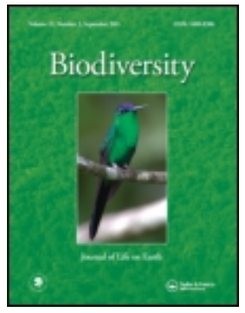

Biodiversity
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tbid20

Biological resources and poverty alleviation in the Indian Himalayas

Hemant K. Badola [a] & Stephen Aitken [b]
[a] G.B. Pant Institute of Himalayan Environment & Development, PO Box-40, Sikkim Unit, Gangtok (Campus at Pangthang), Sikkim, 737 101, India E-mail:
[b] Tropical Conservancy, 94 Four Seasons Drive, Ottawa, Ontario, Canada, K2E 7S1 E-mail:
Version of record first published: 12 Dec 2011.

To cite this article: Hemant K. Badola & Stephen Aitken (2010): Biological resources and poverty alleviation in the Indian Himalayas, Biodiversity, 11:3-4, 8-18

To link to this article: http://dx.doi.org/10.1080/14888386.2010.9712659

Biological resources and poverty alleviation in the Indian Himalayas

Hemant K. Badola[1] and Stephen Aitken*[2]

Authors' Addresses:
[1]G.B. Pant Institute of Himalayan Environment & Development, PO Box- 40, Sikkim Unit Gangtok (Campus at Pangthang), Sikkim 737 101, India
hkbadola@rediffmail.com

[2]Tropical Conservancy, 94 Four Seasons Drive, Ottawa, Ontario, Canada K2E 7S1
aitken@tc-biodiversity.org

*Corresponding author:
hkbadola@gmail.com

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 firewood, 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 biological resources such as medicinal plants, edibles, orchids, rhododendrons and ethnobiological 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 as resources, the ideal choice being the cultivation of high market-value taxa coupled with local entrepreneurship. Also discussed are sustainable strategies to multiply the resources and conserve the source gene bank in the wilderness. The role of civil society is recognized as an essential component of conservation management and with the help of scientific institutions stakeholders can develop the capacity to create bioresource-based entrepreneurships that also meet broader conservation and poverty reduction objectives. The threat of climate change to the availability of biodiversity is also discussed and a framework is presented for further action.

Key Words. Indian Himalaya, alpine meadows, medicinal plants, biological resources, livelihoods

About the Authors:
Hemant K. Badola has been conducting biodiversity conservation research in sensitive and protected areas in north-west, central and north-east Himalaya (India) for about 30 years. His studies have been widely published on tree biology, population-dynamics, bio-resource use, propagation and cultivation of high value and endangered taxa, planning and policies. Dr. Badola is the nodal person for Khangchendzonga Biosphere Reserve (Sikkim) under Lead Biosphere Reserve Program and an Associate Editor of *Biodiversity*.

Stephen Aitken is a biologist, writer and illustrator. In addition to his position as Managing Editor of *Biodiversity* and Executive Secretary of Tropical Conservancy, he has written and illustrated extensively for educational publishers around the world. Stephen is currently writing a 5-book young adult series entitled *Climate Crisis* for Marshall Cavendish Benchmark, NY.

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 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 bioresources themselves (Bandyopadhyay 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 bioresources to improve their livelihoods (Badola and Aitken 2003; Badola 2009a). External pressures 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, partially as a result of the difficult high altitude terrain they inhabit. The authors feel 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 bioresources. Coupled with this of course would be a requirement for the long-term 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 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 boards to publicize the necessary regulations (Nepal and Weber 1995). Still, with strong legislation in place, it is much more important that a thorough and periodic assessment is made to prioritize their conservation and sustainable use, including community level entrepreneurships 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

Himachal Pradesh (H.P.), located in northwest India, has a unique physiography and a rich flora that ranges from deciduous mixed forests in the middle mountains, to scattered alpine and arctic-type vegetation at higher altitudes. Lower altitudes support luxuriant forests of *Pinus roxburghii* and *Alnus nitida* in drier sites and *Quercus leucotrichophora, Rhododendron*

arboreum, on moist, shady slopes. *Quercus semecarpifolia, 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 found 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 km^2) located in the northeastern Indian Himalaya and supporting a population of just over half a million. The world's 3rd highest peak, Mt. Khangchendzonga (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 Sherpas. Lepchas are the oldest 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 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, ethnobiological 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 entrepreneurships 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 1750 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 taxa with a high market demand are:

- *Aconitum heterophyllum* (Patish/Bikhma - used in body-ache, fever, cold, cough, and nose discharge);
- *Angelica glauca* (Chora - used in constipation and vomiting, and as cardioactive, carminative and diaphoretic);
- *Cordyceps sinensis* (Keera-Jhar/Yar Tsagumba - used for immunologic, antineoplastic, antiarrythmic, hypoglycemic and erythropoietic effects);
- *Dactylorhiza hatagirea* (Salam-panja/Pach-unguli - used to treat dysentery, diarrhoea, chronic fever, cough, stomach-ache, wounds, cuts, burns, fractures, and general weakness);
- *Nardostachys jatamansi* (Jatamansi - used in cases of high blood pressure, heart disease and insomnia, and as a tonic and stimulant);
- *Picrorhiza kurrooa* (Kutki, Karu - 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* (Bankakri - used in making a drug for treating cancer;

Photos 1-2. 1, *Swertia chirayita*, a critically endangered medicinal plant of global market value; 2, *Saussurea costus*, an endangered, highly marketed and commercially cultivatable medicinal plant. (Photos © H.K. Badola)

Table 1. Wild medicinal plants with potential for entrepreneurship, including their price range in markets at six major centres in north India. The table also presents Ayurvedic formulations and the level of cultivation potential.

