Sikkim, natives consume over 190 wild plant species and about 43 are sold in the market on a periodic basis. Most wild edibles are locally marketed but under-exploited from an entrepreneurial point of view since existing markets are very local in nature. One of the few species undergoing greater marketing is the fruit Spindora auxillaries (Lapsi), eaten raw or for making pickles, especially in Sikkim (Rai and Badola 2009).

Pandanus nepalensis (Tapri), highly under-exploited, offers great commercial potential for making quality jam/jelly juices (Badola et al. 2009). In both the north-east and north-west Himalaya, Diplazium esculentum (Lingra/Ningra) an edible fern, is harvested and sold in local markets both as a vegetable and a spiced pickle. Large-scale entrepreneurship awaits this product if sustainable cultivation can be developed (Badola 2010a). Other potentially marketable wild edibles commonly available throughout the entire Indian Himalaya include, Alium spp. (Jambu), Phytolacca acmocarpa (Buraka/Ioringo), Rheum australe (Chuchi/Padamchali), Ranner nepalensis (Halhalu), and Urtica sp. (Bichu ghas/Nettle). Species such as Hippophae rhamnoides (Dorchuk or Sea Buckthorn), Rubus ellipticas (Bishua/Ache/Asula or Himalayan Raspberry), and Prunus armeniaca (Jangba/Aptici) have demonstrated successful development of secondary marketing in central Himalaya (Maikuri et al. 2004). Ficus rhuphurghi (Nihra) is a multipurpose fruit tree in Himalaya, often ignored for its commercial scope. It has been confined to village-level uses and marketing, as is Myrica esculenta (Khapha) (Dhyan and Dhar 1994). M. esculenta, an evergreen tree, found in both Sikkim and H.P. at altitudes of 1500-2300m, produces one of the favourite wild fruits of native people in Himalaya. It is relished for its juicy red flesh (with a rough stone inside) and either eaten raw or used in making juice. The bark is aromatic and medicinally used. For the majority of these wild edibles, domestication, breeding and technological interventions are required to maintain the nutritional content and create a viable business venture that will be successful in alleviating poverty in the local communities.

RHODODENDRONS - UNDEREXPLOITED IN INDIAN HIMALAYA

The vast majority of the 960 species of rhododendrons in the world are distributed in South East Asia. Out of 72 rhododendron species in India, the north-east region is the richest reservoir, represented by 61 species in Attacalch Pradeeh and 36 in Sikkim, H.P. and the State of Jammu and Kashmir (the most western part of the Indian Himalaya) are restricted to only 5 species each, are a great indicator of forest health and ecological stability (Badola 2010a). However, due to high levels of pheno1 and flavonoid compounds, rhododendrons are often used as fuel-wood, one of the biggest threats to Himalayan rhododendron species in recent decades.

Rhododendrons have a wide variety of uses that can be developed commercially. The flower extract of Rhododendron arboreum has been successfully used for making squash and wine in both H.P. and Sikkim (Badola 1992; 2010a). Developed into in-situ manipulation, these rhododendrons can aid in reducing harvesting pressure, this usage shows great potential for community entrepreneurship. Rhododendron domestication for show gardens has been successfully exhibited in Sikkim, Meghalaya and Nepal, but this is yet to be commercialized. Some rhododendrons also offer great possibilities as a resource for perfumery and cosmetics (Pradhan and Lachungpa 1990; R. setonum and R. maddi11ii (in north-east), and R. anthopogon in the entire Himalayan belt are potential taxa for this usage. In religious ceremonies, the leaves of R. anthopogon are traditionally used as incense. In Bhutan, bowls made from rhododendron wood have become a tourist attraction. Rhododendron hybrids using Himalayan species have become famous worldwide (see Mainra et al. 2010b) but, ironically, in the Indian Himalaya, such commercial practices have yet to be actualized.

