ASSESSMENT OF PROVISIONING SERVICES AND THE RECREATIONAL VALUE OF NANDA DEVI BIOSPHERE RESERVE

Thesis submitted to the
Saurashtra University Rajkot, Gujarat

For the Award of the Degree of

DOCTOR OF PHILOSOPHY
IN
WILDLIFE SCIENCE

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March 18th, 2015

CERTIFICATE

This is to certify that the Ph.D. thesis of Ms. Pariva entitled **"Assessment of Provisioning Services and the Recreational Value of Nanda Devi Biosphere Reserve"** is an original piece of work submitted to the Saurashtra University, Rajkot, Gujarat, for the award of the degree of **Doctor of Philosophy in Wildlife Sciences**.

Ms. Pariva has put in more than six terms of research work embodied in this thesis under our guidance and supervision. The work presented in this thesis has not been submitted to any other university or institution.

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I also certify that the research work was appreciated by all who remain present and there was no comments made for this research work/comments made are incorporated in the thesis.

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Pariva

LIST OF PLATES

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The ecological services and the natural capital stocks that produce them are critical to the functioning of the earth's life-support system. Because of the direct use of the structural value provided by natural ecosystems and in most cases of free access to such ecosystems they are under heavy utilization pressure. The harmful effects of degrading ecosystem services are being disproportionately borne by the poor and are contributing to the growing economic inequities as well as environmental hazards to which the poor are the most vulnerable. The Himalayas are the life support system for millions of people. They provide several ecosystem services crucial for the well being of mountain communities as well as people living in other parts of South Asia. However, rapid transformations in the Himalayas resulting from anthropogenic pressures have made it susceptible to the impacts of global warming and climate change as well as reduced their ability to provide life support and livelihood security to the local communities. Present work aimed to understand the status of the provisioning and recreational services of the Nanda Devi Biosphere Reserve (NDBR) and their contribution in securing wellbeing of local communities. The study was carried out with five objectives: (a) assess the socioeconomic status of local communities in NDBR, (b) quantify the provisioning services of the Reserve in terms of resource extraction, (c) estimate the recreational and religious value of the Reserve and its contribution to local livelihoods, (d) assess the extent of human-wildlife conflicts in the Reserve; and to (e) examine the attitude of local communities towards the conservation of the Reserve. To achieve these objectives four key research questions were formulated (a) what is the socioeconomic status of local communities residing in the NDBR? (b) what is the extent of resources that are being extracted from the Reserve? (c) does the recreational value of the Reserve significantly enhance local livelihoods? (d) what is the extent of human – wildlife conflicts in the Reserve? (e) how do local communities perceive conservation of natural resource in the Reserve?

The key functions of the western Himalayan landscape evaluated were: provisioning- fresh water, biomass and cultural services- nature based recreation and religious value. Contribution of these services to human wellbeing was also assessed.

Data for the present study was collected in three stages. The first stage involved a rapid assessment of the study area in order to obtain an overall perspective of the villages and collection of secondary information about them. In the second stage secondary data was used to conduct hierarchical cluster analysis to identify and separate out the homologous and representative villages. A total of 11 clusters were formed and representative villages (n=22 with 764 household (hh) interviews) for intensive study were identified from each cluster. In the third stage the primary data to meet the aforementioned objectives was gathered using standard methodologies selected on the basis of review of peer reviewed literature.

To quantify the provisioning services and their contribution in local economy interview based structured questionnaire and informal discussions were conducted. To validate the data about biomass extraction obtained from questionnaire, entry point method was used. It was found that the forested landscapes provide 2510.29 ±67.36 kg fuelwood/hh/year to households of NDBR while 3648.73 ±67.04 kg fodder /hh/year was collected from forest and rocky areas, which supported the livestock population of the local people. 2321.07 ±41.31 kg leaf litter per household was collected by local people every year from the forests of NDBR. 75.5 ±9.21 kg/hh/year of thatching material was extracted by local people for their household use. People collect about 2.87 ±0.08 kg wild vegetables per household per year and 5% of the households sell these collected vegetables to the nearby market or to the other villagers which contribute INR 57.69 ±5.2/hh/year to the total household income of the people. 7.07 ±0.31kg of wild fruits was extracted from forest by every dependent household annually (economic contribution INR 384 ±36.05/hh/year) and 16% of the household sell these products to the markets or to the tourists. The provisioning services contributed 15.6% of the average annual household income of the dependent community. Oak forest contributed most (37.3%) followed by mixed conifer forest (28%). Dependence on natural resources for biomass was found to be decreasing with the availability of the alternative sources of income {$r(764)= -0.088$, $p<0.05$}, but the relation was not very significant as the dependence on forests was increasing with agriculture.

To assess the freshwater provisioned by forested landscapes of NDBR, flow of streams originating from forests was monitored using timed volume method. To explore the reliance of local communities on natural sources of water personal structured questionnaires were used. Streams were selected originating oak, moist temperate deciduous and mixed conifer forest (two streams in each forest). Total water flow of the first stream in oak forest was 3.40 ±0.85 m^3 per hour. While for the second stream the total water flowing in the stream was measured as 1.09 ±0.25 m^3 per hour. The economic value of the services provisioned by these two streams was found to be INR 6653.9 ±162.8/day and INR 2096.2 ±47.5/day, respectively. Total flow in moist temperate deciduous forest was found 5.99 ±0.80 m^3 per hour for the first stream while it was 3.60 ±0.08 m^3 per hour for the second stream. The economic value of the fresh water provisioned by the two streams originating from moist temperate deciduous forest was calculated as INR 11500.6 ±153.4/day and INR 6917.6 ±12.2/day, respectively. For the first stream of the mixed conifer forest the flow was 0.86 ±0.08 m^3 per hour while for the second selected stream it was 0.99 ±0.08 m^3 per hour. The economic value of the functional output of these streams was found to be INR 1659.6 ±16.3/day and INR 1892.4 ±16.9/day. It was found that on an average each household uses 217.78 ±20.32 lts of water per day (39.6 ±3.7 lts/capita/day) of which 116.67 ±14.81 lts/day/hh (21.2 ±2.7 lts/capita/day) was being used to meet the domestic needs, while 101.12 ±9.34 lts/day/hh was being used for livestock. For the irrigation purpose the households which were extracting water from these selected streams were found to be using 826.06 ±33.71 m^3/year/hh. The total economic value of overall household water consumption was INR 627.2 ±55.5/hh/year (INR 114.03 ±10.6 per capita/year) while it was INR 336 ±40.4/hh/year (INR 61.1 ±7.5 per capita/year) for the domestic consumption of the water. The value of water used for livestock and agricultural purposes was INR 291.2 ±25.5 and INR 132170.4 ±269.7, respectively.

Secondary data and interview based structured questionnaire method was used to understand the pattern of human wildlife conflict in NDBR. About 68.6% (n=599) respondents reported loss due to wildlife of which 50% reported loss of cattle. Only seven families have reported the loss of a pack animal (mule); as people generally do not leave mules and horse unsupervised in grazing areas and forests. 12% families' representatives said that they have lost goats and sheep; one of the household lost 10 goats in one night to an unknown predator. Average annual income per household was found to be INR 86642.07 ±5191.15/hh for the household surveyed to assess the human-wildlife conflict (HWC). The average land holding for surveyed household was 0.48 ±0.02 ha while total land raided was calculated to be 0.16 ±0.007 ha/hh, which caused economic loss of INR 3179.5 ±102.7/hh. Average monetary loss due to livestock depredation was calculated as INR 6177.27 ±166.7/hh. Attack on human was also reported during the survey leading to less tolerance among local people towards presence of wildlife. Conflict mainly arises due to scarcity of resources which is a result of high natural resource extraction in the area. Status of the HWC was found to be negatively associated with the average years of schooling {$r(411)= -0.098$, $p<0.05$} and household income from sources other than forest products {$r(411)= -0.136$, $p\leq0.005$}. Livelihood security through more stable means can reduce the intensity of human wildlife conflict in the area by providing alternatives for the natural resources. Nature based tourism can be developed as an alternative source of livelihood to dwindle the local dependence on nature.

The zonal approach travel cost method was used for the evaluation of recreation value. To calculate the recreational value of NDBR a regression analysis was done to know the visitation rate at different travel costs. Curve estimation was used and non-linear inverse curve fit was obtained through the equation VR= -13.015 + (3.67*10^5)/ travel cost. To estimate the consumer surplus, a regression was again carried out with visitation rate as the dependent variable and added travel costs as the independent variable. The curve was fitted through non-linear curve estimation and the logarithmic model ($VR= 4681.7e^{-2E-04\ (travel\ cost)}$) was found to be more appropriate ($R^2= 0.998$). To calculate the religious value of the NDBR regression analysis was done to know the visitation rate at different travel costs. Visitation rate was calculated following same method as used for recreational value calculation. Curve estimation was used and a non-linear inverse curve fit was obtained through the equation VR= -527.815+ (1.193*10^7)/ travel cost. To estimate the consumer surplus, a regression analysis was done with visitation rate, as the dependent variable, and added travel costs, as the independent variable, were used. The curve was fitted through non-linear curve estimation and the exponential model ($VR= = -105.42e^{-1E-04(travel\ cost)}$) was found to be more appropriate ($R^2= 0.999$) to fit the curve. The value of nature based recreation in NDBR was estimated as INR 963819.54 and the consumer surplus was found to be INR 43.71. While religious cultural value was found as INR 9840231.35 and the corresponding consumer surplus was found to be INR 15.01. Households involved in tourism had higher average income than the households dependent on other sources. Nature based tourism was found to contribute more to average annual income of involved households but as more families were involved in religious tourism activities, the overall contribution and dependence on religious tourism was more.

The data for attitude of local people towards benefits from forest and conservation practices was collected in three stages through review of secondary information, selection of villages for extensive survey and semi-structured questionnaire based interviews. The results show that the attitude of people of NDBR was significantly positive towards the environment and its services. Respondents gave high values to all the services, though direct services (fuel wood and fodder) were given maximum value (4) maximum number of times in comparison to indirect services. A significant difference was found between the values, given by people living close to forest and away from forest ($U= 71169.5$, $Z= -3.486$, $p<0.000$). There was a significant difference between the values attached to ecosystem services provided by degraded and less-degraded forest (oak forest: $U= 4672$, $Z= -11.345$, $p<0.000$; mixed conifer forest: $U= 10500$, $Z= -5.299$, $p<0.000$; moist temperate deciduous forest: $U= 4743$, $Z= -6.242$, $p<0.000$; deodar forest: $U=0$; $Z= -12.725$; $p<0.000$). The attitude of respondents was found to be positively correlated with, average years of schooling of households, $r(763)= + .114^{**}$, $p< 0.005$, benefits (both direct and indirect contribution of the forest, $r\ (763)= +.096^{**}$, $p<0.005$ and total income (earning from forest and other livelihoods), $r(763)= +.218^{**}$, $p<0.000$). The attitude towards indirect benefits was found to be positively correlated with, educational status of the individual and overall household, $r(763)= + .131^{**}$, $p<0.005$, benefits (both direct and indirect contribution of the forest, $r\ (763)= +.149^{**}$, $p<0.005$ and total income (earning from forest and other livelihoods), $r(763)= +.189^{**}$, $p<0.005$). Similarly, attitude towards direct benefit was found to be positively correlated with educational status of the individual and overall household, $r(763)= + .080^{*}$, $p< 0.05$, benefits (both direct and indirect contribution of the forest, $r\ (763)= +.077^{*}$, $p<0.05$ and total income (earning from forest and other livelihoods), $r(763)= +.163^{**}$, $p<0.005$). The correlation between attitude towards overall and indirect benefits was found to be more significant as contributions of these services is not visible in the day to day life of dependent families. The contribution of direct benefits was visible and understood by the users irrespective of their educational or economical status. The gender also played an important role in structuring individual's attitude towards ecological services provided by natural land use type. There was significant difference between attitude of male and female member of the community ($H= 7.496$, $p\leq0.005$). Men have given more score to the total benefits provided by the nature than women and similar pattern was observed for direct and indirect benefits. This difference was found to be significant for direct and indirect benefits and total benefits together. The difference in the attitude of men and women can be attributed to the difference in the educational status of both and men get more chances to visit places, participate more in public meetings, get more time and chances to read news paper, watch television. Loss due to human wildlife conflict also found to be related with the attitude of the people and was found negatively associated $\{r(763)= -.206^{**}, p< 0.05\}$.

These services define the overall human wellbeing of the local communities of NDBR. Human wellbeing index was found to be higher for the households living near the forest than those living away from forest. To assess the socio-economic status of the local communities and human wellbeing, interview based questionnaire were used. Different indicators of human wellbeing (environmental, workplace, political, social and health) were used to assess it for the local communities of NDBR. The average annual income per household was found to be INR 95646.4 ±3332.4 of which 15.6% (INR 15315.10 ±495.67/hh/year) and 21% (INR 20702.4 ±617.35/ hh/year) was contributed by natural ecosystem by providing different natural resources and agriculture production, respectively. I compared the overall wellbeing index and found that it was higher for the households living closer to the forest than the households situated away from forest, the difference was statistically significant ($U= 525840$, $Z= -2.589$, $p<0.05$). The difference was also found significant for the environmental wellbeing ($U= 40840$, $Z= -9.402$, $p<0.000$), social wellbeing ($U= 51340$, $Z= -3.399$, $p<0.005$) and health wellbeing ($U= 51054$, $Z= -3.428$, $p<0.005$) which were higher for the households close to forest. Condition of forest (degraded and less degraded) also affected the status of wellbeing for the dependent households and was found high for the households located near less degraded forest. Environmental ($U= 43190$, $Z= -13.434$, $p<0.000$), workplace ($U= 67720$, $Z= -2.058$, $p<0.05$), health ($U= 64830$, $Z= -2.916$, $p<0.005$) and overall wellbeing ($U= 64120.5$, Z= -2.909, p<0.005) were found to be significantly different between the households dependent on degraded and less degraded forest.

Although, the provisioning and cultural services contributed to the human well-being immensely, they are mostly underrepresented in the national market and policy making. The markets for these goods and services are present for only some of the services, due to which services of NDBR landscape do not receive due importance in policy decisions. Existing markets fail to conserve ecosystem services because they lack mechanisms to compensate resource users and thus do not send signals that encourage participants to use and manage natural resources sustainably. The services (especially regulating services) obtained from this region and their linkages with human welfare are being recognized by national level legislative measures, such as National Mission for Sustaining the Himalayan Ecosystem (2009). Also, at local level people were highly aware of the direct services (fuel wood and fodder) provided by the NDBR ecosystem. But almost half of the tourists visiting the pilgrimage sites in the NDBR were not aware of the protection status and objectives of protection for the region. One third of the visitors did not know how the conservation status of the area will improve the condition of natural ecosystems.

Presently the market for services provided by NDBR are nascent as demand on existing services, the opportunity costs of conserving services and unclear property rights, add to the complexities of understanding of the value of ecosystem resources and results in over use of the common property resources. However, I have given estimate of the ecosystem service value of NDBR, which can be used for measuring trade-offs between society and the nature when natural resources can enhance human welfare in a sustainable manner. Regulation and clarification of property rights (ownership and use rights) is considered crucial while dealing with the issue of market failure arising due to notation of ‘free goods’ and ‘easy access’. Market based instruments (MBI), which aim at behavioural change by changing prices in existing markets can be applied in case of NDBR. MBI can be price based or quantity based market instruments, such as environmental taxes, charges, fees and penalties that would internalize negative externalities, payment for ecosystem services and rewards for conservation friendly behavior to address positive externalities. Other MBI aims at making existing markets work better through information and transaction costs. Some of the MIB, such as taxes, tolls, fees, permits, administrative charges can be levied.