Species	Cultivation-potential for HP /Sikkim (High/Medium/ Low)	Part-used in commerce	Propagule used (preference wise)	Potential altitude for cultivation	Use in Tibetan medicine (% formulations; n=175) **	Conservation status (as per IUCN)/marketing	Rate-range (IRs/ Kg)	Ayurvedic formulations in National and International markets*
Aconitum heterophyllum	HP (H) /Sikkim (H)	Root/ tubers	Seed, tuber-segment	2200-2800m	17.7	Critically-endangered/ highly marketed	3000-5000	Pedi tone tonic; Pilsun caplets; Chandraprabha tabs; Mahanarayan oil; Bronchitis/asthma/colds/flu tabs & tincture & syrup; Calendula gel; Ativisha churna
Acorus calamus	HP (M) /Sikkim (H)	Rhizome	Rhizome-segment	1500-2100m	9.7	Highly marketed /bleak conservation	28-45	Vacha caps; Saraswati churana powder; Mahanarayan oil
Angelica glauca	HP (H)	Root/rhizome	Seeds/rhizome-segment	2000-2800m	4.57 (Angelica sps)	Endangered/ highly marketed	80-90	Smooth cycle tea; Mahanarayan oil; Dr Nancy Lonsdorf's teas; Memory support caps; Kumarpistikrit ghrit; Rasnadi churna
Bergenia ciliata	HP (M) /Sikkim (H)	Rhizome	Rhizome/seeds	1600-2200m	-	Threatened/ moderately marketed	19-32	UriKhus syrup; Cardio support, Maharishi ayurveda products; Antisept cream; Uriflow caps
Dactylorhiza hatagirea	HP (H)/Sikkim (L)	Root/Tuber	Tuber/seeds	2500-2800m	0.57	Critically-endangered/ high market	850-1700	Farinaceous food, expectorant, aphrodisiac and as nervine tonic
Dioscorea deltoidea	HP (M)	Rhizome	Seeds/rhizome	1600-2200m	-	Endangered/CITES-Sch. II/ moderate market	27-30	Primaforce Fuze caps
Hedychium spicatum	HP (H) /Sikkim (H)	Rhizome	Seeds/rhizome-segment	1700-2300m	19.4	Highly marketed/ least threat till date	12-40	Detox natural herbal tabs; Antiox tabs; Mahabhringaraj oil; Dasamoolarishta; Cinkara; Himanshu Tel; Vomitab tabs
Heracleum candicans	HP (H)	Root	Seeds/rhizome-segment	2200-2700m	0.57	Endangered/ moderately marketed	48-50	Sun-tan lotion; Oxsoralenultra caps; Zanthotoxin
Nardostachys jatamansi	HP (H) /Sikkim (H)	Root	Seeds	2300-2800m	4.0	Endangered/ highly marketed	15-250	Jatamansi caps; Hair rejuv caps; Mahanarayan oil; Nasya oil; Chywanprash
Picrorhiza kurrooa	HP (H) /Sikkim (H)	Root	Root segments	2500-2900m	17.71	Endangered/CITES-Sch. II/ highly marketed	190-270	Mahasudarshan powder & caps; Arogya vardhani paste; Astragalus herbal tea; Hepasave caps
Podophyllum hexandrum	HP (M) /Sikkim (L)	Root	Seeds/rhizome segment	2200-2800m	0.57	Endagnered/CITES-Sch. II/ moderately marketed	48	Boiron podophyllum pellets & tube; King diarrhea relief; Lucomyn; Livosin, Hipa-10
Polygonatum cirrhifolium/P. verticillatum	HP (M)	Root	Seeds	1600-2600m	4.57	Endangered/Vulnerable/ moderately marketed	38	Chywanprash Jam; Sorig Gae-pa Sowa Chulen (Tibetan); Longevity tonic/ CordyPlus caps; Mahanarayana oil
Saussurea costus	HP (H) /Sikkim (M)	Root	Seeds	2200-2800m	41.71	Critically-endangered/CITES –Sch. I/highly marketed	15-163	Mahanarayan oil; Costus root oil; Yograj guggul; Sareswat churn; Mahamash Tel; Dashmoolarishta
Selinum tenuifolium	HP (M)	Root	Seeds	1700-2700m	-	Low marketed/ unknown conservation status	58-60	-
Swertia chirayita	HP (L) /Sikkim (H)	Whole Plant	Seeds	2000-2500m	17.14	Critically-endangered/ high marketed	60-220	Chirata caps; Mahasudarshan caps & powder
Valeriana jatamansi/v. wallichii	HP (H) /Sikkim (H)	Root	Root segment	2100-2600m	-	Vulnerable/ moderately marketed	38-110	Jatamansi caps & powder; Mahanarayan oil; Chywanprash tabs; Tagar powder & caps

*** Butola and Badola (2008); ** Tsarong (1996)**

- *Swertia chirayita* (Chirayita - used for fever, cough, diarrhoea, stomach-ache, etc.), and *Taxus baccata* (Rikhal/ Dhengre-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 overharvesting 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 entrepreneurships need further support to develop their full potential.