Himalayan temperate forests and alpine meadows studded with blooming rhododendrons are a great attraction to visitors, boosting local tourism and helping to raise seasonal income for native people. The Government of Sikkim, in its “Year of Tourism 2010”, organized an International Festival and also an International Conference on Rhododendrons (Mainra et al. 2010) aimed at strengthening this untapped sector. Even in the north-west (H.P.), where a limited number of rhododendron species are found, rhododendron-trails may offer fascinating packages to adventure/nature organizations. High altitude protected areas in H.P. and Sikkim attract thousands of nature tourists each year, relishing beautiful rhododendron landscapes (Badola 1998; Badola and Pradhan 2009). Local villagers earn money by acting as guides, porters, food suppliers, etc.

Rhododendron resources sustainably managed and developed commercially have the potential to contribute to the alleviation of poverty in the communities inhabiting these areas. However, assessment of the availability of wild rhododendrons through study of population dynamics and other aspects is essential (Badola and Pradhan 2010).

ORCHIDS

Orchids are represented by an estimated 19,500 species worldwide with 750 genera. Approximately 1200 species are found in India (Lucksom 2007). Sikkim is one of the richest hot-spots for orchid diversity with 523 species, in Indian Himalaya (see Figure 2); whereas, comparatively, there are about 244 orchid species in Trans, north-west and west Himalayan regions (Lucksom 2007). Categorized as an endangered group, due to environmental degradation and habitat depletion, orchids have proven to be highly vulnerable to climate change (Lucksom 2007). India is a signatory to CITES under which the orchid trade is regulated and the Wild Life Protection Act (1972), with an amendment in 1992, placed orchids under Schedule VI, which contains a list of plants with legislated protection by the government. However, there is still an illegal orchid trade in the north-east. Mao (2006) reported the illegal trade of an endangered medicinal orchid, Dendrobium nobile, in Mizoram where plants were sold at the meager price of 1000 to 3000 Indian rupees per kg ($22–65 USD). In Manipur,
Ficus roxhburghii, an underexploited multipurpose fruit tree. (photo © H.K. Badola)

Traditionally, wild edibles are used as supplementary foods to treat 66 ailments under 14 broad categories (Badola et al. 2009). Other potentially marketable wild edibles commonly available throughout the entire Indian Himalaya include, Allium spp. (Jambu), Phyllocactus acinosa (Burka’s Joringo), Rheum australe (Chuchi/Padamchali), Ramer nepalensis (Hathale), and Urtica sp. (Bichu ghas/Nettle). Species such as Hippophae rhomoides (Dorckh or Sea Buckthorn), Rubus ellipticus (Hishalu/Achche/Aselu or Himalayan Raspberry), and Pruna armeniaca (Jangbi- Badamu/Apricot) have demonstrated successful development of secondary marketing in central Himalaya (Makari et al. 2004). Ficus roxhuburgii (Nihra) is a multipurpose fruit tree in Himalaya, often ignored for its commercial scope. It has been confined to village-level uses and marketing, as is Myrica esculenta (Kaphali) (Dhyani and Dhar 1994). M. esculenta, an evergreen tree, found in both Sikkim and H.P. at altitudes of 1500-2300m, produces one of the favourite wild fruits of native people in Himalaya. It is relished for its juicy red flesh (with a rough stone inside) and either eaten raw or used in making juice. The bark is aromatic and medicinally used. For the majority of these wild edibles, domestication, breeding and technological interventions are recommended to maintain the nutritional content and create a viable business venture that will be successful in alleviating poverty in the local communities.

RHODODENDRONS - UNEXPLOITED IN INDIAN HIMALAYA

The vast majority of the 960 species of rhododendrons in the world are distributed in South East Asia. Out of 72 rhododendron species in India, the north-east region is the richest reservoir, represented by 61 species in Arunachal Pradesh and 36 in Sikkim. H.P. and the State of Jammu and Kashmir (the most western part of the Indian Himalaya) are restricted to only 5 species each. Rhododendrons are a great indicator of forest health and ecological stability (Badola 2010b). However, due to high levels of phenol and flavonoid compounds, rhododendrons are often used as fuel-wood, one of the biggest threats to Himalayan rhododendron species in recent decades.