The efficacy of vertically integrated governance structure has been advocated to be the ideal model for public participation, and only recently studies have started focusing on hierarchical governance in tourism. A layered and complex institutional arrangement, created with the participation of multiple agencies working in close coordination is able to channel the benefits of tourism to local people. Such institutions are capable of adapting and responding to the challenges of a globalized economy, but the government institutions need to evolve more effective and stricter mechanisms to deal with unforeseen challenges.

The buffer areas of NDBR are being influenced by policies of different sectors, implemented through different government agencies, which often work in isolation. Often the objectives of these sectoral developmental plans are in contradiction to the forest conservation objectives. The National Biodiversity Action Plan 2008 and National Mission for Sustaining Himalayan Ecosystems 2009, provide measures for reducing the environmental impacts of production and use of ecosystem goods and services. These legislative measures emphasize the need for incorporating the costs of depletion of natural resources into the decisions of economic actors to reverse the tendency to treat these resources as “free goods” and to pass the costs of degradation to other sections of society, or to the future generations, thus integrating environmental concerns in economic and social development. These mission and action plans have no legislative backing.

On the basis of the results of the present study following specific recommendations are made:

1. Forest resources have significant contribution to the local economy of the NDBR landscape. This is almost comparable to the contribution of the agricultural output. Policy and management sector have to recognize this.
2. Most of the ecosystem services generated from the forested ecosystem of the NDBR, due to their off-site nature, do not benefit the local communities. To capture ecosystem services such as freshwater, site specific strategies for instance storing and distribution channel should be developed to channelize the functional output of the streams to the villages which are not able to use the services due to terrain and distance from the water resources. Micro-hydel projects can be developed as they help and support local communities more than bigger hydro-electric projects.

3. Almost 100% of the households surveyed were found to be dependent on the forest, which is impacting the quality of forest and also hampering their ability to provide other ecosystem services. Direct dependence on natural resources can be reduced through providing alternative non-forest based livelihoods such as nature and culture based tourism and ensuring equity in benefits.
4. The social and economic vulnerabilities were found to result from lack of better education. Educational facilities, especially vocational training, should be provided to diversify livelihoods.
5. Tourism is clumped at few valleys and pockets in the areas hence, providing niche based jobs such as tourist trekking guide and porters, benefiting only small number of residents. The benefits can be shared by introducing and developing tourist attractions like farm tourism, cultural tourism, homestays.
6. Onsite tourism related leakages occurring due to economic capitalization should be channelized to local communities based business sectors e.g. homestays, market for local handicrafts.
7. Local varieties of crops should be promoted and subsidized (MBIs) for its popularity in nature-based tourism. This will help in maintaining the agro-biological diversity and food security particularly for women and children.
8. Traditional crops production will help in reducing exploitation of natural resources for cash crop based agriculture.
9. Most of the cases of crop depredation reported by respondents were for cash crops, promotion of local varieties can help to reduce the loss caused by such conflict cases.
10. Payment for ecosystem services strategies like, Grain for Green Programme (also known as Grain for Tree policy), REDD+, can be adopted and developed to ecological protection and poverty alleviation of the dependent community.
11. Institutions should be identified to develop integrated plan to ensure the conservation of natural resources and continuous flow of ecosystem services, and for the equitable benefit sharing from conservation of natural resources among different stakeholders.

Chapter 1. Introduction

SUMMARY

Ecosystem functions are the conditions and processes occurring in the natural ecosystems. These services include provisioning, regulating, and cultural services that directly affect people and supporting services needed for production and maintenance of other services. As an ecosystem degrades it loses biodiversity value and ability to optimally perform ecological functions and vice versa. Despite the contribution of natural resources towards local, regional and global economy their social value is significantly undervalued by the society. Social and economical benefits from ecosystem services are often ignored in economic decisions as the genuine net benefits are still indistinct. In developing countries like India, the use of forests by rural communities is entrenched in the history and is part of their culture, social and economical paradigm, and local populations are dependent on nature for meeting their daily subsistence needs. These communities share these resources with wildlife hence putting immense pressure on the ecosystem services and the natural resources providing them. In light of the above discussion, the present study was conducted in the NDBR in western Himalayas, to gain a better understanding of the contribution of ecosystem services to elevate the human wellbeing. The study was carried out with the following five objectives (1) assess the socioeconomic status of local communities in Nanda Devi Biosphere Reserve (2) quantify the provisioning services of the Reserve in terms of resource extraction (3) estimate the recreational and religious value of the Reserve and its contribution to local livelihoods (4) assess the extent of human-wildlife conflicts in the Reserve; and to (5) examine the attitude of local communities towards the conservation of the Reserve. To meet the above objectives following five key questions were formulated (a) what is the socioeconomic status of local communities residing in the NDBR? (b) what is the extent of resources that are being extracted from the Reserve? (c) does the recreational value of the Reserve significantly enhance local livelihoods? (d) what is the extent of human – wildlife conflicts in the Reserve? (e) how do local communities perceive conservation of natural resource in the Reserve?

1.1. Introduction

Ecosystem functions are the conditions and processes occurring in the natural ecosystems (Daily et al., 1997). Ecological services are those ecosystem functions that are perceived to support human welfare (Ehrlich and Ehrlich, 1992; Barbier, 1994; Costanza et al., 1997a; de Groot et al., 2002). These services include provisioning, regulating, and cultural services that directly affect people and supporting services needed for production and maintenance of other services (de Groot et al., 2002; MEA, 2003) (Fig. 1.1). These services provide direct and indirect benefits, some can easily be recognized while others are more subtle, and mainly have off-site nature (MEA, 2003).

The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the earth's life-support system (de Groot, 1992; 1994; Barbier, 1994; Costanza et al., 1997b). They consist of flows of materials, energy and information from natural capital stocks which combine with manufacturers and human capital services to produce human welfare (Costanza et al., 1998). Ecosystem services include preservation of the composition of the atmosphere, amelioration and stability of climate, flood control and drinking water supply, waste assimilation, recycling of nutrients, generation of soils, pollination of crops, provision of food and maintenance of species and genetic diversity. Besides they have recreational, aesthetic and amenity values (Ehrlich and Ehrlich, 1992). Biodiversity at genetic, species, population and ecosystem levels contribute in maintaining these functions and services. As an ecosystem degrades it loses biodiversity value and ability to optimally perform ecological functions and vice versa. Many of the functions are provided by all natural ecosystems regardless of their management or conservation status. This is especially true for the regulation and habitat functions. The other functions are more specifically related to human needs and activities and thus to the management objectives. The first two function groups are essential to the maintenance of natural processes and components and are therefore conditional to the maintenance of the availability of the other two (Fig 1.1).

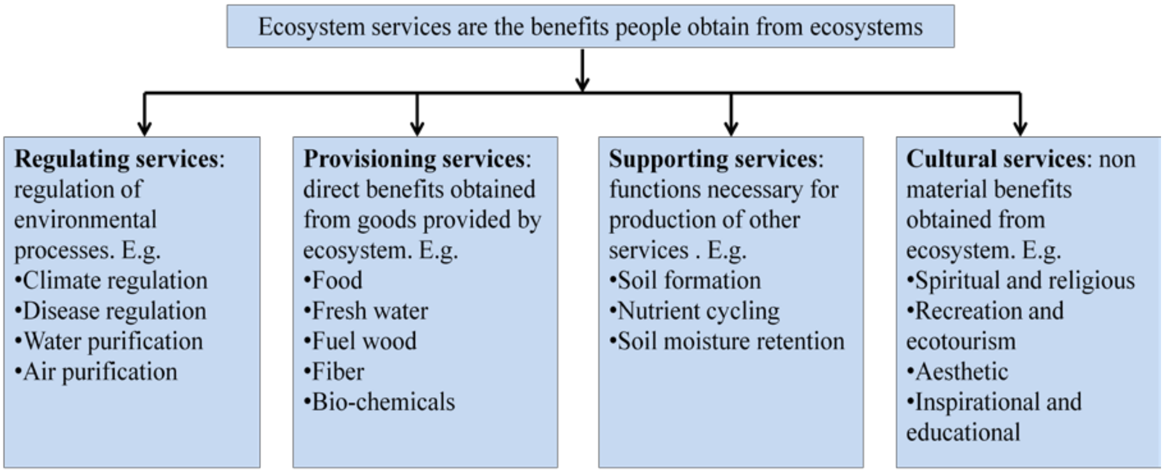

Figure 1.1. Different types of services provided by natural ecosystems (Source: MEA, 2003)

1.1.1. Linking ecosystem services and human wellbeing

Changes in availability of ecosystem services affect human well-being through impacts on security, basic material for a good life, health, and social and cultural relations (MEA, 2005a). Over recent years, much progress has been made towards getting a better understanding of the role of the natural environment in contributing to our economic performance as a country and as individuals. Environmental assets provide benefits that enhance economic performance, offer new opportunities for investment and employment, and improve living standards and quality of life. Enhancing or diminishing the condition of environmental assets increases or reduces the stream of benefits communities can derive from them in the future. Humans utterly depend on ecosystem resources and services for economic and cultural well-being (White and Pettit, 2004; Cummins, 2005). The ecological, economic, personal and social security of the local communities has a direct and strong link with the ability of the natural ecosystems to provide services (MEA, 2003).

In territorial ecosystems, forests provide most of the services especially regulatory (e.g. carbon sequestration and regulation of water regimes) and provisioning services (e.g. provision of freshwater, fodder and food) (Deal et al., 2010; Smith et al., 2011). Forests provide diverse economic and social benefits to human societies. These include contributions to the economy through employment, forest products and energy sources and investments in the forest sector (Sharma et al., 2012). In forested areas of developing countries, there are communities which are dependent on the forest for a range of goods and services. These communities generally lack alternatives to their existing way of life which make them vulnerable to degradation of quality and quantity of ecosystem services (Peluso, 1993; Peluso et al., 1994) (Fig. 2). This also creates a challenge for the society to sustain natural resources while promoting economic growth and achieving the goals of sustainable development (Jordan et al., 2010). The role of forest resources in development, poverty alleviation and improving food security in developing countries have been accepted and confirmed by committee on world food security at sessions in 1996 and 2002, UN's millennium assembly in 2000 and Global Sustainable Development conference in 2002 (Faham et al., 2008). Not only economic but the social organization of the communities are also influenced and dependent on the availability and accessibility of forest resources for the daily requirements e.g. food, fodder, forest product to support the agriculture etc. Despite the contribution of forested landscapes towards local, regional and global economy their social value is significantly undervalued by the society. Social and economic benefits from ecosystem services are often ignored in economic decisions as the genuine net benefits are still indistinct.

Ecosystem degradation tends to harm rural populations more directly than urban populations and has its most direct and severe impact on poor people. The wealthy control access to a greater share of ecosystem services, consume those services at a higher per capita rate, and are buffered from changes in their availability (often at a substantial cost) through their ability to purchase scarce ecosystem services or substitutes (MEA, 2005a). High degree of dependence of people on forest resources and their ecological and economical services, and availability of these resources define the social and economical structure of community (Figure 1.2).

In developing countries like India, the use of forests by rural communities is entrenched in the history and is part of their culture, social and economical paradigm (McSweeney, 2004; Paumgarten and Shackleton, 2011) and local populations are dependent on nature for meeting their daily subsistence needs (Chandola, 2012). Most of the rural communities in India still survive on marginal non-sophisticated agriculture and livestock production which are basically dependent on forest products.

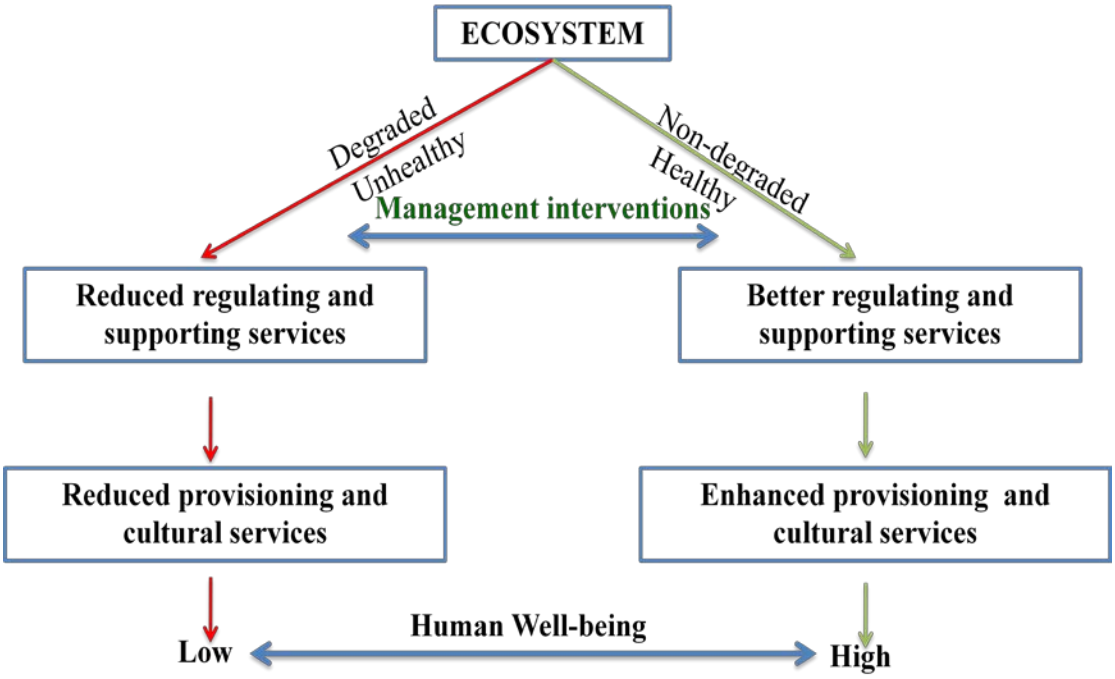

Figure 1.2. Flow of ecosystem services and its impact on human wellbeing

1.1.1.1. Direct benefits: provisioning services

Provisioning services, or the supply of goods of direct benefit to people, and often with a clear monetary value, such as timber, medicinal plants, fuelwood, fodder and food. Human societies are highly dependent on the supply of provisioning services (food security, environmental and ecological security and sustainability) provided by natural ecosystems of their vicinity (Power, 2010).

The concept of dependence stems from a rural sociological perspective on communities and their interaction with risky resources, primarily in a North American context (e.g., Machlis and Force, 1988; Machlis et al., 1990; Freudenburg, 1992). The direct contribution of natural resources depends on the availability, accessibility and economic and physical condition of the user. The dependence on resources for direct benefits relates to communities and individuals whose social order, livelihood and stability are a direct function of their resource production and localized economy (Machlis et al., 1990). The World Bank (2002) highlighted that more than one billion people depend on forests for their livelihoods to varying degrees. The direct benefits to communities vary with time, place and economical and social conditions (Adhikari et al., 2004). The rural communities are dependent directly on forests for almost all the basic necessities of life. Provisioning services of the forest are more valued than other services locally (Power, 2010) as they help the people to meet the daily needs. Contribution of forests in household economy of communities who live in or close to the forests has been increasingly recognized (Byron and Arnold, 1997). For millions of forest forms such a dominant part of their physical, material, economic and spiritual lives that its importance is not most appropriately described and assessed in terms of the individual products or services that the forest provides. Especially in the developing countries, forests are the main source of fuel, timber and fodder. Diminution of forest will degrade the living standards of the local communities as well as ecosystem stability of the landscape (Singh and Sundriyal, 2009). Traditionally the fuel wood has been the only source of energy to the rural mountain communities. Livestock and agriculture has always been completely dependent on the forest products. Local communities who live in the close vicinity of forests will face both direct (depletion of ecosystem goods) and indirect (climate change) impact of degradation of forest resources. These natural resources form the base for the sustainability of both wildlife and human society. Constriction of resources and growth in any population forms a condition of conflict among them.