Yar Tsagumba (*Cordyceps 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 (3,600-4,200 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 2500-3500m 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 *Bunium persicum* (Kala zira), the former, has been successful in the Lahaul area, and the latter in Kinnaur district of HP (Badola and Pokhriyal 2001).

Species that have potential for successful local entrepreneurships 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).

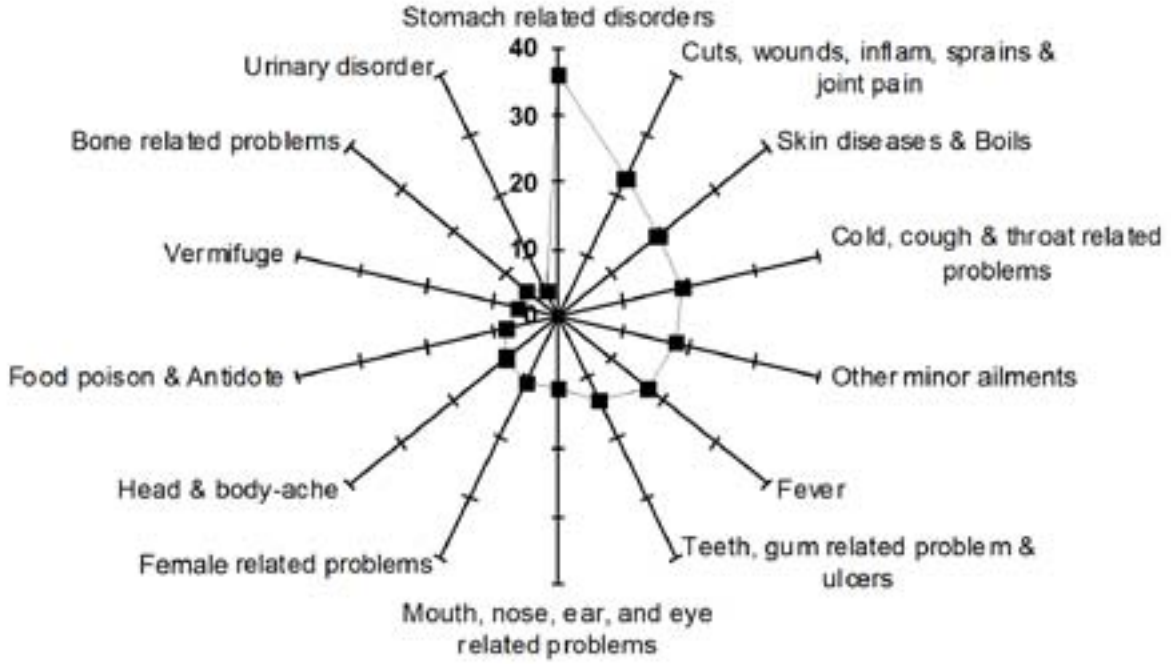

Figure 1. Major ailments treated using number of plant species (number against vertical axis) in Dzongu valley (Khangchendzonga Biosphere Reserve), Sikkim (*Based on* Pradhan and Badola 2008a)

Photo 3. *Ficus roxhburghii,* an underexploited multipurpose fruit tree. (Photo © H.K. Badola)

ETHNOBIOLOGICAL RESOURCES

Indian tribal populations in rural Himalayan areas, possess vast ethnobiological 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 2008a; Uniyal *et al*. 2006).

The Lepcha tribe of Dzongu in Khangchendzonga Biosphere Reserve-Sikkim uses over 118 ethnomedicinal plant species to treat 66 ailments under 14 broad categories (**Figure 1).** *Pandanus nepalensis* in the north-east is another taxa 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 ethnobiological knowledge can lead to socio-economic gains for the local people. However, this ethnobiological 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 *Spondias axillaries* (Lapsi), eaten raw or used for making pickles, especially in Sikkim (Rai and Badola 2009).