Rhododendrons have a wide variety of uses that can be developed commercially. The flower extract of Rhododendron arboreum has been successfully used for making squash and wine in both H.P. and Sikkim (Badola 1992, 2010b). A hybrid of Rhododendron arboreum has been successfully hybridized for show gardens and has been commercially exhibited in Sikkim, Meghalaya, and Nepal, but this is yet to be commercialized. Some rhododendrons also offer great possibilities as a resource for perfumery and cosmetics (Pradhan and Lachungpa 1990). R. setom et and R. maddeniai (in north-east) and R. anthopogon in the entire Himalayan belt are potential taxa for this usage. In religious ceremonies, the leaves of R. anthopogon are traditionally used as incense. In Bhutan, bowls made from rhododendron wood have become a tourist attraction. Rhododendron hybrids using Himalayan species have become famous worldwide (see Mainra et al. 2010) but, ironically, in the Indian Himalaya, such commercial practices have yet to be actualized.

Himalayan temperate forests and alpine meadows studded with blooming rhododendrons are a great attraction to visitors, boosting local tourism and helping to raise seasonal income for native people. The Government of Sikkim, in its “Year of Tourism 2010”, organized an International Festival and also an International Conference on Rhododendrons (Mainra et al. 2010) aimed at strengthening this unexploited sector. Even in the north-west (H.P.), where a limited number of rhododendron species are found, rhododendron-trails may offer fascinating packages to adventure/nature organizations. High altitude protected areas in H.P. and Sikkim attract thousands of nature tourists each year. Beautiful rhododendron landscapes (Badola 1998, Badola and Pradhan 2009). Local villagers earn money by acting as guides, porters, food suppliers, etc.

Rhododendron resources sustainably managed and developed commercially have the potential to contribute to the alleviation of poverty in the communities inhabiting these areas. However, assessment of the availability of wild rhododendrons through study of population dynamics and other aspects is essential (Badola and Pradhan 2010).

ORNCHIDS

Orchids are represented by an estimated 19,500 species worldwide with 750 genera. Approximately 1200 species are found in India (Lucksom 2007). Sikkim is one of the richest hot-spots for orchid diversity with 523 species, in Indian Himalaya (see Figure 2); whereas, comparatively, there are about 244 orchid species in Trans, north-west and west Himalayan regions (Lucksom 2007). Categorized as an endangered group, due to environmental degradation and habitat depletion, orchids have proven to be highly vulnerable to climate change (Lucksom 2007). India is a signatory to CITES under which the orchid trade is regulated and the Wild Life Protection Act (1972), with an amendment in 1992, placed orchids under Schedule VI, which contains a list of plants with legislated protection by the government. However, there is still an illegal orchid trade in the north-east. Mao (2006) reported the illegal trade of an endangered medicinal orchid, Dendrobium nobile, in Mizoram where plants were sold at the meager price of 1000 to 3000 Indian rupees per kg ($22-65 USD). In Manipur, domestication for show gardens has been successfully exhibited in Sikkim, Meghalaya and Nepal, but this is yet to be commercialized. Some rhododendrons also offer great possibilities as a resource for perfumery and cosmetics (Pradhan and Lachungpa 1990); R. setom et and R. maddeniai (in north-east) and R. anthopogon in the entire Himalayan belt are potential taxa for this usage. In religious ceremonies, the leaves of R. anthopogon are traditionally used as incense. In Bhutan, bowls made from rhododendron wood have become a tourist attraction. Rhododendron hybrids using Himalayan species have become famous worldwide (see Mainra et al. 2010) but, ironically, in the Indian Himalaya, such commercial practices have yet to be actualized.
Figure 2. Number of orchid species in relation to geographical area of respective states in north-east Indian Himalaya

Figure 3. Current and projected trend of deforestation in western Himalaya (combined: J&K, HP and Uttarakhand) and Eastern Himalaya (combined: Arunachal Pradesh and Sikkim) of India, as per data from Satellite (Si) and the India Agriculture Statistics (iAS) summary (Pandit et al. 2007).