Forests also act as a source of freshwater for the local communities. This freshwater plays multiple roles as provider of supporting, regulating, provisioning and recreational services (MEA, 2005b; Smith et al., 2006; Greiber, 2009; Mayers et al., 2009) and is thus critical for water ecosystems (Shiklomanov, 1998). With rising demands of the growing population and development needs, water is becoming increasingly scarce and vulnerable, compromising its environmental functions. Considering the importance of freshwater systems to human survival and well-being, natural processes and properties that maintain freshwater ecosystem should be identified and monitored on both local and global scales (Karr, 1991) and all water resources should be treated as an ecological and economical commodity. Climate change has affected the stream flow directly by altering the trends of precipitation, temperature and evaporative demand (Stern, 2006; Alavian et al., 2009) resulting in dryer dry seasons, wetter rainy seasons and degradation of water resources (IPCC, 2007). As ‘‘water towers,’’ mountains supply water to nearly half the human population, including some regions far from mountains, and mountain agriculture provides subsistence for about half a billion people. Key mountain resources and services include water for hydroelectricity, flood control, mineral resources, timber, and medicinal plants.

1.1.1.2. Indirect benefits: Cultural services

The human activities on earth have expanded to such an extent that all ecosystems are modified and degraded (Boulding, 1966; Daly and Cobb, 1989; Vitousek et al., 1997). This forced the managers to focus on indirect values and services of forested landscapes. As these benefits do not generally attract a price, they are often referred to as non-market benefits (NMBs): they include open access recreation, public amenity and landscape benefits, biodiversity, and carbon sequestration, as well as a number of other environmental and educational benefits. These NMBs can be described as ‘public goods’ - they can be enjoyed by everybody, and the fact that one person benefits from them does not usually affect the enjoyment of anyone else. The open-access nature of such public goods means that it is difficult to charge people who want to enjoy them, and therefore such goods are not provided by market mechanisms which tend to be driven by profit. For the same reason these public good benefits are not reflected in the national income accounts. Nevertheless, the public-good aspects of forest management make a significant contribution to the overall welfare of it. If the NMBs of forests are incorrectly valued, or if NMBs are not fully incorporated into decision making on resource allocation, or into management decisions on the structure of individual forests, then an optimally efficient allocation of resources will not be achieved, and societal welfare will not be maximized. Recreation is one of the numerous services provided by ecosystems. The value that users attach to nature recreation can be substantial although it is not reflected by market prices and is provided as quasi- public goods (Zandersen and Tol, 2009). Nature based tourism has emerged as an instrument for employment generation, poverty alleviation and sustainable human development.

Globally, an estimated 842 million people were international tourists in 2006. The number of international tourists is expected to double again by 2020 (Manfredo, 2008). However, overexploitation and increased social costs of natural resources is an important issue on the global agenda. Environmental valuation methods have been widely applied to value these benefits and losses to support sustainable management of natural resources (Barbier et al., 1997; Gürlük and Rehber, 2008). On a practical level, taking these values into account can make a significant difference in the management, conservation and planning options for nature recreation. On a research level, gaining knowledge on the range of values attributed to ecosystems, dependent on population characteristics, quality and quantity of the natural resource as well as specification of demand models is essential when assessing general trends and impacts on the use of forests for recreation. The recognition of economical benefits of recreation has provided a sound economic rationale globally and has been identified as a tool for biological conservation (Ahmed et al., 2007). The benefits of nature-based tourism to biodiversity conservation are often presumed but rarely quantified (Naidoo and Adamowicz, 2003).

1.1.2. Impact of degradation of important ecosystem services: a function of ecosystem

Human Wildlife Conflict

In developing nations and especially in rural areas, human societies and wildife share and compete for the same natural resource. This extra pressure degrade the quantity and quality of ecosystem services and also affects the ability of the natural ecosystem to provide these services (Chan et al., 2006; Barua et al., 2013). Human wildlife conflict (HWC) is a result of actions which degrade and fragment habitats of wild population e.g. logging, animal husbandry, agricultural expansion and developmental projects (Fernando et al., 2005; Thirgood et al., 2005) and impede the economical and social security of people e.g. attack on livestock and human and crop raiding (Graham et al., 2005). Due to high intensity and frequency of HWC marginal human societies and wild population face vulnerability. Intensity and frequency of conflict also determine and frame the attitude of people towards wildlife which directly affects the survival of many populations (Manfredo and Dayer, 2004; Woodroffe et al., 2005). Incidences of livestock lifting, crop raiding and attack on human reduce tolerance of human societies towards wildlife (Linkie et al., 2007; Campbell-Smith et al., 2010). Conflict and attitude of people are mainly location specific and influenced by personal experiences, socioeconomic and political conditions (Messmer, 2000; Graham et al., 2005). HWC confront human welfare, health and security, and have economic and social costs (Ogra, 2008; Ogra and Badola, 2008) as well has become a threat to many endangered wild species (Woodroffe et al., 2005).

HWC or negative interaction between people and wildlife has recently become one of the fundamental factor of wildlife management as it represents the most widespread and complex challenge currently being faced by the conservationist around the world (Woodroffe et al., 2005). HWC is the not only a main concern for the conservation of biodiversity but also major challenge for social and economical security of local communities. To resolve this issue dependence of people on nature should be reduced by providing alternative means of livelihood. Sustainable indirect use or recreation use of resources can be developed as a tool to enhance the economical status of communities.

Human well-being can be enhanced through sustainable human interaction with environment and its products with the support of appropriate management instruments, institutions and improved technology. Creation of these through participation and transparency may contribute to people's freedoms and choices and to increased economic, social, and ecological security. For poor people, the greatest gains in well-being will occur through more equitable and secure access to ecosystem services. In the long run, the rich can contribute greatly to human well-being by reducing their substantial impacts on ecosystems and by facilitating greater access to ecosystem services by the poor. The quantification of environmental income may serve as an input into conservation policy, and particularly establishment of protected areas, by determining the potential loss to rural dwellers of reduced access to environmental resources. Economic valuation of biodiversity is important since it provides a useful vehicle to highlight and quantify the range of benefits delivered by biodiversity. Importantly, placing monetary values on biodiversity and its ecosystem services will bring biodiversity into a common currency for use in decision-making, allowing its benefits to be directly compared with other development trajectories.

1.2. Review of literature

Previously, attention of studies was focused to the relationship between community stability and sustained timber yields (Beuter and Schallau, 1978; Huebner and Holden, 1988; Jackson and Flowers, 1983; MacCleery, 1983; Machlis and Force, 1988; Schallau and Maki, 1983; Waggener, 1977), and only few attempts have been made to identify and measure other aspects of contribution of the natural resources to human well-being in forest-dependent communities. Kaufman and Kaufman (1946) studied forest dependence more than a half-century ago, focusing on sustained yield's role in supporting forest sector employment and local economic development. Dependence on forest resources influences households' participation decisions (Jumbe and Angelsen, 2007; Mwangi et al., 2011), as forest dependence is associated with increased income but relatively unstable employment (Patriquin et al., 2007; Musyoki et al., 2013). Forest product collection from community forests is dependent on various socioeconomic variables (Adhikari et al., 2004; Sapkota and Oden, 2008). Sapkota and Odén (2008) exemplify that individual household's socioeconomic status reflects the fuelwood needs and their ability to access the community forest for fuelwood collection. More precisely, poor depends directly on the forest as their pattern of fuelwood collection is very high (Fisher, 2004; Jaiswal and Bhattacharya, 2013).

Various studies have estimated income generated from non-timber forest products (NTFP) using household data (Gunatilake et al., 1993; Sills et al., 2003; Jimoh and Haruna, 2007; Mulenga et al., 2012). Berck et al. (2003) suggested that a primary motive in defining forest dependency is its relevance for policy. Mallik (2000) estimated the total percentage of income derived from forest varied from 22% to 41% in different forest areas. Chopra (1997) discussed user valuation of different NTFPs and evaluated marketing channels from the viewpoint of efficiency. Kant (2000) showed that the rate of change in social and economical attributes of rural households is directly proportional to the rate of change in resource use. Badola (1997); Ogra and Badola (2008), found that people living near the protected areas are largely dependent upon nearby forests for domestic and subsistence resources. Forests have not only influenced the economical but also the social structure of the dependent communities (Bray et al., 2008; Mbairamadji, 2009) and vice versa (Dietz et al., 2006). From the analysis of Hegde and Enters (2000), level of education was also found to be an important variable in reducing the forest dependence. The number of years of education as well as of employment available to the villagers is highest in the villages that are located farthest away from the protected area boundary while it is the lowest for the villages that are adjacent to the protected area boundary (Badola and Hussain 2003; Hussain and Badola, 2010). Studies on socioeconomic structure of forest dependent communities are mainly focused on the contribution of forest products in term of NTFPs but have overlooked the relationship between overall human well-being and forest resources, although workers have looked into forest dependence and human well-being separately (Gibson, 1944; Kaufman and Kaufman, 1946; Frey and Stutzer, 2010; Demps et al., 2012).

Only few studies have been conducted globally to link the human well-being and forest condition. Studies by Elo and Beale (1983), Fortmann et al. (1991), Overdevest and Green (1995) and Stedman et al. (2005) investigated the relationship between forest dependence and community well-being. However, these studies did not adopt a holistic approach for the study of communities' well-being and concentrated mainly on economic well-being and were unaware about the other services of forests and their influence on over all well-being of people which depends on political, social and health well-being of the community. The dependence on forest products leads to the degradation of the resources and end up in a conflict between human societies and wildlife (Wolfe et al., 1998).

Interaction between human and wild animals has increased in last few decades (Zack et al., 2003; Baruch-Mordo et al., 2008). It has been considered as a major challenge for conservation and management of many wildlife populations (Fascione et al., 2004; Manfredo and Dayer, 2004). Reducing conflict between wildlife and people is considered a top conservation priority, particularly in landscapes where high densities of people and wildlife co-occur (Treves and Karanth, 2003; Dickman, 2010; Karanth et al., 2012). The HWC is mainly attributed to change in agriculture practices (Campbell-Smith et al., 2010), land use pattern (Okello, 2005) and growing human population (Newmark et al., 1994; Mishra, 1997). Frequency and intensity of HWC varies from place to place (Mwangi, 2013) and depends on species (McPherson et al., 2004) and forest resource availability (Barua et al., 2013). Status of HWC frames the attitude of people towards wild animals and conservation practices (Manfredo and Dyer, 2004). Positive attitude of people have been observed in area with less or no conflict and where people are being benefitted by presence of wildlife (Gillingham and Lee, 1999), while high conflict have caused negative attitude among community (Gore and Kahler, 2012). Understanding and assessing social factors as perception and attitude is an important aspect of human wildlife conflict mitigation strategy (Lowery et al., 2012).

Previous studies on attitude towards provision of ecosystem services, have mainly focused on services of man modified landscapes i.e. agriculture (Swinton et al., 2007; Power, 2010; Sandhu et al., 2010). Lindemann-Matthies et al. (2013) found a preference towards high biodiversity value in China. Badola and Hussain (2005) also observed the same pattern of attitude and awareness among local communities towards benefits provided by the mangrove forests of east coast of India. Gadd (2005) found that pastoral communities of Kenya with indirect financial benefits expressed the positive attitude towards ecosystem for aesthetic value.

Conservationists are increasingly giving more importance to the attitude of local people to strike a balance between the biodiversity conservation and socioeconomic needs of forest-dependent communities. Natural resource managers and conservationists in the recent years view local peoples' support for protected areas management as an important element of biodiversity conservation (Sekhar, 2003). There are many scholars that studied attitude of local people towards conservation. Wallner et al., (2007) demonstrates that in order to improve ecosystem based management, it is important to know the mental models of the local population living in the surroundings of protected areas. Tessema et al. (2010) found that local residents of Ethiopia generally held positive attitudes towards wildlife and nearby protected areas mainly due to its attraction to tourists, hunting opportunities during drought, enjoyment derived from viewing wildlife, and its value for future generations. Harada (2003) states that people recognize and understand the importance of the global conservation of the PA and agree that local participation is indispensable for conservation. Wang et al. (2006) examined the important issue of the attitudes and feelings of people concerning conservation policies and wildlife conflicts which affect their behaviour, and understanding in Jigme Singye Wangchuck National Park, Bhutan. Their results shows that the almost half of the respondents (52.2%) had a negative attitude towards the Park and its conservation policies because they believed that their livelihoods were in jeopardy because of the Park and its policies, and the majority expressed discontent with the restrictions imposed by authorities on access to Park resources. The findings of Rao et al. (2003) indicate that local residents do not have adequate knowledge about objectives of the biodiversity conservation and protected areas. Walpole and Goodwin (2001) state that costs associated with conservation (such as wildlife damaging crops) have negative effects on local attitudes, whilst benefits from conservation (such as tourism and game meat) may have some positive effects. Mehta and Kellert (1998) found that attitudes towards protected area tourism were more positive among those receiving economic benefits from tourism than those not economically benefiting. Badola and Silori (1999) shown that, after explaining the concept of biosphere reserve in terms of conservation and natural resources, people agreed on the concept but at the same time they repeated their demand for a right on resources from the reserve. Badola and Hussain (2003) found that in Bhitarkanika mangrove ecosystem majority of the local people (89.6%) were aware about the protected status of the area and that it is a Wildlife Sanctuary and National Park and high percentage of respondents felt a sense of responsibility towards conservation of flora and fauna. They conclude that the education is one of the major variables, which can affect conservation, attitudes and awareness. A study by Sinha and Badola (2006) shows that the local people understand the forest very well in terms of biology, physiology and use of various species found there. They are aware of and appreciate the contribution of forest in protecting their lives from the natural hazards and sustaining their livelihood. Ambastha et al. (2007) shown that as local people living near Kabartal wetland, India are not getting any direct benefits and are poor, have low literacy levels and high dependence on wetland, want that wetland should be drained and the land used for agriculture. However, they are willing to participate in collaborative management initiatives with the state.

Previously few scholars have said that these issues (conflict between human society and wildlife and negative attitude of people) can be addressed by providing alternative source of income. Often eco-tourism and wildlife tourism is proposed to be used as a tool to develop sustainable livelihood for people who bear the cost of conservation and repeatedly been ignored while making strategies for conservation and development. Before incorporating any plan to develop recreation value of a place into livelihood one should know the potential value of that place.

Estimation of recreation value now has become a great tool for decision and policy making. Many studies have been done to estimate the recreation value of different places all over the world. The travel cost method (TCM) has been developed by Clawson (1959) to evaluate the recreational value of natural sites. TCM has been used extensively around the world to value public recreation sites with minimal or no admission charges. Greig's (1973) study of the Grampian Mountains in Victoria, Australia represents one of the earliest applications of the travel cost method to estimate the recreational value of the place. Western and Thresher (1973) estimated tourism value of protecting an area to maintain a big animal population under ‘optimistic’ agricultural returns. Western and Henary (1979) estimated the gross worth of lions in Amboseli National Park in Kenya. Many subsequent studies have paid particular attention to estimating the recreational values of protected areas across the globe (Ulph and Reynolds, 1981; Knapman and Stanley, 1991; Scoccimarro, 1992; Stoeckl, 1994; Beal, 1995a, b; Herath and Kennedy, 2004; Fleming and Cook, 2007). Othman et al. (2004) assessed the economic values of sport fishing recreational services at Matang mangroves by estimating a TCM demand function. Mendes and Proença (2011) used the travel cost method to estimate the recreation value of an ecosystem, Study by Iamtrakul et al. (2005) in Saga city, Japan; shows that assignment of monetary value demonstrates an intuitive appreciation for environmental valuation based on park visitors’ preference. Houston (1996) establishes the importance of shoreline preservation to the U.S. economy and the importance of tourism, and particularly visits from abroad, to the economies of coastal states and to the nation as a whole. Stronge (2001) takes the same approach one step further, by establishing in detail the economic benefits that accrue from shoreline preservation. King (2002) documented the benefits of beaches and beach nourishment to the State of California. He concludes, “the loss of tax revenue from diminished tourism substantially exceeds the cost of maintaining these beaches." Pompe and Rinehart (1995) using a hedonic pricing model, estimate the effect of beach quality on property values in two South Carolina coastal towns. The authors conclude that “the willingness to pay for wider beaches is an indication of the size of the storm protection and recreational values produced by wider beaches." Carr and Mendelsohn (2003) address an important issue concerning measuring international travel cost.