Pandanus nepalensis (Tarika), highly under-exploited, offers great commercial potential for making quality fruit jam/jelly/juices (Badola *et al*. 2009). In both the north-east and north-west Himalaya, *Diplazium esculentum* (Lingra/Ningru) 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, *Allium* sps. (Jambu), *Phytolacca acinosa* (Jharka/Joringo), *Rheum australe* (Chuchi/Padamchal), *Rumex nepalensis* (Halhale), and *Urtica* sp. (Bichu ghas/Nettle). Species such as *Hippophae rhamnoides* (Durchuk or Sea Buckthorn), *Rubus ellipticus* (Hishalu/Achche/Aselu or Himalayan Raspberry), and *Prunus armeniaca* (Jangli-Badam/Apricot) have demonstrated successful development of secondary marketing in central Himalaya (Maikhuri *et al.* 2004). *Ficus roxhburghii* (Nibara) 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* (Kaphal) (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 intervention is recommended 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 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). Developed into mass multiplication and with domestication to avoid *in-situ* harvesting pressure, this usage shows great possibility 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. setosum* and *R. maddenii* (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 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 denudans* in Mizorum where plants were sold at the meager price of 1000 to 3000 Indian rupees per kg ($22- 65 USD). In Manipur,

Photos 4. A, Inflorescence of *Rhododendron arboreum;* B, Forest of *R. arboreum* in Khandi landscape; C, Collecting *R. arboreum* flowers in Khandi, 17 km from Bajaura in H.P. The spectacular *R. arboreum* forests in full bloom offer opportunities for eco-tourism. (Photos © Stephen Aitken)

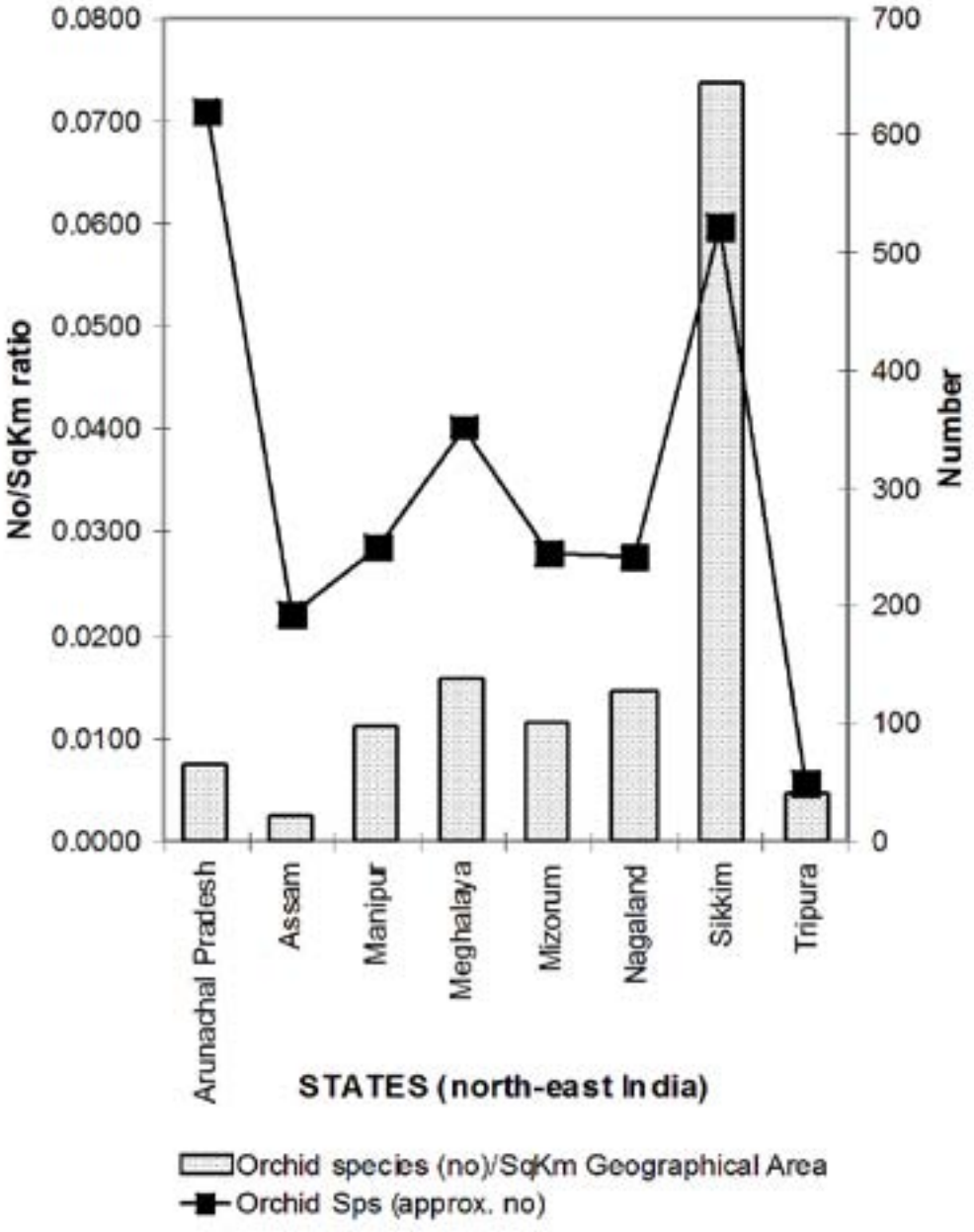

Figure 2. Number of orchid species in relation to geographical area of respective states in north-east Indian Himalaya

this species was sold for even less by local villagers. A critically endangered medicinal orchid from Himalaya, *Dactylorhiza hatagirea*, which is traded on the international market (Badola and Pal 2002), showed a quick increase in selling rate for dry tubers between 1999 and 2002 (Butola and Badola 2006).