Biodiversity Loss

Several factors threaten biodiversity in this region. These include unsustainable resource use, habitat loss and fragmentation, an increasing human population, land-use change, global marketing of natural resources, and natural disasters (Badola 2009a). The mountains are prone to excessive harvesting of forest bioresources, and cutting for fodder, fuelwood and timber. The western and eastern regions of Indian Himalaya are projected to experience huge forest degradation over this century (Figure 3) thus possibly resulting in the extinction of a wide range of taxonomic groups. The dense forests, with >40% canopy cover, could be reduced to 10% of land area in Indian Himalaya, leading to extinction of about a quarter of endemic species, including 36 endemic vascular plants and 35 endemic vertebrate taxa (Pandit et al. 2007).

Unsustainable harvesting of bioresources to meet market demand is threatening numerous species including orchids and rhododendrons. Threatened groups include endemic Himalayan medicinal plants (Butola and Badola 2008) such as Aconitum for a (Sikkim Himalaya), A. deinorrhizum (Himalaya), Angelica glanca (Indian Himalaya), A. tubifera (Sikkim), Coptis teeta and Panax pseudo-ginseng (eastern Himalaya), P. harrou (Himalaya), and Podophyllum emodi var. axillaris (Sikkim). Cases of illegal insect and butterfly collection, natural pollinators of the flora, have been recorded to extinction of about a quarter of endemic species, including 36 endemic vascular plants and 35 endemic vertebrate taxa (Pandit et al. 2007).

Domestication and horticulture for orchids is extensively encouraged at the policy level, specifically in the north-eastern Himalaya of India. The large tribal population possesses traditional knowledge of orchids, using them in medicine, religion and cultural practices (Butola and Badola 2006; Mao 2006). Several orchids from this region, especially Sikkim, are treasured as beautiful ornamentals and contribute to commercial hybrids, such as Dactylorhiza hatagirea, which is traded on the international market (Butola and Pal 2002), showed a quick increase in selling rate for dry tubers between 1999 and 2002 (Butola and Badola 2006).

Common approaches for promoting orchid commercialization amongst the north-east states and with neighbouring countries in the eastern fringe of South East Asia would be beneficial (Lucksm 2007). The government has recently provided policy support to growers and horticulturists in Sikkim; and in H.P., successful cultivation demonstrations of Dactylorhiza hatagirea have proven lucrative for growers (Indian Rupees 250,000 - 350,000 hectare). These returns far exceed revenues from wild harvesting (Butola and Badola 2006). Scientific guidelines and incentives for adopting orchid cultivation would help motivate people to take up orchid crops as a source of income.

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Climate Change and Biodiversity Loss

Ecosystems in the Indian Himalaya are exhibiting climate change impacts such as a lengthened growing season for plants, species loss, altered crop cycles and enhanced susceptibility towards disease and pests. Alterations in adaptability mechanisms and biological cycles in species are subtle processes, adversely influencing the availability of genetic resources, particularly in the case of endemic and high value threatened taxa. Global warming can influence the distributional range of living organisms as well (Walthier et al. 2002). Himalayan ecosystems exhibit diverse micro-habitats and rich biodiversity with a wide range of climatically varied zones within short distances due to altitude differences (Xu and Wilkes 2004). The balance in these micro-habitats can shift dramatically due to increases in ambient temperature associated with global warming.

There are many predicted species extinctions due to climate change in mountain environments (Schwartz et al. 2006). The upward movement of the tree-line and intrusion of woody communities in alpine meadows has been widely reported (Eriksson et al. 2009). Insects are highly sensitive to temperate fluctuations and many insect infestations in high altitude herbs have been reported. Heracleum candelaris, a high-value
Biodiversity loss

Several factors threaten biodiversity in this region. These include unsustainable resource use, habitat loss and fragmentations, an increasing human population, land-use change, global marketing of natural resources, and natural disasters (Badola 2009a). The mountains are prone to excessive harvesting of forest bioresources, and cutting for fodder, fuelwood and timber. The western and eastern regions of Indian Himalaya are projected to experience huge forest degradation over this century. This thus possibly resulting in the extinction of a wide range of taxonomic groups. The dense forests, with >40% canopy cover, could be reduced to 10% of land area in Indian Himalaya, leading to extinction of about a quarter of endemic species, including 366 endemic vascular plants and 35 endemic vertebrate taxa (Pandit et al. 2007).