Some studies have been done on recreational value in Indian context. Chaudhry and Tewari (2006) estimated the recreation value of Chandigarh city by using travel cost method. He calculated that the recreation value of the city as 92.40 millions. Chaudhry and Tewari (2008) collected data of Indian tourists to estimate the recreation value of Rock garden in Chandigarh by travel cost. Economic valuation of biodiversity of Keoladeo National Park, Bharatpur was estimated using travel cost approach (Chopra, 1997). Badola et al. (2010) have estimated the recreation value of Corbett National Park (CTR), India by using the travel cost method.

From the review of past studies, it is evident that anthropogenic pressures have made Himalayan ecosystems susceptible to the impacts of global warming and climate change as well as reduced their ability to provide life and livelihood security to the local communities. There are wide variations in the level of dependence on NTFP either on the basis of per household or per unit of area, depending on the various socioeconomic factors and the status of the forest. Many studies consider stock of NTFP for valuation purpose. Even though stock is more relevant for forest conservation purpose, from the viewpoint of livelihood of local community, flow concept is more relevant. In the Indian context, none of the studies considered the 'net value' realized by the households. The importance of foregone benefits of forest conservation or the opportunity cost of loss of access to the forest has not received the needed attention in the literature except for a couple of studies; moreover dependence of overall well-being of the local communities on forests has been overlooked. Considering the available literature the present study was carried out to explore the linkages between different type of the human well-being and availability and accessibility of natural resources. The study also explored how degradation and scarcity of natural resources is leading to a situation of conflict among different communities sharing the same resource (wild communities and human societies). Study also aimed to assess the attitude of people towards the different ecosystem services provided by the natural systems. The recreational value of an area can be developed as an alternative livelihood and can be used to upgrade the living standards of forest dependent households and conserving biological diversity by reducing the direct dependence of people. To achieve this present study also tried to evaluate the recreational service and its contribution to the local economy.

1.3. Objectives of the study

The study was carried out with the following five objectives:

1. Assess the socioeconomic status of local communities in Nanda Devi Biosphere Reserve.
2. Quantify the provisioning services of the Reserve in terms of resource extraction.

3. Estimate the recreational and religious value of the Reserve and its contribution to local livelihoods.
4. Assess the extent of human-wildlife conflicts in the Reserve; and to
5. Examine the attitude of local communities towards the conservation of the Reserve.

To meet the above objectives following five key questions were formulated:

1.3.1. Key research questions

1. What is the socioeconomic status of local communities residing in the NDBR?
2. What is the extent of resources that are being extracted from the Reserve?
3. Does the recreational value of the Reserve significantly enhance local livelihoods?
4. What is the extent of human – wildlife conflicts in the Reserve?
5. How do local communities perceive conservation of natural resource in the Reserve?

1.4. Significance of the study

Forest not only provides livelihood opportunities but also the direct and indirect benefits such as aesthetic and recreation. Over the years several studies have been carried out in the Himalayas to study the local communities in terms of culture, lifestyle and their dependence on natural ecosystems. However there are few empirical studies that explored the relationship between forests and human well-being by integrating socioeconomic studies with the direct and indirect services provided by the forested ecosystems. In spite of fulfilling the needs of a large population directly and indirectly (rural and urban respectively) contribution of forest products have been underestimated and undervalued at all levels (locally, regionally and globally). Despite the well established fact that the ecosystem services are the mainstay of human well being (MEA, 2005b), due to poor understanding (Guo et al., 2000) and lack of baseline information (Pagiola et al., 2005) they have largely been ignored both in domestic and international markets and land use law and policy decisions (Barbier, 2007; TEEB, 2010).

Integration of economic and ecological sciences into operational decision support system is fundamental for global conservation and sustainability which is not being possible due to absence of information on status of human well-being and its linkages with the availability and condition of the forest ecosystem services. Although they have been studied separately but the linkage between these two important aspects have been ignored and poorly studied and are generally not considered when planning for the development of the community. This is mainly due to failure of the markets to capture the costs or price associated with the ecosystem services at all levels (regionally, nationally and internationally). This failure is mainly due to lack of primary data on status of availability (type and quantity) and condition (degraded or intact) of ecosystem services, their contribution to economical and social security. There is not much information available that how the presence of good forests can influence the social, environmental, political and professional security of a community which is completely or partially dependent. There is also a need to identify people who bear the cost of forest conservation and those who are benefitted by it. Existing markets have failed to conserve and secure the sustainability of flow of ecosystem services because they lack mechanisms to compensate resource users and thus do not send signals that encourage participants to use and manage natural resources sustainably (Whitten and Shelton, 2005; Arifin and Hudoyo, 1998).

Mountain ecosystem of NDBR provides numerous services including protection of water quality and supply, sequestration and storage of greenhouse gases like carbon dioxide, removal of air pollutants, storm-water storage, soil formation and retention, pollination of plants, habitat and refuge for species of interest to human beings, and others. The flow of these goods and services provide benefits to local inhabitant, downstream communities, visitors, businesses and society in general. Local economy and social setup is completely dependent on the forests and other natural resources of the Reserve. But the contribution of these resources to human well-being and economy has been ignored or underestimated while planning for development of the area. Although studies have been conducted on fuel wood and fodder extraction but only few studies have been conducted in the area to examine the status of many other crucial ecosystem services. The linkage between human well-being and forest has never been studied before.

The study of economical contribution of forest has been centered on biomass extraction or direct uses. Despite of the fact that NDBR is among the most visited

Biosphere reserve for both religious and nature based tourism and tourism being the main source of monetary income for local community, the recreational value of the area has never been estimated before. There is only one study (i.e. Gera et al., 2008) from Valley of Flowers National Park (VoF) which estimated the recreational service of VoF but it is a small part of NDBR and does not fully represent the condition of the whole area. This study is thus a pioneering study on these aspects.

1.5. Organization of the thesis

The thesis is organized into nine chapters. First and the present chapter discussed the social and economical contribution of forests to human wellbeing, dependence of local communities on direct and indirect benefits from forest and interaction between human and wildlife communities. It reviewed the existing studies conducted globally on the subject. The chapter finally highlighted the significance and objectives of the study. Second chapter describes the study area's geographical location, conservation status, environmental and socio-economic attributes. Third chapter assess the biomass provisioned by different forest types and its contribution to local economy. Fourth chapter presents the results of quantification of fresh water provisioned by different forest types. Fifth chapter assesses the economic loss to human society due to different type of human-wildlife conflicts. Sixth chapter presents the estimation of the cultural value (both recreational and religious) value of the NDBR, profile of tourist, reason for visit and attitude and awareness of tourists towards the conservationv status of the area. Seventh chapter assesses the attitude of local communities towards forest and wildlife in their vicinity and direct and indirect benfits they get from forests. Eighth chapter synthesize the social and economical determinants of human wellbeing of the forest dependent community. Ninth chapter concludes the findings of the study and policy reccomendation. Alphabetically arranged bibliographical list follows the ninth chapter.

The framework for the study, represented in figure 1.3 depicts the research approach used for the purpose of quantifying the provisioning and cultural services provided by the natural ecosystem of NDBR and their contribution to the status of human wellbeing of the local communities of the area.

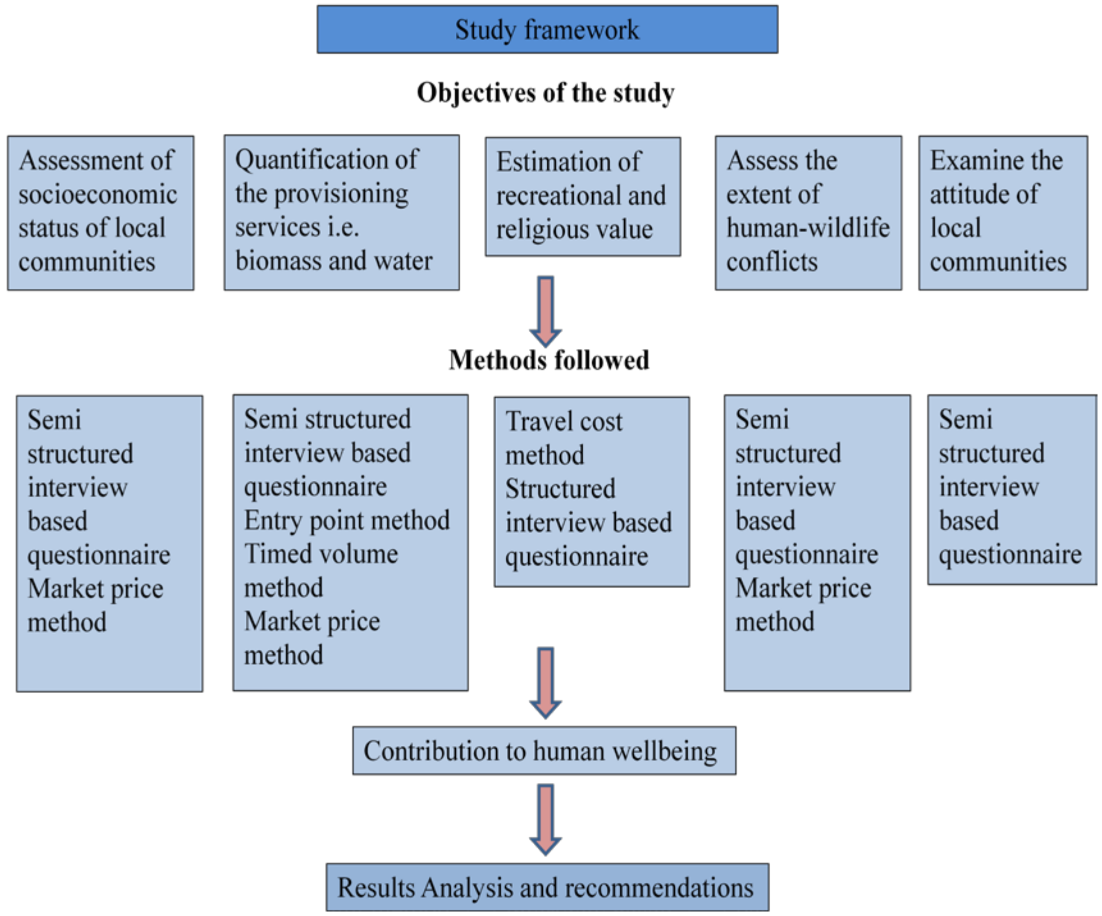

Figure 1.3. Pictorial representation of the approach used to assess the contribution of natural resources in human wellbeing

Chapter 2. Study area: Nanda Devi Biosphere Reserve

SUMMARY

The study has been conducted in Nanda Devi Biosphere Reserve (NDBR). NDBR (30^o 05’-31^o 02’N Latitude, 79^o 12’-80^o 19’E Longitude), located in the state of Uttarakhand, India, falls in the biogeographically classified zone, 2B. The reserve is spread over Chamoli district in Garhwal region and Bageshwar and Pithoragarh districts in Kumaun region of the Uttarakhand State. The NDBR with an area of 6020.43 km^2 is comprised of two core zones i.e. Nanda Devi National Park, 630 km^2; Valley of Flowers National Park, 87.5 km^2; surrounded by a buffer and a transition zones. Both the core zones have been recognized as World Heritage Site by UNESCO. Being in the inner Himalayan region it has a microclimatic condition. Vast altitudinal variation (1800-7817m asl) has given rise to a variety of climates ranging from temperate, sub-alpine and alpine. The climate is temperate and monsoonal and can be divided into long winter, short summer and rainy seasons. Conditions are generally dry with low annual precipitation, but there is heavy rainfall from late June to August. Geologically, the area falls within the Greater Himalaya or Himadri System. A small part of Niti valley has characteristics of trans-Himalaya. Natural forested areas, alpine and temperate grasslands, water bodies (river, small streams and high altitude glacial lakes), snow and glacier area, natural landslide and rocky and barren areas fall under the categories of natural LULCs found in NDBR. Settlements (small townships and villages), agricultural land (terrace farms), orchards, plantation and developmental areas are human modified landscapes. Most of the flora and fauna in the NDBR is native and endemic. Forest types of NDBR can be divided into six categories: Subtropical pine, Himalayan moist temperate, Subalpine, Moist alpine scrub and Dry alpine scrub.

Human habitations are absent inside the core zones but there are 47 villages in the buffer zone and 33 villages in the transition zone with six villages in the immediate buffer of the core zones. *Bhotia* (Indo-Mongoloid) and Garhwali (Indo-Aryan) are the main communities in the area. *Bhotia* people are mainly dependent on handicraft and tourism while agriculture and cattle and goat rearing are the main occupation for the Garhwali communities. Communities of NDBR are culturally and economically dependent on natural resources. Human-wildlife conflict is a major

issue in management of the natural resources of the area. The area hosts a large number of religious and recreational tourists per year, which provide alternative livelihood to the people but also impact the quality of the natural ecosystem.

2.1. Introduction

The Himalayan ecosystems form the baseline for the overall well-being of human communities (Byers, 2005; Kaur et al., 2012) and provide regulating, provisioning, supporting and cultural services necessary for sustenance of life forms on earth (Negi and Agrawal, 2006). These services are very crucial for the survival of the local and downstream communities. 3.8% of India's population inhabits the Indian Himalayas. The region is low in human density (mean=123.7 persons/km^2, as against 273.0 persons/km^2 for the rest of India), underdeveloped (mean Center for Monitoring of Indian Economy Index of development being 82.0 as against 100 for India), as compared to the rest of India (Government of India, 2010). Rain fed marginal agricultural is the most important occupation (Chauhan, 2010) hence dependence on natural resources is very high. The region is characterized by harsh, undulating terrain, small isolated villages, an agro-pastoral economy, small land holdings, dominance of dry farming and less area covered by irrigation. Himalayan glaciers are the origin of major rivers of North India, serving local and downstream communities. However, the capacity of Himalaya to provide many life supporting services has been degraded due to high resource use, rapid development and construction and uncontrolled higher visitations by tourists (Byers, 2005; Shrestha et al., 2012).

Nanda Devi Biosphere Reserve (NDBR) is one of the great wilderness areas of the western Indian Himalaya. NDBR (30^o 05'-31^o 02'N Latitude, 79^o 12'-80^o 19'E Longitude), located in the state of Uttarakhand, India, falls in the biogeographically classified zone, 2B (Rodgers et al., 2000). The reserve is spread over Chamoli district in Garhwal region and Bageshwar and Pithoragarh districts in Kumaun region of the Uttarakhand State. The NDBR with an area of 6020.43 km^2 is comprised of two core zones i.e. Nanda Devi National Park (NDNP), 630 km^2; Valley of Flowers National Park (VoF), 87.5 km^2; surrounded by a buffer and a transition zones. Altitude varies within the range of 1800-7817 m asl. This wide geographical variation has added to the biological diversity of the Biosphere Reserve. The basin is dominated by Nanda Devi, a natural monument and India's second highest peak (7817 m) (Maikhuri et al., 2001) (Figure 2.1). The diverse ecosystems of NDBR provide food, fuel, and fresh water which are needed for human well-being (Silori and Badola, 2000; Bosak, 2008). However anthropogenic factors including unsustainable resource use (Silori, 2007), unplanned development activities such as over constructions of roads, residential buildings, hotels and hydroelectric power projects (Dangwal et al., 2011) and leakage in the tourism revenue have put natural resources under tremendous pressure. Transformation of local economy to market based economy has resulted in loss of forest and agricultural biodiversity (Plate 1).