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 *Paphiopedilum insigne, P. villosum, P. venustum, Aerides multiflora, Vanda coerulea, V. teres, Rhynchostylis retusa, Pleione maculate, P. humilis, Cymbidium devonianum, C. gigantium, 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/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.

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 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 glauca* (Indian Himalaya), *A. nubigena* (Sikkim), *Coptis teeta* and *Panax pseudo-ginseng* (eastern Himalaya), *P. kurrooa* (Himalaya), and *Podophyllum emodii* var. *axillaris* (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.

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 candicans*, a high-value

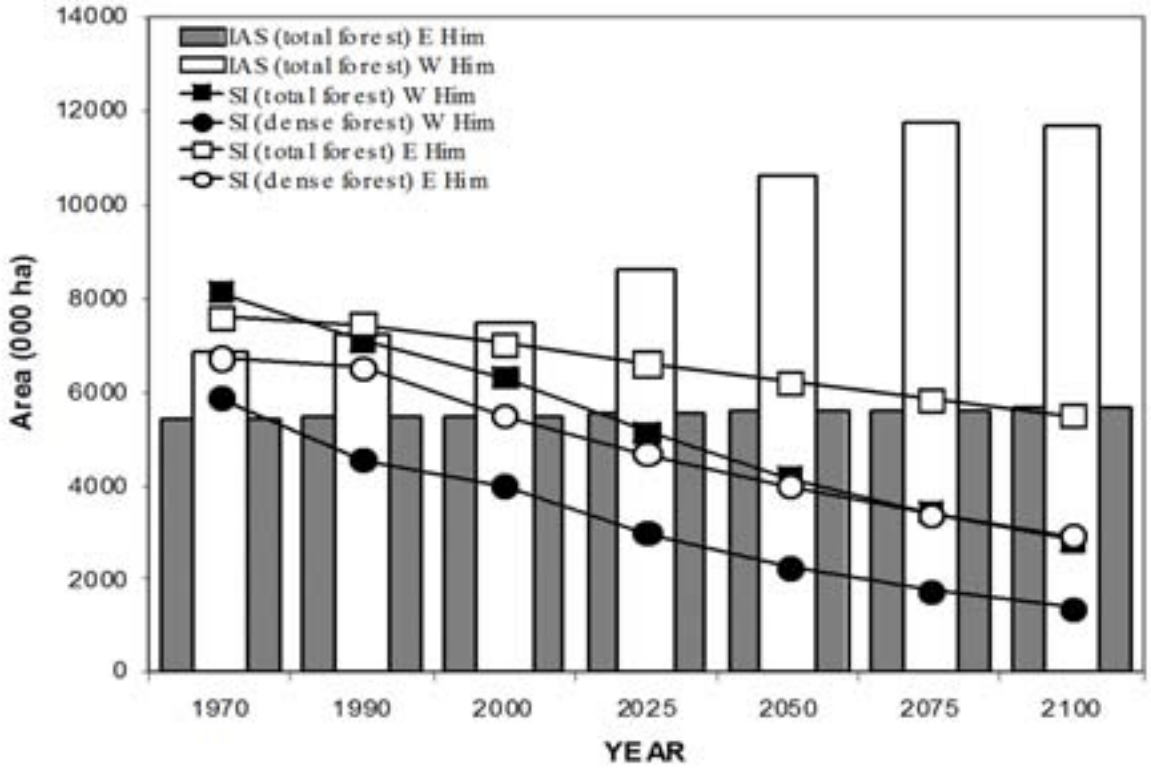

Figure 3. Current and projected trend of deforestation in western Himalaya (combined: J&K, HP and Uttarakhand) and Eastern Himalaya (combined: Arunachal Pradehsh and Sikkim) of India, as per data from Satellite (SI) and the India Agriculture Statistics (IAS) summary (*Figure construction, based on* Pandit *et al*. 2007)

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 poor people, now and into the future.

BIO-RESOURCE 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 2008) supports the potential for cultural/ 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 Chhota Bangal, H.P. (Uniyal *et al*. 2006). Traditional conservation practices by the Bhutia tribe of Lachung and Lachen 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 Mizorum (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.

IN-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.

EX-SITU CONSERVATION INITIATIVES

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 agro-climatic 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, Dactylorhiza kurrooa, Picrorhiza kurrooa, Podophyllum hexandrum,* and *Saussurea costus* are medicinal plants found in both regions with commercial potential for *ex-situ* cultivation. *Angelica glauca* and *Heracleum candicans* also have potential in the north-west, and *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 Aitken 2003). Experimentation to ascertain optimal ploughing 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 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 (Ved *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 (Kuniyal *et al*. 2004). It is ideal to have strong cooperation amongst stakeholders, accompanied by sensible 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 bioresouce-based entrepreneurships 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.