Unsustainable harvesting of bioresources to meet market demand is threatening numerous species including orchids and rhododendrons. Threatened groups include endemic Himalayan medicinal plants (Butola and Badola 2008) such as Aconitum ferox (Sikkim Himalaya), A. deinorrhizum (Himalaya), Angelica graveolens (Indian Himalaya), A. nubigena (Sikkim), Coptis teeta and Panax pseudo-ginseng (eastern Himalaya), and Podophyllum emodi var. alpinum (Sikkim). Cases of illegal insect and butterfly collection, natural pollinators of the flora, have been recorded in Sikkim. Understanding the complexity of factors leading to species endangerment is crucial to the development of conservation strategies.

Climate change and biodiversity loss

Ecosystems in the Indian Himalaya are exhibiting climate change impacts such as a lengthened growing season for plants, species loss, altered crop cycles and enhanced susceptibility towards disease and pests. Alterations in adaptability mechanisms and biological cycles in species are subtle processes, adversely influencing the availability of genetic resources, particularly in the case of endemic and high value threatened taxa. Global warming can influence the distributional range of living organisms as well (Walther et al. 2002). Himalayan ecosystems exhibit diverse micro-habitats and rich biodiversity with a wide range of climatically varied zones within short distances due to altitude differences (Xu and Wilkes 2004). The balance in these micro-habitats can shift dramatically due to increases in ambient temperature associated with global warming.

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Domestication and horticulture for orchids is extensively encouraged at the policy level, specifically in the north-eastern Himalaya of India. The large tribal population possesses traditional knowledge of orchids, using them in medicine, religion and cultural practices (Butola and Badola 2006; Mao 2006). Several orchids from this region, especially Sikkim, are treasured as beautiful ornamentals and contribute to commercial hybrids, such as Phalaenopsis amabilis, P. villosa, P. venusta, A. multiflora, P. cintuera, V. teres, Rhyynchostylis renata, Pleione maculata, P. humilis, Cymbidium davidiunum, C. gigantum, Dendrobium aphyllum, D. densiflorum, and D. thrysiflorum. The orchid-floriculture industry has great potential to improve the livelihoods of impoverished people, particularly in Sikkim.

Common approaches for promoting orchid commercialization amongst the north-east states and with neighbouring countries in the eastern fringe of South East Asia would be beneficial (Lucksom 2007). The government has recently provided policy support to growers and horticulturists in Sikkim; and in H.P., successful cultivation demonstrations of Dactylorhiza hatagirea have proven lucrative for growers (Indian Rupees 250,000-350,000/ha). These returns far exceed revenues from wild harvesting (Butola and Badola 2006). Scientific guidelines and incentives for adopting orchid cultivation would help motivate people to take up orchid crops as a source of income.
commercial herb in H.P. has been subject to these effects, compromising crop productivity (Badola and Butola 2005).

**CONSERVATION STRATEGIES AND LIVELIHOODS**

For the conservation and sustainable use of biodiversity, it is necessary to understand and assess the species and genetic composition on the ecosystem and landscape level. The evaluation of raw material availability, population dynamics, use feasibility, mass multiplication potential and quality assessment of the chosen species is crucial for successful use. Also, insight into the nature of threats towards species is necessary to formulate conservation and use strategies. These strategies may decide the availability of biodiversity resources to support the livelihoods of local people now and into the future.

**BIODIVERSITY CONSERVATION USING TRADITIONAL PRACTICES**

The sacredness of landscapes is a basic traditional ethos in the community-governed resource management widespread in Indian Himalaya for generations (Ramakrishnan 2007). The ‘landscape as sacred’ concept as practiced by the Lepcha tribe of Sikkim (Pradhan and Badola 2008a; Badola and Pradhan 2008b). The Lepcha people and the potential for cultural and environmental tourism packages to boost the rural economy. Also, ethnomedicinal practices by the Lepcha tribe using medicinal plants are an age-old tradition. Similar traditional practices are present in Chhotia Bungal, H.P. (Uniyal et al. 2006). Traditional conservation practices by the Bhutia tribe of Lachen and Lachung valleys of Sikkim maintain the community’s socio-cultural identity and conserve biodiversity through self-governance with law or ‘Zumsa’ administered through an elected head or ‘pipon’ (Rai 2007).