2.2. Conservation status

The Nanda Devi basin was declared as Nanda Devi Sanctuary in 1939 (Green, 1993), later in 1982 the 630.33 km^2 area was declared as Nanda Devi National Park. In 1988, the area got the status of Biosphere Reserve (Bosak, 2008), with the Nanda Devi National Park as its core zone and an additional buffer zone of 1612 km^2. On February 7th, 2000 the Govt. of India extended the total area of NDBR from 2236.74 km^2 to present area 5881 km^2, by adding the Valley of Flower National park as the second core zone. Additionally these two cores areas, NDNP and VOF were declared as a World Heritage Sites, in 1998 and 2005, respectively (Bosak, 2008). NDBR comprises of 12 beats i.e. Benakuli, Bhyundar, Pandukeshwar, Aira, Urgam, Malari, Dunagiri, Reni, Tapovan, Barhgaon, Joshimath, Salur). These beats are further divided into 11 blocks (Kosa, Kurkuti, Malari, Joshimath, Dasholi-VI, Dasholi-VII, Dronagiri-I, Dronagiri-II, Talla painkhanda, Malla painkhanda and Urgam. These blocks are further divided into 60 compartments (Uttarakhand Forest Department Joshimath Records).

2.3. Administrative zones:

The different types of administrative areas identified within the boundary of the biosphere reserve are as under:

(a) Core zone: This area includes Nanda Devi National Park (630.33 km^2) and Valley of Flower National Park (87.50 km^2).

(b) Buffer zone: This area includes biosphere reserve excluding the area of the core zone. This also includes the areas of multiple use zones.

(c) Multiple use zone: The area of the Buffer zone extends on the south east (up to Nanda Ghunti), north- west (from Nanda Ghunti to village Peng), about five kilometer wide strip (including village Garpag) along Dhauliganga river from village Peng to

Malari, and east about four and a half kilometer wide strip along Goriganga from Samdu to Tota Shilling.

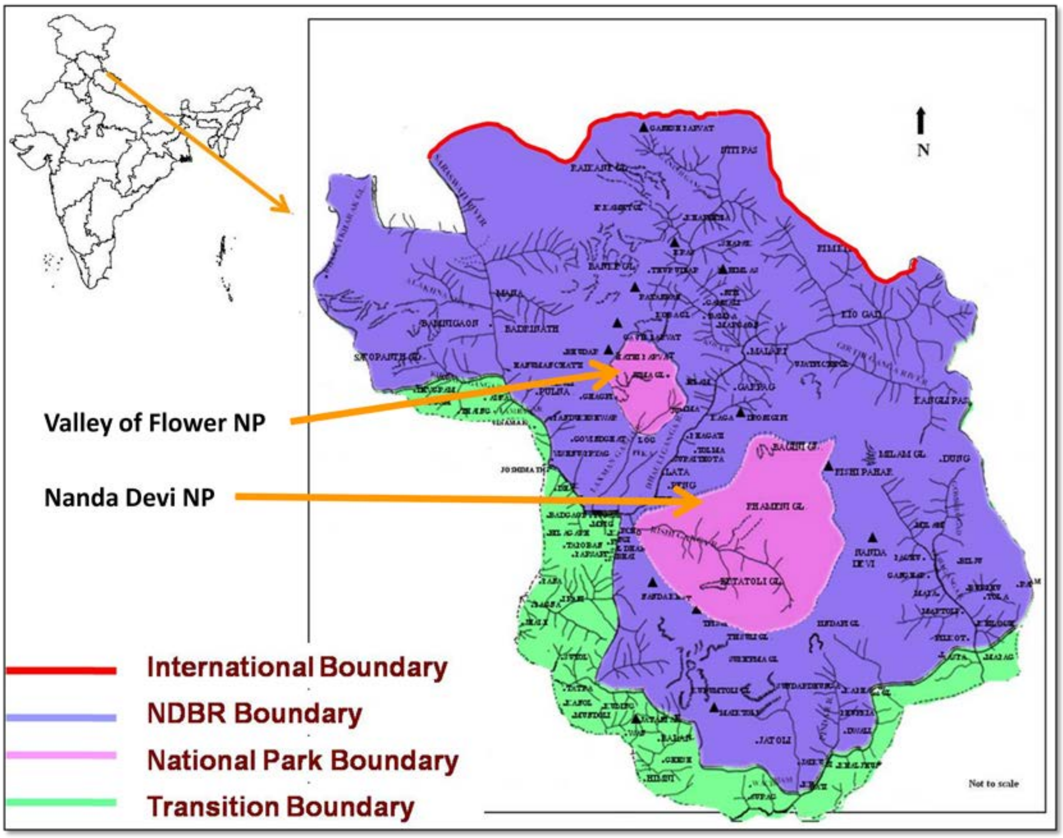

Figure 2.1. Map showing locations of National Parks within NDBR, transition zone and International boundary

2.4. Environmental attributes

2.4.1 Climate

Nanda Devi Basin enjoys the distinctive microclimate, being an inner Himalayan Valley. Vast altitudinal variation (1800-7817m asl) has given rise to a variety of climates ranging from temperate, sub-alpine and alpine. The climate is temperate and monsoonal and can be divided into long winter, short summer and rainy seasons (Purohit et al., 2001). Conditions are generally dry with low annual precipitation, but area receives and heavy rainfall from late June to August (Green, 1993). Most of the area remains snow bound for more than six months in a year. The higher reaches (4500 m asl) remain snow bound throughout the year (Khacher, 1978). Summers are very short starting from mid-May till late August. The temperature in the area vary between -2.3°C to 31.7°C, humidity ranges between 18-88% and average rainfall is 550 mm per year. The area experiences three main seasons i.e. (1) Winter - from

November to March, with heavy snowfall in the months of December, January and February, (2) Summer - from April to mid June and (3) Rainy season - from mid June to September (Gaur, 1999). The region has been divided into five climatic zones by Kaushik et al. (1962) (Table 2.1).

Table 2.1. Climatic zones of Nanda Devi Biosphere Reserve

Sl. No.	**Climatic Zones (Altitude in m asl)**	**Temperature in ^{0}C**		
		Rainy	**Summer**	**Winter**
1	**Sub tropical**	18.9-21.1	19.4-27.2	11.1-13.3
2	**Warm temperate (1800-2400)**	13.9-18.9	21.1-27.2	6.1-11.1
3	**Cool temperate (1800-2400)**	10.3-13.9	17.2-21.1	1.7-2.8
4	**Cold zone (2400-3000)**	4.4-10.3	13.3-17.2	1.7-2.8
5	**Alpine zone (3000-4200)**	3.9-4.5	5.6-13.3	Below zero
6	**Glacial zone (above 4200)**	-	Below zero	-

2.4.2. Geology and edaphic characteristics

Geologically, the area falls within the Greater Himalaya or Himadri System. A small part of Niti valley has characteristics of trans-Himalaya. The crystalline rocks found in the Rishi Ganga basin are sub-divided into four formations i.e., Lata, Ramni, Kharapatal and Martoli. The rock type includes Mica Schist, Mica Quartzite and Schist etc. The soil is mainly black, gray and brown in color. In the higher elevation it is skeleton type. The pH of the soil varies from 4.2 to 6.4 and moisture content oscillates between 21-65% (NDBR, 2002). Region is the head water of several rivers and streams such as Gori Ganga, Rishi Ganga, Dhauli Ganga and Girthi Ganga which are the tributaries of Alaknanda River which later meets Bhagirathi at Devprayag. Pindari and Milam are the most important glaciers of the region.

2.4.3. Land use and land class categories

Area of NDBR can be divided into natural and human modified land use land cover classes (LU/LC). Natural forested areas, alpine and temperate grasslands, water bodies (river, small streams and high altitude glacial lakes), snow and glacier area, natural landslide and rocky and barren areas fall under the categories of natural

LULCs found in NDBR. Settlements (small townships and villages), agricultural land (terrace farms), orchards, plantation and developmental areas are human modified landscapes. About 85% area of the Biosphere Reserve falls under snow and glacier and barren rocky categories. In vegetation classes alpine grasslands occupy the largest area. To support a large volume of tourist every year many governmental and privately owned hotels, inns and guest houses have been built up. In last few years many developmental activities have taken place in the area e.g. hydroelectric dams, new roads to remote villages of area. Conversion between LULCs has also been reported in the Reserve. Agricultural land is being abandoned as new non-farm opportunities are available to the people. Alpine grasslands were converted to summer settlements and agricultural land long back but no such conversion is taking place at present. Land holding division or fragmentation is taking place due to increase in population. People are now growing more cash crops (potato and cabbage) than the traditional grains and millets (Ragi, Fafar, Ogal, Foxtail millet etc.), which has changed locally self sufficient economy to market dependent economy. For the present study a land use land cover map of NDBR was generated using LISS IV imagery National Remote Sensing Centre (Fig. 2.2) (Plate 2).

2.4.4. Forest types

The wide altitudinal range, soil, climatic and microclimatic conditions found in the area has naturally produced highly diverse floral and faunal classes. Most of the flora and fauna in the NDBR is native and endemic (Tak and Kumar, 1983). According to classification given by Champion and Seth (1968) forest types of NDBR can be divided into six categories: Subtropical pine, Himalayan moist temperate, Subalpine, Moist alpine scrub and Dry alpine scrub (Fig. 2.2).

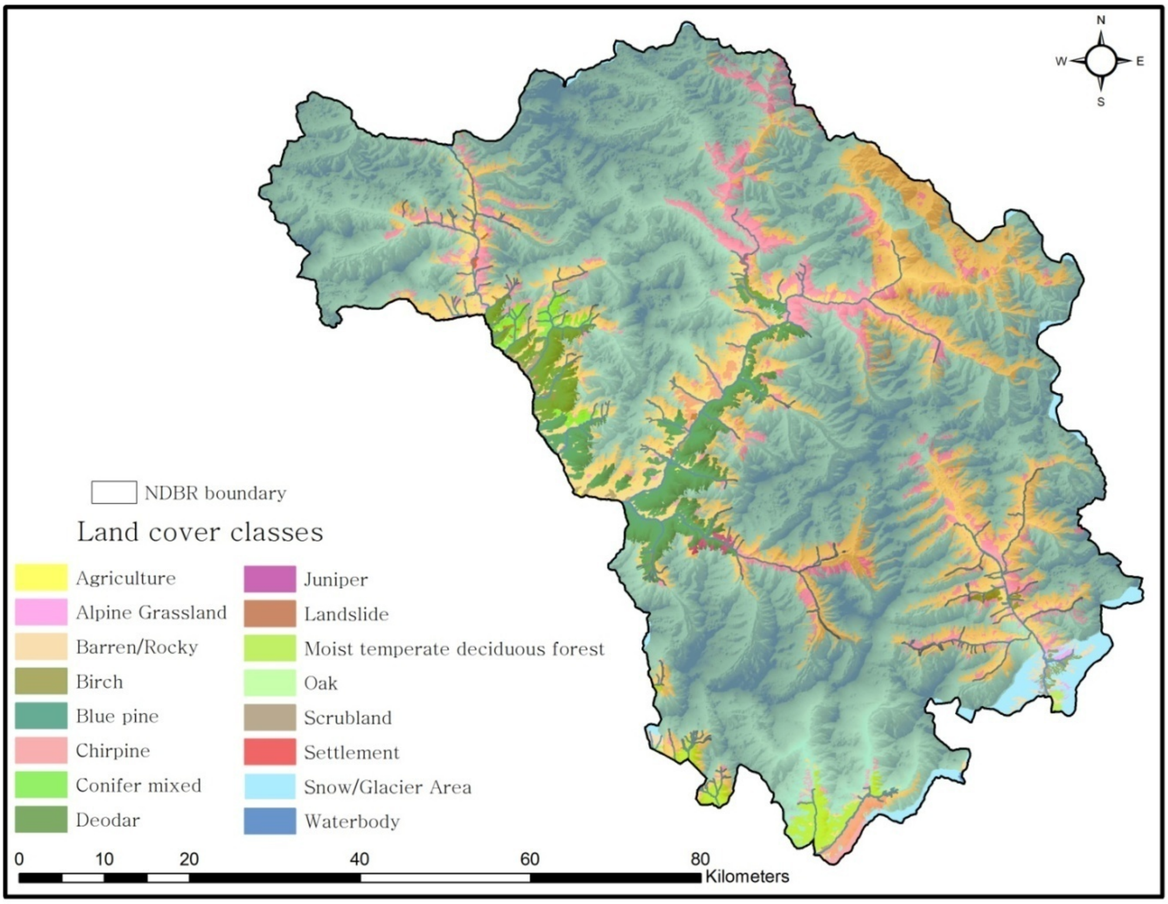

Figure 2.2. Land use land cover map of Nanda Devi Biosphere Reserve

2.4.5. Flora

The biosphere enjoys a very distinctive climate, which helps in harboring a rich floral and faunal diversity. The reserve supports over 1,000 species of plants including bryophytes, fungi and lichens (Uniyal, 2004). The vegetation mainly comprises of temperate, sub alpine and alpine types. The alpine meadow of NDBR supports a wide variety of flowering plants such as *Potentilla* spp, *Geranium* spp, *Androsace* spp, *Primula* spp, *Cyananthus* spp, *Gentiana* spp, and *Morina* spp etc. (Samant, 1993; Samant and Joshi, 2005). The NDNP has about fifteen rare and endangered plant species viz. *Aconitum* spp, *Circeaster agrestis*, *Epipogium aphyllum*, *Listera* spp, *Meconopsis aculeata*, *Nardostachys grandiflora*, *Orchis latifolia*, *Podophyllum hexandrum*, *Saussurea obvallata* and *Taxus baccata* (Hazra and Jain, 1983; Samant et al., 1996).

From NDNP a total of 490 species belonging to 281 genera and 89 families of Angiosperms (480 species, 274 genera and 85 families) and Gymnosperms (10 species, 7 genera and 4 families) have been recorded. Of these, 357 species were herbs, 103 shrubs and 30 trees (Samant and Joshi, 2005). From VoF, 520 species of vascular plants belong to 72 families and 248 genera were recorded. Of 520 species, 498 belong to angiosperms or flowering plants (61 families and 234 genera), 18 Pteridophytes and 4 Gymnosperms. The VoF harbours 472 species of herbs, 41 species of shrubs and 8 species of trees (Kala, 2005).

2.4.6. Fauna

About 520 species of fauna including mammals, birds, reptiles, amphibians, fishes, insects, molluscs and annelids have been recorded from the area (Arora et al., 1995). Nearly 200 avifaunal species have been reported for the reserve (Sankaran, 1994). The important mammals are Snow leopard (*Panthera uncia*), Asiatic black bear (*Ursus thibetanus*), Himalayan brown bear (*Ursus arctos*), Himalayan musk deer (*Moschus chrysogaster*), Bharal (*Pseudois nayaur*) Himalayan tahr (*Hemitragus jemlahicus*) (Kandari, 1981). The area of the reserve lies within the Western Himalayas Endemic Bird Area. Many of the birds species found in the area move down to lower altitudes in the lower Himalayas and foothill while a few migrate down even to the northern plains and peninsular India in the winters. Abundant species recorded include Crested black tit (*Parus melanolophus*), Yellow-bellied fantail flycatcher (*Rhipidura hypoxantha*), Orange flanked bush robin (*Erithacus cyanurus*), Blue-fronted redstart (*Phoenicurus frontalis*), Indian tree pipit (*Anthus hodgsoni*), Rosy pipit (*A. roseatus*), Common rosefinch (*Carpodacus erythrinus*) and Nutcracker (*Nucifraga caryocatactes*) (Sankaran, 1994).