ACKNOWLEDGMENTS

The senior author (HK Badola) is highly grateful to the director of the institute, Dr L.M.S. Palni for inspiration and continuous encouragement. Also, thanks go to those local Himalayan entrepreneurs who have successfully identified and developed bioresources for market sale while at the same time conserving the natural local ecosystems.

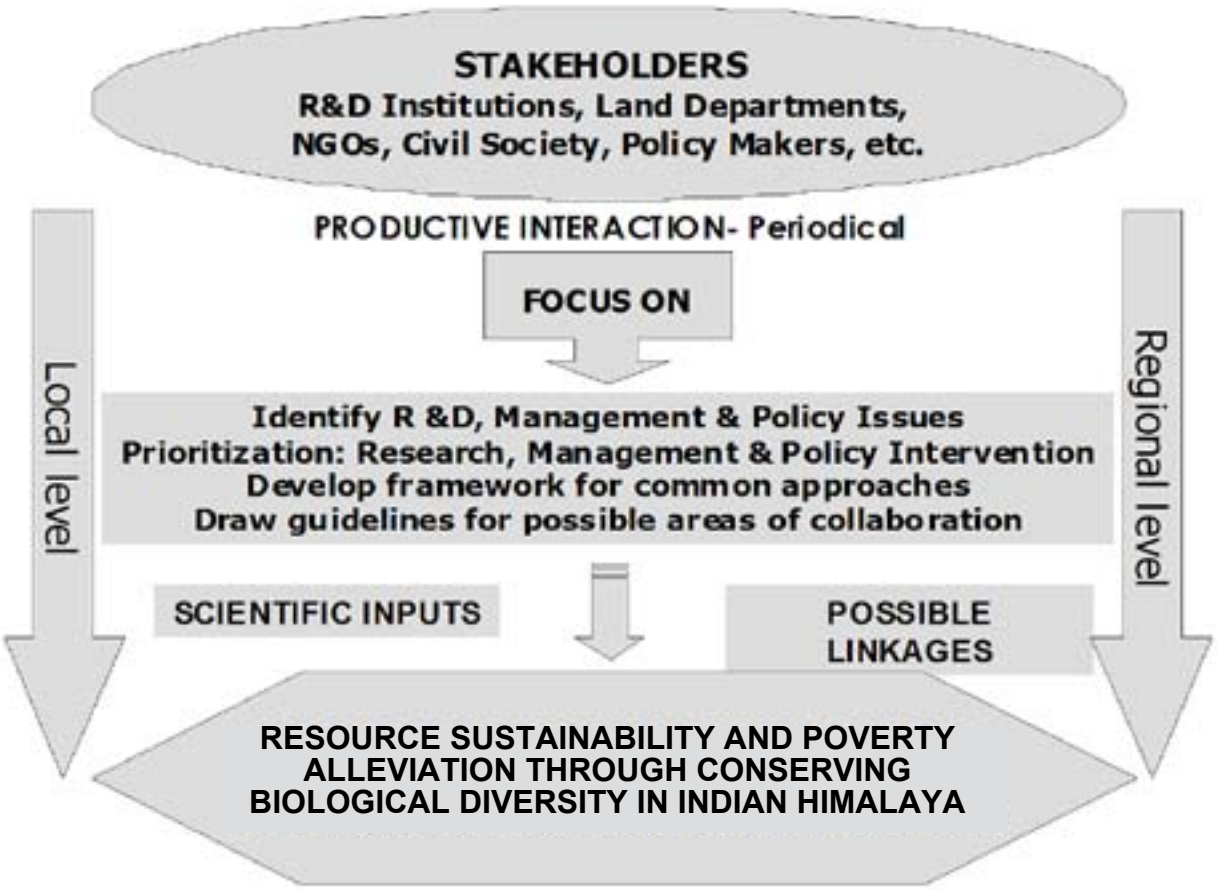

Figure 4. A framework for action and cooperation amongst stakeholders to address the sustainable use of biodiversity for poverty alleviation in the Indian Himalaya.

REFERENCES

Badola, H.K. 1992. The Himalayan Glory: Burans and its world. *Himalaya Today* 4: 2-5.

Badola, H.K. 1998. Biodiversity conservation study of Kanawar Wildlife Sanctuary in Himachal. pp. 407-430. In, Himavikas Publ. No. 12, '*Research for Mountain Development: Some Initiatives and Accomplishments'*,Gyanodaya Prakashan, Nainital. p. 452.

Badola, H.K. 2009a. Agrobiodiversity, livelihood and conservation: focusing north-east Himalaya. pp 34-58. *In*: Borgohain, R. & Pathak, P.K. (*eds*), "*Promoting Conservation and Sustainable Use of Agrobiodiversity in North-East India*". Assam Agriculture Univ, Jorhat, Assam, India and Wageningen International, Wageningen Univ & Res. Centre, Wageningen, The Netherlands. p.67.