In north Sikkim, over 35 sacred groves conserve rich biodiversity - the largest, Kabbi grove, holds over 210 flowering plant species of multiple utility (Das 2005). Community woodlands in Mizoram (north-east) are subjected only to regulated harvesting (Ramakrishnan 1996). Integration of scientific and traditional knowledge can allow for conservation and sustainable resource use, along with better economic opportunities for marginalized peoples.

**EX-SITU CONSERVATION PRACTICES**

Protected areas in their present management context raise questions about their ability to provide for biodiversity conservation and resource sustainability. In addition to outright banning the harvesting of biodiversity resources, a periodic assessment of bioresource availability and quality potential is needed. The use of high-value, but endangered, genetic material for mass multiplication and farming in adjacent transition zones with community participation is essential for both poverty alleviation in local populations as well as for in-situ conservation of species.

**IN-SITU CONSERVATION PRACTICES**

The availability of standardized propagation packages is vital in establishing commercial cultivation of high value species. The propagation packages for many high-value threatened medicinal plants from north-west (Butola and Badola 2008) and north-east Himalaya (Pradhan and Badola, 2010) are available. Establishment of technical demonstrations of targeted taxa at various agronomic sites can also provide useful information for ex-situ cultivation (Butola and Badola 2006). Since seeds from different sources may differ in viability, assessing the effect of storage periods on germination, especially for seeds kept for next growing season, is helpful in predicting potential populations and therefore useful for long-term cultivation planning (Pradhan and Badola 2008b). Aconitum heterophyllum, Dactylorhiza karrum, Pierocypea karrum, Pedicellaria luzubum, and Saussuresa costus are medicinal plants found in both regions with commercial potential for ex-situ cultivation. Angelica glauca and Harecium candidum also have potential in the north-west, and A. ferox and Swertia chirimol in the north-east Himalaya.

For successful ex-situ cultivation of wild bioresources, community participation from both genders is imperative (Palni 1997). Also, knowledge of climate-driven adaptive mechanisms of plants is essential (Badola and Aftab 2003). Experiments to ascertain optimum conditions are vital to attain high crop productivity (Badola and Butola 2005). Whether the resource is a medicinal plant or other crop, a successful economic venture is possible by following internationally recommended criteria (Badola and Pal 2002), particularly in the case of high-value endangered taxa. These criteria include: (i) endangered status (conservation protection); (ii) existing knowledge (availability in nature, propagation and multiplication, cultivation trials); (iii) cultivation prospects (technical feasibility, economic viability, farmers’ acceptability), and (iv) marketing status (national and international levels). It is vitally important to understand issues like traceability to source planting material, back-rack, linkages with pharmaceuticals and other consumer establishments for raw material, technical status of cropping and primary processing of raw produce to ensure viability of commercial cultivation (Badola and Pal 2002). Additionally, it is imperative for locally established institutions and experts to provide scientific monitoring and guidelines for agro- and conservation practices of targeted taxa.

**CONCLUSIONS**

The challenge of using biodiversity as a resource in poverty alleviation is to consider each species as an important component of a sensitive and complex environment. Under the current situation of over-harvesting and climate change, many high-value genetic resources are in a fragmented state. Their protection through a complete ban in protected areas is no assurance of retaining them in the long-term. It is necessary to develop sustainable strategies with short-term goals and long-term planning to multiply the resources and conserve the source gene bank in the wilderness.

The qualitative and quantitative assessment of biological resources is a prerequisite for commercial use. The sustainable use and conservation of bioresources requires expertise from multidisciplinary institutions at the local (Vel et al. 2003) and/or international level (Badola and Pal 2002). Both the immediate needs and the long-term prospects will help determine the strategy for the particular bioresource under study. Assessing populations of targeted species is essential before they should be used as resources (Badola and Pradhan 2010). The cultivation of high-market-value taxa is the ideal choice coupled with local entrepreneurship.