2.5. Socio-economic attributes

2.5.1 Communities of NDBR

NDBR is named after the bliss giving goddess Nanda Devi worshipped by the communities of the region. Human habitations are absent inside the core zones but there are 47 villages in the buffer zone and 33 villages in the transition zone with six villages in the immediate buffer of the core zones. These villages are distributed in Chamoli, Bageshwar and Pithoragarh districts of Uttarakhand state. Along the Dhauli Ganga lies the famed Niti Valley that draws its name from the last village before the Indo-Tibetan frontier. Besides Lata and Reni villages that remain among the best known settlements in this region due to their involvement in the *Chipko* movement, other villages include Jamgavar, Juma, Garpag, Kaga, Peng, Phagti, Surai, Tolma and

Malari. However, these villages are further divided into summer and winter encampments situated at different elevations to cope with the climatic conditions throughout the year (Badola and Silori, 1999; Nautiyal et al., 2003).

Bhotia (Indo-Mongoloid) and Garhwali (Indo-Aryan) are the main communities in the area. *Bhotias* are semi-nomads and have summer settlements in the higher altitudes while their winter houses are in lower regions inside and outside of the biosphere reserve. Most of the Garhwali people have permanent settlements while some of the inhabitants seasonally migrate from summer house (higher altitude or upper ridge of the same mountain) to winter settlements (lower altitude or lower part of the village generally near river) within the same village. Migration from higher altitude to lower altitude takes place because of the harsh winter and unavailability of basic resources. Villagers migrate within same village or locality as the lower settlement (winter) is nearer to collect the riverain outcrop as the flow and volume of the river is less in the winter and it is easy to cross it. Villagers make a temporary bridge of logs to cross the river and participation from every family is mandatory. Families which are not willing or unable to provide any physical input have to pay a small amount to use the bridge.

Bhotia people are mainly dependent on handicraft and tourism while agriculture and cattle and goat rearing are the main occupation for the Garhwali communities. *Bhotia* is transhumant community and has divided into different subgroups. Garhwal region is inhibited by *Marcha*, *Tolcha* and few families of *Johar* while in Kumaun *Shaukya* and *Johar* are the main subgroups of *Bhotias*. *Bhotia* people have similarities with Hindu and Buddhist cultures while Garhwali people are the follower of Hindu beliefs. *Bhotia* have traditionally gained a livelihood as transhumant shepherds and traders. *Bhotia* used to trade with Tibet, which has been closed due to Indo-China conflict in 1962. In the entire region farming remains subsistence oriented, but food grain output is no longer adequate for subsistence. Added to these are the multiple environmental hazards that have further jeopardized the economic condition the people (Badola and Hussain, 2003). Thus the economy lacks resilience and is highly vulnerable to shocks and stresses. This leads to migration of people in search of employment phenomenon that was reflected in the human population trends, registering 15% decline between 1981 and 1991 and another 13% between 1991 and 1996 (Silori, 2004).

High and low elevation villages differed more in terms of the rate of increase in number of households and migration of families than total population growth during 1981-2001 period and population in low elevation zone villages increased by 22% compared to 18% in high elevation zone. Outmigration occurred at higher rates in high elevation-buffer zone villages compared to low elevation-outside reserve villages. Immigrant Nepalese people settled only in low elevation-outside reserve villages (Saxena et al., 2011).

2.5.2 Livestock holdings

Cow, bullocks, goat, sheep, mules and horses are the main livestock reared by the local people of the area. Mules and horses are used in transportation of goods by the local villagers while during peak seasons of tourism they are used as medium of transportation by the tourist and are one of the important sources of income for the local communities (Saxena et al., 2011). Goats are mainly reared for meat and manure, sheep are kept for wool, cows are reared for dairy products and manure and bullocks are mainly used for agricultural work. People now have started keeping hybrid cows for better production of milk. Population of goats and sheep has declined drastically after the area was declared as national park. Closure of business with Tibet has also made people less willing to keep sheep and goats as these species were used for transportation of goods across the snow covered areas. This has also affected the traditional livelihood – handloom, of *Bhotia* community. The population of livestock reared by the inhabitants of the NDBR buffer zone villages showed a drastic decline in the periods 1970–1975 and 1990–1995. This was due to sharp reductions in the sheep and goat populations and near extinction of yak breeds in the area (Nautiyal et al., 2003).

2.5.3. Dependence on natural resources

Communities of NDBR are completely dependent on natural resources for their survival. Culture of the area also shows a significant influence of the nature on it. Economy of the area is completely dependent on the services of the natural resources of NDBR. Livestock production of the area is completely dependent on the availability of the forest and grasslands of the area. Most of the basic necessities are met by using natural resources. Forests are the only source for fuelwood, fodder, leaf litter and support for leguminous crops. Although hydroelectric projects on rivers have negative impacts on environment of the area but also are main source of revenue for state and have provided alternative livelihoods to the locals, in terms of daily wages received as labour work. The natural resources of the biosphere reserve are facing threats because of high dependence of local and downstream communities. Human communities have also become vulnerable to the degradation in the environment.

Second highest peak of the country, rich natural and cultural diversity make NDBR one of the hotspots of cultural, adventure and nature tourism (Silori, 2004). Nanda Devi peak is located inside the NDNP, once was the most popular for mountaineering and expedition till the ban on tourism in 1982. Ban on tourism has affected the local economy and has raised conflict among management and communities in the nearby area (Silori, 2004). Sustainable nature-based tourism is being developed as a tool to manage the conflict, provide alternative livelihood and conservation of natural resources.

2.5.4. Human-wildlife conflict and attitude of people towards forest and wildlife

Human-wildlife conflict is a major issue in management of the natural resources of the area. Declaration of the two national parks in the area and ban on tourism has reduced the tolerance level of people towards wildlife. Incidences of crop raiding, attack on human and livestock has played a major role in shaping up the negative attitude of people. Cases of poaching and illegal felling of trees have been reported from the area. Some studies, conducted in the past revealed that incidences of livestock lifting have increased (Rao et al., 2002). Attack on human especially on women folk during agricultural work and fodder and fuel wood collection is not so uncommon. Crop raiding is a main threat to economically marginal communities. Uttarakhand Forest Department does provide cash compensation for any loss due to wildlife but the amount is very less in comparison to the real loss.

STUDY AREA

View of Nanda Devi peak from Auli

Valley of flowers National Park

Hemkunt Sahib

Adventure tourism at Auli

Cultural dependence on nature

PLATE 1

LAND USE LAND COVER CLASSES OF NDBR

Deodar forest

Kharsu Oak forest

Alpine meadows

Mixed forest with retained fresh water

Blue pine forest

Agriculture land

Multiple use area

PLATE 2

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2.3. Administrative zones:

The different types of administrative areas identified within the boundary of the biosphere reserve are as under:

(a) Core zone: This area includes Nanda Devi National Park (630.33 km^2) and Valley of Flower National Park (87.50 km^2).

(b) Buffer zone: This area includes biosphere reserve excluding the area of the core zone. This also includes the areas of multiple use zones.

(c) Multiple use zone: The area of the Buffer zone extends on the south east (up to Nanda Ghunti), north- west (from Nanda Ghunti to village Peng), about five kilometer wide strip (including village Garpag) along Dhauliganga river from village Peng to

Malari, and east about four and a half kilometer wide strip along Goriganga from Samdu to Tota Shilling.

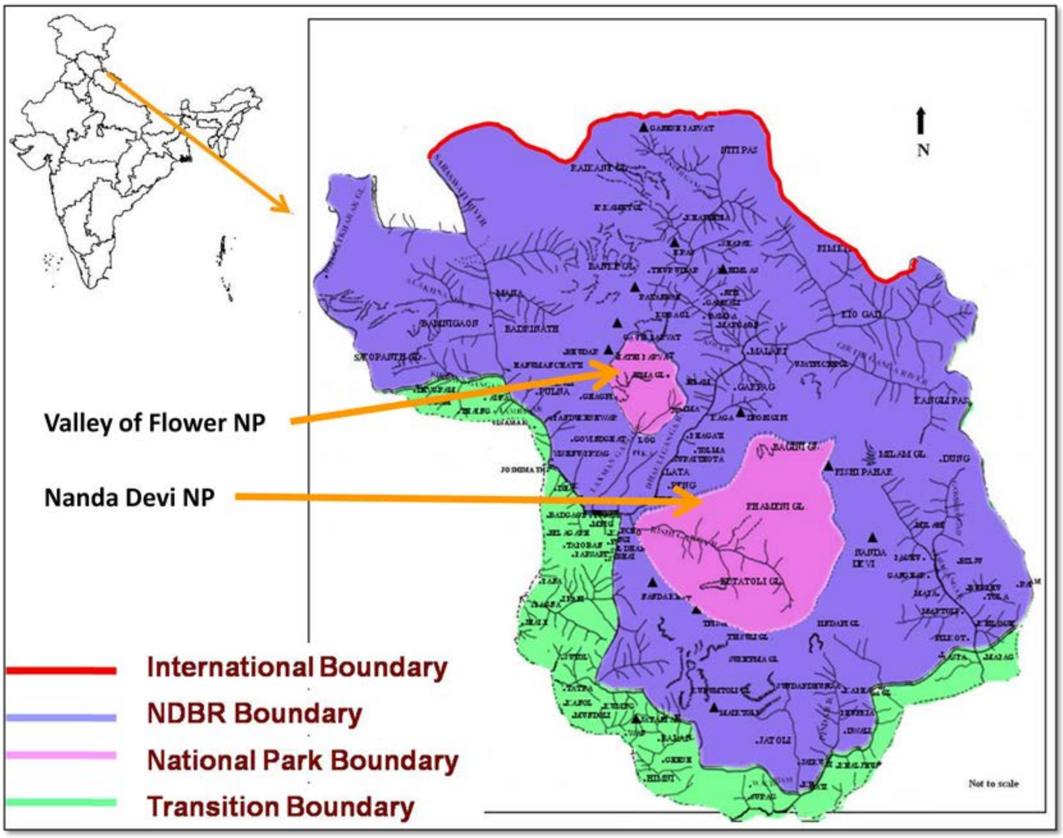


Figure 2.1. Map showing locations of National Parks within NDBR, transition zone and International boundary

2.4. Environmental attributes

2.4.1 Climate

Nanda Devi Basin enjoys the distinctive microclimate, being an inner Himalayan Valley. Vast altitudinal variation (1800-7817m asl) has given rise to a variety of climates ranging from temperate, sub-alpine and alpine. The climate is temperate and monsoonal and can be divided into long winter, short summer and rainy seasons (Purohit et al., 2001). Conditions are generally dry with low annual precipitation, but area receives and heavy rainfall from late June to August (Green, 1993). Most of the area remains snow bound for more than six months in a year. The higher reaches (4500 m asl) remain snow bound throughout the year (Khacher, 1978). Summers are very short starting from mid-May till late August. The temperature in the area vary between -2.3°C to 31.7°C, humidity ranges between 18-88% and average rainfall is 550 mm per year. The area experiences three main seasons i.e. (1) Winter - from

November to March, with heavy snowfall in the months of December, January and February, (2) Summer - from April to mid June and (3) Rainy season - from mid June to September (Gaur, 1999). The region has been divided into five climatic zones by Kaushik et al. (1962) (Table 2.1).

Table 2.1. Climatic zones of Nanda Devi Biosphere Reserve

Sl. No.	Climatic Zones (Altitude in m asl)	Temperature in ^{0}C		
		Rainy	Summer	Winter
1	**Sub tropical**	18.9-21.1	19.4-27.2	11.1-13.3
2	**Warm temperate (1800-2400)**	13.9-18.9	21.1-27.2	6.1-11.1
3	**Cool temperate (1800-2400)**	10.3-13.9	17.2-21.1	1.7-2.8
4	**Cold zone (2400-3000)**	4.4-10.3	13.3-17.2	1.7-2.8
5	**Alpine zone (3000-4200)**	3.9-4.5	5.6-13.3	Below zero
6	**Glacial zone (above 4200)**	-	Below zero	-

2.4.2. Geology and edaphic characteristics

Geologically, the area falls within the Greater Himalaya or Himadri System. A small part of Niti valley has characteristics of trans-Himalaya. The crystalline rocks found in the Rishi Ganga basin are sub-divided into four formations i.e., Lata, Ramni, Kharapatal and Martoli. The rock type includes Mica Schist, Mica Quartzite and Schist etc. The soil is mainly black, gray and brown in color. In the higher elevation it is skeleton type. The pH of the soil varies from 4.2 to 6.4 and moisture content oscillates between 21-65% (NDBR, 2002). Region is the head water of several rivers and streams such as Gori Ganga, Rishi Ganga, Dhauli Ganga and Girthi Ganga which are the tributaries of Alaknanda River which later meets Bhagirathi at Devprayag. Pindari and Milam are the most important glaciers of the region.

2.4.3. Land use and land class categories

Area of NDBR can be divided into natural and human modified land use land cover classes (LU/LC). Natural forested areas, alpine and temperate grasslands, water bodies (river, small streams and high altitude glacial lakes), snow and glacier area, natural landslide and rocky and barren areas fall under the categories of natural

LULCs found in NDBR. Settlements (small townships and villages), agricultural land (terrace farms), orchards, plantation and developmental areas are human modified landscapes. About 85% area of the Biosphere Reserve falls under snow and glacier and barren rocky categories. In vegetation classes alpine grasslands occupy the largest area. To support a large volume of tourist every year many governmental and privately owned hotels, inns and guest houses have been built up. In last few years many developmental activities have taken place in the area e.g. hydroelectric dams, new roads to remote villages of area. Conversion between LULCs has also been reported in the Reserve. Agricultural land is being abandoned as new non-farm opportunities are available to the people. Alpine grasslands were converted to summer settlements and agricultural land long back but no such conversion is taking place at present. Land holding division or fragmentation is taking place due to increase in population. People are now growing more cash crops (potato and cabbage) than the traditional grains and millets (Ragi, Fafar, Ogal, Foxtail millet etc.), which has changed locally self sufficient economy to market dependent economy. For the present study a land use land cover map of NDBR was generated using LISS IV imagery National Remote Sensing Centre (Fig. 2.2) (Plate 2).

2.4.4. Forest types

The wide altitudinal range, soil, climatic and microclimatic conditions found in the area has naturally produced highly diverse floral and faunal classes. Most of the flora and fauna in the NDBR is native and endemic (Tak and Kumar, 1983). According to classification given by Champion and Seth (1968) forest types of NDBR can be divided into six categories: Subtropical pine, Himalayan moist temperate, Subalpine, Moist alpine scrub and Dry alpine scrub (Fig. 2.2).