Badola, H.K. 2009b. *Hedychium spicatum* - a commercial Himalayan herb needs entrepreneurship at local level. *Non-wood News (Rome)* 19: 26-27.

Badola, H.K. 2010a. A vegetable fern, *Diplazium esculentum* - potential to food security and socio-economic development in Himalaya. *Non-wood News (Rome)* 20: 10-11.

Badola, H.K. 2010b. Phenology and climate responses in Himalayan rhododendrons. pp. 48-59. In: Mainra, A., Badola, H.K. and Mohanty, B. (eds), *Proc., International Conference, Rhododendrons:Conservation and Sustainable Use,* FEWMD, Government of Sikkim, Gangtok-Sikkim. Printed at CONCEPT, Siliguri-India. p.100.

Badola, H.K. and S. Aitken, 2003. The Himalayas of India: A treasury of medicinal plants under siege. *Biodiversity* 4: 3-13.

Badola, H.K. and J.S. Butola 2004. Threatened medicinal plant cultivation succeeds in Himachal Himalaya. *Biological Conservation Newsletter* 229: 1.

Badola, H.K. and J.S. Butola, 2005. Effect of ploughing depth on the growth and yield of *Heracleum candicans*: a threatened medicinal herb and a less-explored potential crop of the Himalayan region. *Jour. Mountain Science* 2: 173-180

Badola, H.K. and M. Pal, 2002. Endangered medicinal plant species in Himachal Pradesh. *Current Science* 83: 797-798.

Badola, H.K. and A. Pokhriyal 2001. *Documentation on Agrotechniques and Post Harvest Processing of Medicinal Plants of the Indian Himalayan Region*. FINAL REPORT (Himachal Pradesh). IUCN-Himal Project, by GBPIHED, Mohal-Kullu.

Badola, H.K. and B.K. Pradhan, 2008. (Design and concept). *Dzongu Landscape in Khangchendzonga Biosphere Reserve: Biodiversity and unique cultural spots along Tholung-Kisong eco-trek in north Sikkim*. Technical Brochure. Dec. 2008. Beracah Printers, Deorali, India.

Badola, H.K. and B.K. Pradhan, 2009. Singba Rhododendron sanctuary in Sikkim … an explorer's paradise. *The Rhododendron (Off. Jour Australian Rhodo. Soc)* 49: 24-30.

Badola, H.K, and BK. Pradhan, 2010. Population exploration of *Rhododendron maddenii* in Sikkim, bordering Khangchendzonga Biosphere Reserve - questioning rarity and endangerment. *NeBIO* 1: 1-9.

Badola, H.K., B.K. Pradhan, , S. Subba, , L.K. Rai, and Y.K. Rai, 2009. Sikkim Himalayan screw-pine, *Pandanus nepalensis*: a much neglected and underexplored NTFP. *Non-wood News (Rome)* 18: 44-45.

Bandyopadhyay, J. and S. Parveen, 2004. *Moving the Mountains Up in the Global Environmental Agenda*. CDEP Occasional Paper 3, CDEP, Indian Institute of Management, Calcutta. p.39.

Butola, J.S. and H.K. Badola 2006. Growth, phenology and productivity of *Dactylorhiza hatagirea* (D. Don) Soo, a critically endangered medicinal orchid in Himalaya: domestication compared with wild. *Jour. Orchid Soc. India* 20: 37-43.

Butola, J.S. and H.K. Badola 2008. Threatened Himalayan medicinal plants and their conservation in Himachal Pradesh. *Jour Trop. Med. Plants* 9: 125-142.

Christie, A., 2001. *Herbs for Health, But How Safe Are They*. Bulletin of the World Health Organization, 79: 691-92.

Das, S.S. 2005. Kabi sacred grove of North Sikkim. *Current Science* 89: 427-428.

Dhyani, P.P. and U. Dhar 1994. Box Myrtle (*Myrica esculenta*, Kaiphal)- A promising underexploited tree crop of the Himalaya. Himavikas Occ. Publ. No. 3, GBPIHED-Almora. p.33.

Eriksson, M., X. Jianchu, A.B. Shrestha, R.A. Vaidya, S. Nepal and K. Sandström, 2009. *The Changing Himalayas: Impact of Climate Change on Water Resources and Livelihoods in the Greater Himalayas*. ICIMOD-Nepal. p.25.

Kuniyal, J.C., S.C.R. Vishvakarma, H.K. Badola, and A.P. Jain 2004. *Tourism in Kullu Valley: An Environmental Assessment.* HIMAVIKAS Publ. No. 15, Bishan-Singh Mahendra-Pal Singh, Dehradun, India. p.210.

Lucksom, S.Z. 2007. *The Orchids of Sikkim and north east Himalaya*. Concept, Siliguri, India.

Maikhuri, R.K., K.S. Rao and K.G. Saxena, 2004. Bioprospecting of wild edibles for rural development in the central Himalayan mountains of India. *Mounnt.Res.Dev.* 24: 110–113.