On the landscape level, identification and prioritization of ideal eco-tourism zones and assessment of their carrying capacities is useful for framing long-term natural resource management and socio-economic development (Kunyal et al. 2004). It is ideal to have strong cooperation amongst stakeholders, accredited by feasible political and economic actions. The immediate need is to accelerate time-bound partnerships between mountain states to strengthen scientific/technological mechanisms for the multiplication and conservation of bioresources, with common priorities and common approaches.

The role of civil society should be integrated as an essential component of conservation management. Simultaneously, inter-cultural dialogues amongst stakeholders, including governments of similar states in Himalayan region, are important (Eriksson et al. 2009). Communities and local NGOs need scientific training and education, to tackle the local problems and undertake resource management themselves. Such collaborations have effectively emerged in Himalaya through civil society involvement in the formation of committees for joint forest management, eco-development, and forest conservation.

Scientific institutions may assist in the development of capacity building in different stakeholders, thereby allowing them to take up bioresource-based entrepreneurship and conserve biodiversity. A framework for immediate action and possible cooperation amongst stakeholders in the Indian Himalayan region is suggested in Figure 4. The initiatives, recommendations and methodologies suggested presented in this review can be used to frame broader policy implementation to allow for the sustainable use of biodiversity to alleviate poverty in the Indian Himalaya.

**ACKNOWLEDGMENTS**

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Figure 4: A framework for action and cooperation amongst stakeholders to address the sustainable use of biodiversity for poverty alleviation in the Indian Himalaya.
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**CONSERVATION STRATEGIES AND LIVELIHOODS**

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Protected areas in their present management context raise questions about their ability to provide for biodiversity conservation and resource sustainability. In addition to outright banning the harvesting of biodiversity resources, a periodic assessment of bioresource availability and quality potential is needed. The use of high-value, but endangered, genetic material for mass multiplication and farming in adjacent transition zones with community participation is essential for both poverty alleviation in local populations as well as for in-situ conservation of species.

**EX/SITU CONSERVATION INITIATIVES**

The availability of standardized propagation packages is vital in establishing commercial cultivation of high value species. These propagation packages for many high-value threatened medicinal plants from north-west (Butola and Badola 2008) and north-east Himalaya (Pradhan and Badola, 2010) are available. Establishment of technical demonstrations of targeted taxa at various agro-ecological zones can also provide useful information for ex-situ cultivation (Butola and Badola 2006). Since seeds from different sources may differ in viability, assessing the effect of storage periods on germination, especially for seeds kept for next growing season, is helpful in predicting potential populations and therefore useful for long-term cultivation planning (Pradhan and Badola 2008b). *Aconitum heterophyllum*, *Dactyloclora kurzoe*, *Picrorhiza kuranth*, *Pedispermum hirsutum*, and *Saussurea costus* are medicinal plants found in both regions with commercial potential for ex-situ cultivation. *Angelica glauca* and *Heracleum candidum* also have potential in the north-west, *A. ferox* and *Swertia chirayita* in the north-east Himalaya.

For successful ex-situ cultivation of wild bioresources, community participation from both genders is imperative (Palni 1997). Also, knowledge of climate-driven adaptive mechanisms of plants is essential (Badola and Afskan 2003). Experiments to determine the potential optimum longitude-depths is vital to attain high crop productivity (Badola and Butola 2005). Whether the resource is a medicinal plant or other crop, a successful economic venture is possible by following internationally recommended criteria (Badola and Pal 2002), particularly in the case of high-value endangered taxa. These criteria include: (i) endangered status (conservation protection); (ii) existing knowledge (availability in nature, propagation and multiplication, cultivation trials), (iii) cultivation prospects (technical feasibility, economic viability, farmers’ acceptability), and (iv) marketing status (national and international levels). It is vitally important to understand issues like traceability to source planting material, buy-back, linkages with pharmaceutical and other consumer establishments for raw material, technical status of cropping and primary processing of raw produce to ensure viability of commercial cultivation (Badola and Pal 2002). Additionally, it is imperative for locally established institutions and experts to provide scientific monitoring and guidelines for agro- and conservation practices of targeted taxa.