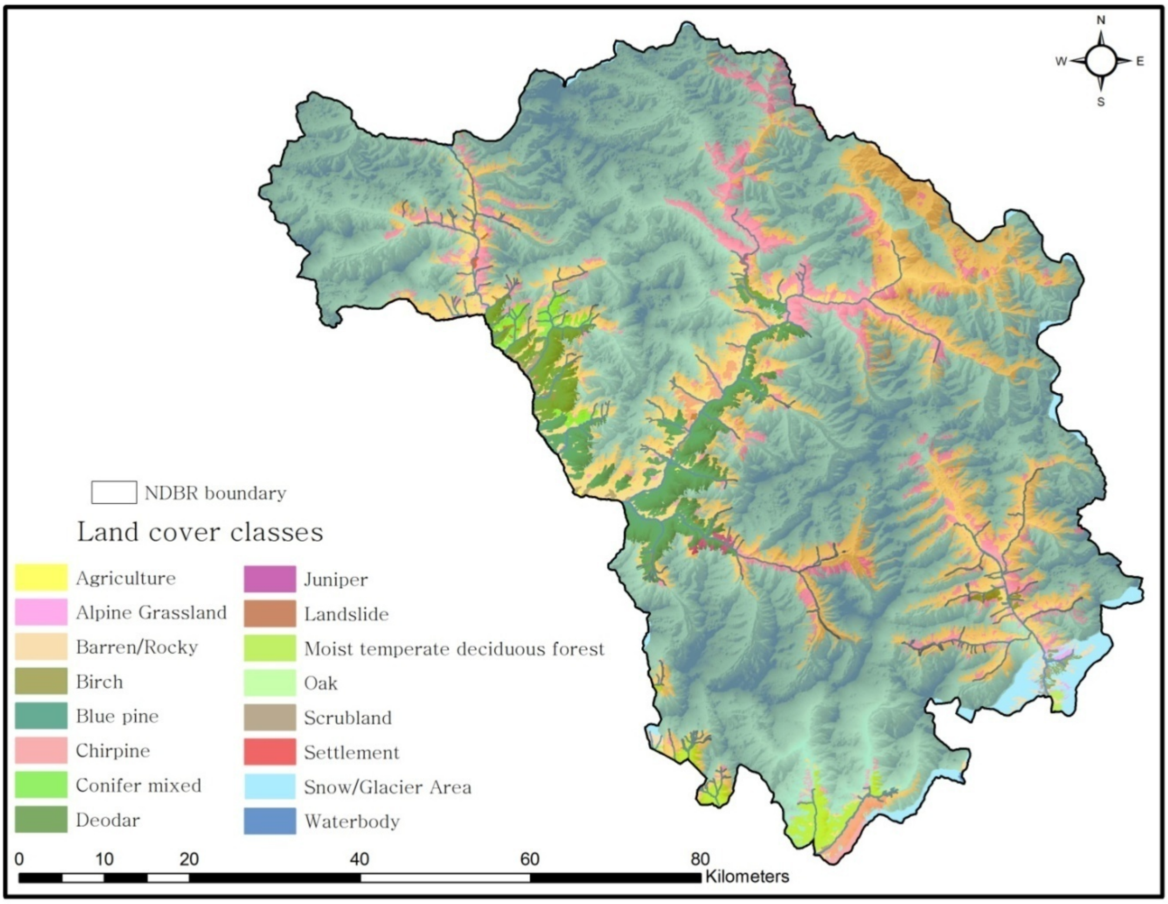


Figure 2.2. Land use land cover map of Nanda Devi Biosphere Reserve

2.4.5. Flora

The biosphere enjoys a very distinctive climate, which helps in harboring a rich floral and faunal diversity. The reserve supports over 1,000 species of plants including bryophytes, fungi and lichens (Uniyal, 2004). The vegetation mainly comprises of temperate, sub alpine and alpine types. The alpine meadow of NDBR supports a wide variety of flowering plants such as *Potentilla* spp, *Geranium* spp, *Androsace* spp, *Primula* spp, *Cyananthus* spp, *Gentiana* spp, and *Morina* spp etc. (Samant, 1993; Samant and Joshi, 2005). The NDNP has about fifteen rare and endangered plant species viz. *Aconitum* spp, *Circeaster agrestis*, *Epipogium aphyllum*, *Listera* spp, *Meconopsis aculeata*, *Nardostachys grandiflora*, *Orchis latifolia*, *Podophyllum hexandrum*, *Saussurea obvallata* and *Taxus baccata* (Hazra and Jain, 1983; Samant et al., 1996).

From NDNP a total of 490 species belonging to 281 genera and 89 families of Angiosperms (480 species, 274 genera and 85 families) and Gymnosperms (10 species, 7 genera and 4 families) have been recorded. Of these, 357 species were herbs, 103 shrubs and 30 trees (Samant and Joshi, 2005). From VoF, 520 species of vascular plants belong to 72 families and 248 genera were recorded. Of 520 species, 498 belong to angiosperms or flowering plants (61 families and 234 genera), 18 Pteridophytes and 4 Gymnosperms. The VoF harbours 472 species of herbs, 41 species of shrubs and 8 species of trees (Kala, 2005).

2.4.6. Fauna

About 520 species of fauna including mammals, birds, reptiles, amphibians, fishes, insects, molluscs and annelids have been recorded from the area (Arora et al., 1995). Nearly 200 avifaunal species have been reported for the reserve (Sankaran, 1994). The important mammals are Snow leopard (*Panthera uncia*), Asiatic black bear (*Ursus thibetanus*), Himalayan brown bear (*Ursus arctos*), Himalayan musk deer (*Moschus chrysogaster*), Bharal (*Pseudois nayaur*) Himalayan tahr (*Hemitragus jemlahicus*) (Kandari, 1981). The area of the reserve lies within the Western Himalayas Endemic Bird Area. Many of the birds species found in the area move down to lower altitudes in the lower Himalayas and foothill while a few migrate down even to the northern plains and peninsular India in the winters. Abundant species recorded include Crested black tit (*Parus melanolophus*), Yellow-bellied fantail flycatcher (*Rhipidura hypoxantha*), Orange flanked bush robin (*Erithacus cyanurus*), Blue-fronted redstart (*Phoenicurus frontalis*), Indian tree pipit (*Anthus hodgsoni*), Rosy pipit (*A. roseatus*), Common rosefinch (*Carpodacus erythrinus*) and Nutcracker (*Nucifraga caryocatactes*) (Sankaran, 1994).

2.5. Socio-economic attributes

2.5.1 Communities of NDBR

NDBR is named after the bliss giving goddess Nanda Devi worshipped by the communities of the region. Human habitations are absent inside the core zones but there are 47 villages in the buffer zone and 33 villages in the transition zone with six villages in the immediate buffer of the core zones. These villages are distributed in Chamoli, Bageshwar and Pithoragarh districts of Uttarakhand state. Along the Dhauli Ganga lies the famed Niti Valley that draws its name from the last village before the Indo-Tibetan frontier. Besides Lata and Reni villages that remain among the best known settlements in this region due to their involvement in the *Chipko* movement, other villages include Jamgavar, Juma, Garpag, Kaga, Peng, Phagti, Surai, Tolma and

Malari. However, these villages are further divided into summer and winter encampments situated at different elevations to cope with the climatic conditions throughout the year (Badola and Silori, 1999; Nautiyal et al., 2003).

Bhotia (Indo-Mongoloid) and Garhwali (Indo-Aryan) are the main communities in the area. *Bhotias* are semi-nomads and have summer settlements in the higher altitudes while their winter houses are in lower regions inside and outside of the biosphere reserve. Most of the Garhwali people have permanent settlements while some of the inhabitants seasonally migrate from summer house (higher altitude or upper ridge of the same mountain) to winter settlements (lower altitude or lower part of the village generally near river) within the same village. Migration from higher altitude to lower altitude takes place because of the harsh winter and unavailability of basic resources. Villagers migrate within same village or locality as the lower settlement (winter) is nearer to collect the riverain outcrop as the flow and volume of the river is less in the winter and it is easy to cross it. Villagers make a temporary bridge of logs to cross the river and participation from every family is mandatory. Families which are not willing or unable to provide any physical input have to pay a small amount to use the bridge.

Bhotia people are mainly dependent on handicraft and tourism while agriculture and cattle and goat rearing are the main occupation for the Garhwali communities. *Bhotia* is transhumant community and has divided into different subgroups. Garhwal region is inhibited by *Marcha*, *Tolcha* and few families of *Johar* while in Kumaun *Shaukya* and *Johar* are the main subgroups of *Bhotias*. *Bhotia* people have similarities with Hindu and Buddhist cultures while Garhwali people are the follower of Hindu beliefs. *Bhotia* have traditionally gained a livelihood as transhumant shepherds and traders. *Bhotia* used to trade with Tibet, which has been closed due to Indo-China conflict in 1962. In the entire region farming remains subsistence oriented, but food grain output is no longer adequate for subsistence. Added to these are the multiple environmental hazards that have further jeopardized the economic condition the people (Badola and Hussain, 2003). Thus the economy lacks resilience and is highly vulnerable to shocks and stresses. This leads to migration of people in search of employment phenomenon that was reflected in the human population trends, registering 15% decline between 1981 and 1991 and another 13% between 1991 and 1996 (Silori, 2004).

High and low elevation villages differed more in terms of the rate of increase in number of households and migration of families than total population growth during 1981-2001 period and population in low elevation zone villages increased by 22% compared to 18% in high elevation zone. Outmigration occurred at higher rates in high elevation-buffer zone villages compared to low elevation-outside reserve villages. Immigrant Nepalese people settled only in low elevation-outside reserve villages (Saxena et al., 2011).

2.5.2 Livestock holdings

Cow, bullocks, goat, sheep, mules and horses are the main livestock reared by the local people of the area. Mules and horses are used in transportation of goods by the local villagers while during peak seasons of tourism they are used as medium of transportation by the tourist and are one of the important sources of income for the local communities (Saxena et al., 2011). Goats are mainly reared for meat and manure, sheep are kept for wool, cows are reared for dairy products and manure and bullocks are mainly used for agricultural work. People now have started keeping hybrid cows for better production of milk. Population of goats and sheep has declined drastically after the area was declared as national park. Closure of business with Tibet has also made people less willing to keep sheep and goats as these species were used for transportation of goods across the snow covered areas. This has also affected the traditional livelihood – handloom, of *Bhotia* community. The population of livestock reared by the inhabitants of the NDBR buffer zone villages showed a drastic decline in the periods 1970–1975 and 1990–1995. This was due to sharp reductions in the sheep and goat populations and near extinction of yak breeds in the area (Nautiyal et al., 2003).

2.5.3. Dependence on natural resources

Communities of NDBR are completely dependent on natural resources for their survival. Culture of the area also shows a significant influence of the nature on it. Economy of the area is completely dependent on the services of the natural resources of NDBR. Livestock production of the area is completely dependent on the availability of the forest and grasslands of the area. Most of the basic necessities are met by using natural resources. Forests are the only source for fuelwood, fodder, leaf litter and support for leguminous crops. Although hydroelectric projects on rivers have negative impacts on environment of the area but also are main source of revenue for state and have provided alternative livelihoods to the locals, in terms of daily wages received as labour work. The natural resources of the biosphere reserve are facing threats because of high dependence of local and downstream communities. Human communities have also become vulnerable to the degradation in the environment.

Second highest peak of the country, rich natural and cultural diversity make NDBR one of the hotspots of cultural, adventure and nature tourism (Silori, 2004). Nanda Devi peak is located inside the NDNP, once was the most popular for mountaineering and expedition till the ban on tourism in 1982. Ban on tourism has affected the local economy and has raised conflict among management and communities in the nearby area (Silori, 2004). Sustainable nature-based tourism is being developed as a tool to manage the conflict, provide alternative livelihood and conservation of natural resources.

2.5.4. Human-wildlife conflict and attitude of people towards forest and wildlife

Human-wildlife conflict is a major issue in management of the natural resources of the area. Declaration of the two national parks in the area and ban on tourism has reduced the tolerance level of people towards wildlife. Incidences of crop raiding, attack on human and livestock has played a major role in shaping up the negative attitude of people. Cases of poaching and illegal felling of trees have been reported from the area. Some studies, conducted in the past revealed that incidences of livestock lifting have increased (Rao et al., 2002). Attack on human especially on women folk during agricultural work and fodder and fuel wood collection is not so uncommon. Crop raiding is a main threat to economically marginal communities. Uttarakhand Forest Department does provide cash compensation for any loss due to wildlife but the amount is very less in comparison to the real loss.

STUDY AREA

View of Nanda Devi peak from Auli

Valley of flowers National Park

Hemkunt Sahib

Adventure tourism at Auli

Cultural dependence on nature

PLATE 1

LAND USE LAND COVER CLASSES OF NDBR


Deodar forest


Kharsu Oak forest


Alpine meadows


Mixed forest with retained fresh water


Blue pine forest


Agriculture land


Multiple use area

PLATE 2

Chapter 3. Provision of biomass by forests

SUMMARY

The present chapter deals with the contribution of provision of biomass by different forest types to the local economic security. The data for provision of biomass by forested landscapes of NDBR was collected in three stages, using semi-structured questionnaire based interviews. The first stage involved in a rapid assessment of the study area in order to obtain an overall perspective of the villages. In the second stage secondary data was used to conduct hierarchical cluster analysis. A total of 11 clusters were formed and 22 representative villages for intensive study were identified from each cluster. In third stage, extensive data on provision of biomass was collected. Households were selected on the basis of forest type and distance from forest. A total of four forest types were found to be used by selected villages (oak, mixed conifer, moist temperate deciduous and Deodar forest). The villages were further categorized on the basis of condition of forest (degraded and less degraded) and distance from forest {near (500-2500m) and away from forest (2500 and more)} to get a better understanding of impact of condition and type of forest on provision of biomass. Households were sampled randomly (n=764) in the representative villages. Interview based structured questionnaire was used to collect data on resource use pattern and the information was verified monitoring forest entry and exit points (n=30). To assess the economic value of contribution of biomass to local economy market price method was used.

The provisioning services in terms of biomass contributed 15.6% (INR 15315.10 ±495.67/hh/year) to the average annual household income (INR 95646.4 ±3332.4) of the dependent community. Oak forest contributed most (37.3%) followed by mixed conifer (28%). It was observed that the forest situated in close proximity with villages are being exploited more, hence are contributing more to the average household economy than the forests located away from forest. The dependence on forest was found to be decreasing with the additional income from other sources (jobs in government and private sectors) {$r(764) = -0.088$, $p<0.05$}. The dependence on natural resources was positively contributing to the total household income (income from forest and non-forest sources) {$r(764) = +0.214$, $p<0.005$}.

3.1. Introduction

Human societies and wildlife are dependent on products of the forest for their sustenance (CBD, 2010). The conception of dependency comes from a rural sociological standpoint on communities and their interface with risky resources (Machlis and Force, 1988; Machlis et al., 1990; Freudenburg, 1992). Resource dependency relates to communities and individuals whose social order, livelihood and stability are a direct function of their resource production and localized economy (Machlis et al., 1990). The dependency of individuals does not necessarily depend on a single resource, but in some circumstances on integrated ecosystem (Adger et al., 2001). Communities residing in and nearby areas of forested landscapes are dependent on forest resources for their daily needs and livelihoods. The degree of dependence varies between households and communities.

Forest resources provide an array of benefits such as direct use values, indirect use values, option values and existence or non-use values but provisioning services make a major part of the human dependence (Shackleton and Shackleton, 2004; Shackleton et al., 2007). Non-timber forest products (NTFPs) comprise a significant livelihood option for forest fringe communities (Narain et al., 2007). In India, over 50 million people are dependent on NTFPs for their survival and economic benefits (Hegde et al., 1996; Uma Shaanker et al., 2004). Mountain communities of Indian Himalayan region are dependent on forest products, grasslands and water resources for their daily requirements. Due to low connectivity with other areas and unavailability of resources, forests form the main source of energy and fodder requirements (Bhatt and Sachan, 2004).

Before introduction of modern techniques local villagers were completely dependent on fuelwood for their requirements. Wood from forest was the main source for cooking and heating. Livestock production of a certain area is always dependent on the availability and accessibility of the fodder species in forest and grazing area. At many places a reduction was observed in livestock holding due to degradation and inaccessibility of fodder. Agriculture in the mountainous communities is dependent on the forest products e.g. leaf litter as manure, support for the leguminous crop and fencing for crops as protection from wild animals. Thatching and construction is also dependent on the resources available in the nearby forests (Plate 3).