Mainra, A., H.K. Badola and B. Mohanty (Eds.) 2010. *Proc., International Conference, Rhododendrons: Conservation and Sustainable Use,* FEWMD, Government of Sikkim, Gangtok-Sikkim. Printed at CONCEPT, Siliguri, India. p. 100.

Mao, A.A. 2006. Notes on Dendrobium denudans D. Don- an endangered medicinal orchid of north east India. *Jour. Orchid Soc. India* 20: 53-55.

Miller, K.R. 1999. International wilderness provides ecological services for sustainable living. *Intl. Jour. Wilderness* 5: 35-39.

Myers, N., R.A. Mittermier, C.G. Mittermier, G.A.B. da Fonseca, and J. Kent 2000. Biodiversity hotspots for conservation priorities. *Nature* 40, 853–858.

Nepal, S.K. and K.E. Weber 1995. Prospects for coexistence: wildlife and local people. *Ambio* 24: 238-45.

Oli, K.P. and J.D. Gupta 2008. *Regional framework on access and benefit sharing (ABS) in the Himalayan region*. ICIMOD, Kathmandu, Nepal. p. 4.

Palni, L.M.S. 1997. Preamble. Pp.1-4. In: U. Dhar (*Ed.*), *Himalayan Biodiversity: Action Plan*. Gyanodaya Prakashan, Nainital.

Pandit, M. K., N.S. Sodhi, L.P. Koh, A. Bhaskar and B.W. Brook, 2007. Unreported yet massive deforestation driving loss of endemic biodiversity in Indian Himalaya. *Biodiv. Conserv.* 16: 153-163

Pradhan, B.K. and H.K. Badola, 2008a. Ethnomedicinal plant use by Lepcha tribe of Dzongu valley, bordering Khangchendzonga Biosphere Reserve, in North Sikkim, India. *Jour. Ethnobiol. Ethnomed.* 4:22 doi:10.1186/1746-4269-4-22.

Pradhan, B.K. and H.K. Badola, 2008b. Seed germination response of populations of *Swertia chirayita* following periodical storage. *Seed Technology (USA)* 30: 63-69.

Pradhan, B.K. and H.K. Badola, 2010. Chemical stimulation of seed germination in *ex-Situ* produced seeds in *Swertia chirayita*, a critically endangered medicinal herb. *Res. Jour. Seed Science* 3: 139-149.

Pradhan, U.C. and S.T. Lachungpa, 1990. *Sikkim Himalayan Rhododendrons,* Primulaceae Books, Kalimpong, West Bengal, p. 130.

Rai, S.C. 2007. Traditional ecological knowledge and community-based natural resource management in northeast India. *Jour. Mountain Sci.* 4: 248-258

Rai, Y.K. and H.K. Badola, 2009. *Spondias axillaris* Roxb. (Lapsi), a wild edible in Sikkim Himalaya: potential for entrepreneurship. *Ecotone* 1: 6-8.

Ramakrishnan, P.S. 1996. Conservation the sacred: from species to landscape. *Nature and Resources* 32: 11-19.

Ramakrishnan, P.S. 2007. Traditional forest knowledge and sustainable forestry: a northeast India perspective. *For. Ecol. Manag.* 249: 91–99.

Samant, S.S., U. Dhar U. and L.M.S. Palni, 1998. *Medicinal Plants of Indian Himalaya: Diversity, Distribution Potential Values*. HIMAVIKAS Publication No. 13, Gyanodaya Prakashan, Nainital. p.163.

Sundriyal, M. and R. C. Sundriyal, 2003. Underutilized edible plants of the Sikkim Himalaya: Need for domestication. *Current Science* 85: 731-736.

Schwartz, M.W., L.R. Iverson, A.M. Prasad, S.N. Matthews and R.J. O'Connor, 2006. Predicting extinctions as a result of climate change. *Ecology* 87: 1611-15.

Tsarong, T.J. 1996. *Handbook of Traditional Tibetan Drugs: Their Nomenclature, Composition, Use, and Dosage*. Tibetan Medical Publications, Kalimpong, India. p. 101.

Uniyal, SK., K.N. Singh, P. Jamwal and B. Lal, 2006. Traditional use of medicinal plants among the tribal communities of Chhota Bhangal, Western Himalaya. *Jour. Ethnobiol. Ethnomed.* 2:14 doi:10.1186/1746-4269-2-14.

Ved, D.K., Kinha, G.A., Ravikumar, K., Prabhakaran, V., Ghate, U., Sankar, R.V. and Indresha, J.H. (Eds.), 2003. Conservation Assessment and Management Prooritisation for the medicinal plants of Jammu & Kashmir, Himachal Pradesh & Uttaranchal. FRLHT-Bangalore. p 206.

Walther, G.R., E. Post, P. Convey, A. Menzel, C. Parmesan, T.J.C. Beebee, J.M. Fromentin, O. Hoegh-Guldberg, and F. Bairlein, 2002. Ecological responses to recent climate change. *Nature* 416: 389-395.

Xu, J.C. and A. Wilkes, 2004. 'Biodiversity impact analysis in Northwest Yunnan, Southwest China. *Biodiv. Conserv.* 13: 959-983.