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On the landscape level, identification and prioritization of ideal eco-tourism zones and assessment of their carrying capacities is useful for framing long-term natural resource management and socio-economic development (Kunyal et al. 2004). It is ideal to have strong cooperation amongst stakeholders, accredited by responsible political and economic actions. The immediate need is to accelerate time-bound partnerships between mountain states to strengthen scientific/technological mechanisms for the multiplication and conservation of bioresources, with common priorities and common approaches.

The role of civil society should be integrated as an essential component of conservation management. Simultaneously, inter-cultural dialogues amongst stakeholders, including governments of similar states in Himalayan region, are important (Eriksson et al. 2009). Communities and local NGOs need scientific training and education, to tackle the local problems and undertake resource management themselves. Such collaborations have effectively emerged in Himalaya through civil society involvement in the formation of committees for joint forest management, eco-development, and forest conservation.

Scientific institutions may assist in the development of capacity building in different stakeholders, thereby allowing them to take up bioresource-based enterprises and conserve biodiversity. A framework for immediate action and possible cooperation amongst stakeholders in the Indian Himalayan region is suggested in Figure 4. The initiatives, recommendations and methodologies suggested and presented in this review can be used to frame broader policy implementation to allow for the sustainable use of biodiversity to alleviate poverty in the Indian Himalaya.

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**Figure 4.** A framework for action and cooperation amongst stakeholders to address the sustainable use of biodiversity for poverty alleviation in the Indian Himalaya.
Wild Barley - Harbinger of biodiversity
Ya Shen*, Ephraim Philip Lansky and Evistar Nevó

Abstract
Wild barley, Hordeum spontaneum, is the progenitor of barley, Hordeum vulgare, an important cereal grain and food employed throughout the Fertile Crescent from where it (and H. spontaneum) originated as a medicine against cancer, inflammation, and diabetes. These uses of barley may be partially related to the presence of relatively high amounts of certain Vitamin E isoforms or tocols, namely tocotrienols, synthesized by barley from the more common tocols, namely tocopherols. Cultivated barley is also a very rich source of valuable water soluble fibers and minerals, especially selenium, but also manganese, phosphorous, and copper. Wild barley has been collected from hundreds of sites across the Fertile Crescent over the past few decades, and preliminary genetic, genomic, and metabolomic studies have revealed diversity coinciding with diverse environmental stress factors. These include ionic stresses (e.g., NaCl, bacterial and fungal diseases), and acidoses (e.g., drought, UV radiation, and salinity). These attributes make wild barley an attractive candidate for studying the effects of environmental factors on the emergence of fitness, as well as representing a promising source of generic material for improving the hardness and economic value of cultivated barley.

Key Words
Wild barley, Fertile Crescent, tocols, tocotrienols

Introduction
Wild barley, Hordeum spontaneum, is a group of wild and weedy barley shapes of brittle, two-rowed, diploid (2n=14) forms with predominantly self-pollination and an annual life cycle. Wild barley, the progenitor of cultivated barley, Hordeum vulgare, is cross-compatible and fully inter-fertile with the cultivated version. Their hybrids display normal chromosome pairing in meiosis, and their physical appearances resemble each other (Zohary and Hopf 2000).

According to archaeological evidence, the brittle, two-rowed Hordeum, spontaneum, was first found from the natural flora on the south coast of the Sea of Galilee in the Near East (7000-8000 B.C.). It is the earliest evidence of collecting foodstuffs (Kislev et al. 1992). The center of wild barley H. spontaneum lies in the Fertile Crescent, starting from Israel and Jordan in the southwest, stretching north-to-south in Turkey, bending southeast to Iraq, and southwest to Iran. Not only did it spread over the east Mediterranean basin, but also to western Asian such as Afghanistan and Tibet (Zohary and Hopf 2000).

H. spontaneum is not only found in primary habitats, but also in secondary, man-made habitats like abandoned fields and road sides. It is an annual component of open herbaceous formations and especially common in the summer-dry deciduous oak forest-belt, east, north and west of the Syrian Desert and the Euphrates basin, and on the slopes facing the Jordan Rift Valley. From there, it spreads over to the drier steps and semideserts (Nevó 1992). The peripheral