Dependence on provisioning services is not only economical but also social and cultural. The influence of the natural system on cultural activities and social setup is noteworthy. The dependence on provisioning services is more significant for the local communities and has more influence on local and regional levels. The significance of provisioning services and people's dependence on them has often been inadequately recognized and underestimated at the local, national, regional and global levels (UN, 1996). A paucity of proper markets for most of the provisioning services makes economic valuation of contribution of forest to local economy difficult and leads to difficulty in policy decisions. The present study estimated the use value of non timber forest products (fuelwood, fodder, thatching, medicine, leaf litter and support for the leguminous crops) provided by the forested landscapes of the NDBR. Pragmatic exploration of dependency on forest resources will facilitate to improve macro-level poverty estimates and improve policy planning and implementation. The quantification of environmental income may serve conservation policy, and particularly identification and conservation of the sensitive areas, by estimating the potential loss to rural dwellers of reduced access to environmental resources and degree of degradation of natural resources. In the past the approach towards forest dependence was that conservation of forests could be achieved only through lowering forest dependence of local communities (Stronkhorst, 2005). But most of the people are dependent on forest resources for their sustenance and hence the extraction is minimum and very less in comparison to commercial use. The recently developed linked incentives model provides a solution to this limitation of past approaches by assuming direct linkage between local livelihoods and conservation. Directly dependent non use livelihood alternatives will provide increased incentive for positive conservation attitudes and behaviour (Angelsen and Wunder, 2003) as attitude and behaviour of the people towards natural resources change with the contribution of these resources to the economy.

Since effective management practices at smaller and larger areas can restore degraded ecosystems, quantifying dependence of local communities on forest is a significant tool. These estimations can provide information to policy makers and natural resource managers for effective policy and management interventions for efficient economic and financial allocation of resources for biodiversity conservation and enhancement of living standards. Previous literature on dependence on forest resources focused only on the economic contribution of biomass but has neglected the linkages between the human well-being and flow of provisioning services.

The present chapter examines the contribution of the provisioning services to meet the daily energy, fodder and other non timber forest products requirements of the local communities of NDBR.

3.2. Methodology

The data for provision of biomass by forested landscapes of NDBR was collected three stages, using structured questionnaire based interviews. The first stage involved a rapid assessment of the study area in order to obtain an overall perspective of the villages. Secondary data regarding access to basic facilities such as PHCs, schools, transportation, fuel distribution centers, types of roads, livestock information, land utilization, demographic profile of the villages, location and distribution of villages with respect to forest and their dependency on forests for fuelwood, fodder, NTFPs etc. was collected. In the second stage secondary data was used to run hierarchical cluster analysis. A total of 11 clusters were formed and representative villages (n=22) for intensive study were identified from each cluster. In third stage, extensive data on provision of biomass was collected. Households were sampled randomly in the selected representative villages. Interview based structured questionnaire (Rigg et al., 2011) and informal discussions (Bagchi and Mishra, 2006; Ogra and Badola, 2008) were conducted (Kumssa and Bekele, 2013). Questionnaire method was used to get responses in a standardized and cost-effective way (Fowler, 2008). To collect data on resource use pattern amongst large number of respondents, interview based questionnaire was used (Harris and Brown, 2010) and the information was verified using entry point method.

3.2.1. Interview based questionnaire method

Personal interview were conducted to overcome the poor response rates of a normal questionnaire survey (Austin and Cunningham, 1981). Personal interviews provide opportunity to evaluate the validity of the respondent's answers by observing non-verbal indicators. The questionnaire had both open and close-ended questions (Holmern et al., 2007). Closed-ended questions were used to get quick information for simplicity of analysis of the data while open-ended questions were used to get unique responses and exploratory data about the subject (Gurung et al., 2008). The questionnaire was pre-tested on 25 people of varying ages, sexes and economic background to ensure clarity and effectiveness of the questions before use (Sletto, 1940). A total of 764 respondents were interviewed from 22 selected villages, regarding use of biomass provided by different forest types. Respondents were selected from different sex, age group, educational, social and economical classes.

3.2.2. Entry point survey

To validate the data about biomass extraction, obtained from questionnaire, entry point method was used (Dhaundiyal, 1997). All the traditional entry points to forests were identified and monitored (Ganesan, 1993) as villagers use these fixed points to access the forest resources (Soussan et al., 1991). Weight of head loads of all the people carrying fuelwood, fodder, thatching material, grasses and leaf litter were recorded using a spring balance. A total of 30 entry points were monitored (Fig. 3.1). Difference between quantities of the biomass provisioned by forests of NDBR was calculated using Mann–Whitney U test. The economic value of the forest products was calculated using market price method.

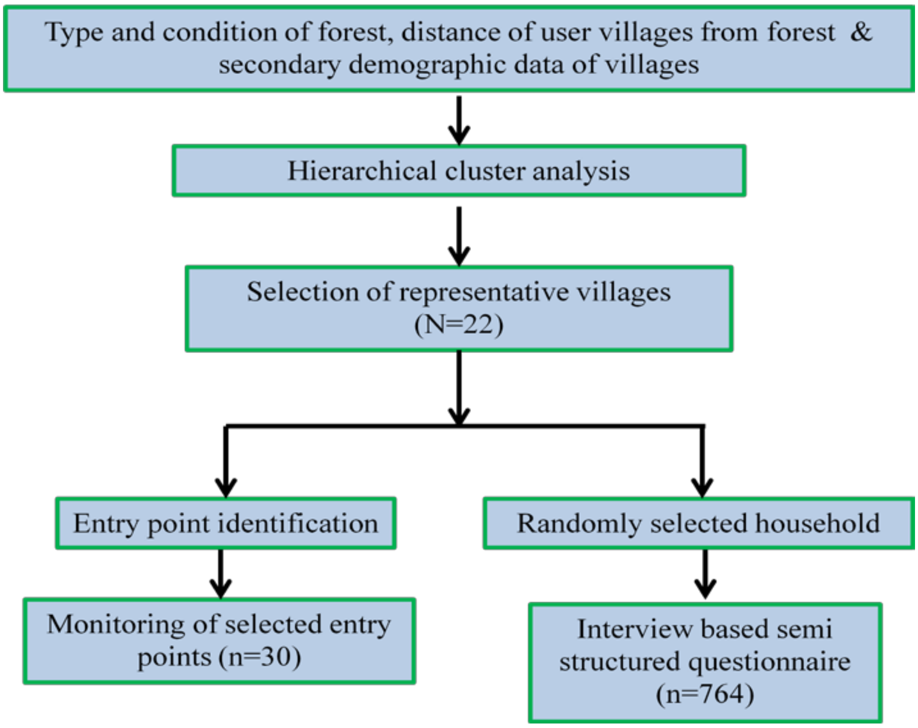


Figure 3.1. Methodology used to assess the dependence for biomass

3.2.3. Data analysis

Biomass provisioned by different forests annually, to the people of NDBR was calculated by using the quantity they use in one day, frequency of visits (i.e. daily, on alternative days and once in three days). For the data analysis, program SPSS v16 (SPSS, 2007) was used. Association between contribution of forest with income from other sources and education status was investigated using Spearman's rho correlation test.

Total biomass provisioned/ day = biomass extracted for (fodder + fuelwood + leaf litter + thatching + food + medicinal plant + agricultural use)

Amount used in one year = (biomass used in one day × number of visits in one month) × 12

Contribution of the biomass to average household income = (total biomass extracted/year of a particular product) × price per unit

3.3. Results

A total of 22 villages were selected and to evaluate the contribution of natural products especially of forest products to local livelihood. A total of 764 households were surveyed, 744 household representatives (97.38%, n=764) agreed that they collect food, fuelwood and fodder from forest and medicinal plant from grasslands and forested lands. 98.25% respondent said that they collect fuelwood from forest while about 90% of households are dependent on forest and rocky outcrop (mainly areas near banks of Alaknanda and Dhauli Ganga rivers) for fodder. Fodder is collected from forest during summer and monsoon while rocky outcrop is used during winters. Leaf litter and fuelwood are collected throughout the year once in 2-3 days but amount extracted increases before winters. Leaf litter is collected by 87% of the total households surveyed while less than 6% of the respondents said that they use the thatching material available in the nature. More than 50% of the households use food (vegetable and fruits) provided by the forests and grasslands of the NDBR, 8% of which sell these products in the market. About 5% of respondents said that they collect medicinal plants but only two of them said that they sell different parts of plant (Table 3.1).

Forested landscapes provide 2510.29 ±67.36 kg/hh/year fuelwood to dependent households while 3648.73 ±67.04 kg/hh/year fodder is extracted from forest and rocky areas to support the livestock population owned by local people of the area. 2321.07 ±41.31 kg per household leaf litter is collected by local people every year from the forests of NDBR. 75.5 ±9.21 kg/hh/year of thatching material is extracted by local people for their household use. People collect about 2.87 ±0.08 kg wild vegetables per household per year while 5% of them sell the collected vegetables to the nearby market or to the other villagers which contribute INR 57.69 ±5.2/hh/year to the total household income of the people. 7.07 ±0.31kg of wild fruits are extracted from forest per year per household but only 16% of the households sell these products to the markets or to the tourists. The economic contribution of the fruits collected from forests is INR 384 ±36.05/hh/year (Table 3.1). The provisioning services contributed 15.6% (INR 15315.10 ±495.67/hh/year) of the average annual household income (INR 95646.4 ±3332.4) of the dependent community. Oak forest contributed most (37.3%) followed by mixed conifer (28%). The pattern and seasonality of resources use of main species used have been summarized in table 3.2.

Table 3.1. Natural resources collected and used by local community of NDBR

Natural resource	No. of household extracting the resource	Amount extracted (kg/hh/year)	Amount used (kg/hh/year)	No. of households selling the resource	Amount sold (kg/hh/year)	Direct earning (INR /hh/year)
Fodder*	671	3648.73 ±67.04	Whole	NA	NA	7297.47 ±134.08
Fuel wood*	731	2510.29 ±67.36	Whole	NA	NA	3765.44 ±101.05
Leaf litter*	648	2321.07 ±41.31	Whole	NA	NA	3481.59 ±61.96
Thatching	41	75.5 ±9.21	Whole	NA	NA	15100 ±1843.84
Vegetables	290	2.87 ±0.08	2.82 ±0.08	13	1.15 ±0.1	57.69 ±5.2
Fruits	123	7.07±0.31	6.29 ±0.23	20	4.8 ±0.45	384 ±36.05
Medicinal plant	34	0.25 ±0.01	0.23 ±0.01	2	0.43 ±0.02	2125 ±125
Cordyceps sinensis	8	0.38 ±0.9	NA	8	Whole	58750 ±29058.9

* Fodder and leaf litter are collected every alternate day while fuelwood is collected once in 2-3 days and the contribution of these natural resources has been calculated accordingly. Thatching collected once per year, vegetables, fruits, and medicinal plants are collected twice or thrice seasonally while *C. sinensis* collected once in a year.

Table 3.2. Resource use pattern of local communities of NDBR

Natural resource	**Seasons and sources**	**Important species**
Fodder	During winters fodder is collected from nearby forests. During pre-winters people collect grasses from the rocky riverine areas, as it is easy to cross rivers when the flow is low. In monsoon green grasses from forests and agricultural fields are collected. Agricultural residue is stored and fed to livestock with other fodder types and also used during period of fodder shortage. The visitation rate for the fodder collection is once in one to two days, but the visitation rate varies with the number of livestock left in grazing fields during summer.	Oak species (*Quercus floribunda*, *Quercus semecarpifolia*, *Quercus leucotrichophora*), *Elaeagnus parviflora*, *Prunus cerasoides*
Fuelwood	Although collected throughout year but during snow people use the stored fuelwood. For fuelwood visitation rate is one visit/2-3 days, visitation rate varied with the family size and members available to collect the resource.	*Aesculus indica*, *Alnus nepalensis*, *Celtis australis*, *Dactylorhiza hatagirea*, *Juniperus recurva*, *Lyonia ovalifolia*, *Rhododendron arboreum*
Leaf litter	Leaf litter is mainly collected in pre-winters after fall in households situated in lower altitude while in household in higher altitude it is collected before and after monsoon to be used to keep cowshed and later in the agriculture as manure.	Oak species (Moru, Kharsu, Banj), *Juglans regia*, *Abies pindrow*, *Aesculus indica*, *Acer caesium*, *Lyonia*, *Rhododendron* and *Litsea*
Fruits	Fruits are mainly collected in June and July while wild akhrot *Juglans regia* is collected during pre-winters.	*Corylus jacquemontii*, *Juglans regia*, *Hippophae salicifolia*, *Taxus baccata*
Vegetables	Vegetables are mainly collected after snow fall and pre-winters	*Allium* spp., *Diplazium esculentum*, *Phytolacca acinosa*, *Amaranthus bilatum*, *Chenopodium foliolosum*
Medicinal plant	Medicinal plants are collected in summers and before monsoon.	*Amaranthus paniculatus*, *Brassica campestris*, *Echinochloa frumentocea*, *Eleusine coracana*, *Glycine max*, *Hordeum himalayens*, *Pennisetum typhoides*, *Pisum sativum*, *Triticum aestivum*, *Allium humile*, *Angelica glauca*
Cordyceps sinensis	*Cordyceps sinensis* is collected in summers and before monsoon.	-

3.3.1. Dependence on different forest types on the basis of distance between villages and forests

Households were selected on the basis of forest type and distance from forest. A total of four forest types were found to be used by selected villages (oak, mixed conifer, moist temperate deciduous and Deodar forest). The villages were further categorized on the basis of condition of forest (degraded and less degraded) and distance from forest {near (500-2500m) and away from forest (2500m and more)}.

Oak Forest – less degraded (500-2500m)

It was found that villages located near less degraded oak forest use 2113.13 ±72.41 kg of fuelwood and 3433.16 ±106.7 kg of fodder per household per year which contributed INR 3169.68 ±108.6/hh/year and INR 6866.32 ±213.4/hh/year to the local economy, respectively. Villagers also get access to good quality and more quantity of leaf litter (2527.04 ±85.41kg/hh/year) worth of INR 3790.56 ±128.1/hh/year. Thatching material is not being used much (76.29 ±4.23kg/hh/year; INR15258.1 ±847.7/hh/year) as people have started building modern houses instead of traditional ones. The less degraded oak forest is also a source of vegetable (2.64 ±0.08kg/hh/year, INR 132.45 ±4.4/hh/year) and fruits (6.02 ±0.14 kg/hh/year, INR 301.16 ±7.2/hh/year). In total less degraded oak contributed INR 15959.1 ±757.05/hh/year (Table 3.3 and 3.4).

Oak forest - degraded

People residing near degraded oak forest extract 6150 ±247.2 kg of fuelwood/hh/year (economic value – INR 9225 ±370.7/hh/year) while villagers living away from degraded forest use 1480.76 ±78.84 kg/hh/year (INR 2221 ±118.3/hh/year). 5925 ±182.12 kg of fodder is being extracted from degraded oak forest which is located near villages while 2514.58 ±106.9 kg/hh/year is being used by the households located away from forest that indirectly contributed INR 11850 ±364.2/hh/year and INR 5029.2 ±213.8/hh/year to local economy, respectively. More leaf litter is being extracted by the people living near the forest (2700 ±208.44 kg/hh/year, contributing INR 4050 ±312.6/hh/year) than the people living away from forest 1381.13 ±54.50 kg/hh/year (contributing INR 2071.7 ±81.7/hh/year). It was found that food material is only being extracted (2.0 ±0.00 kg/hh/year) from forest located near villages and contributing economic value of INR 100 ±0.0/hh/year to the household income. In total degraded oak close contributed INR 25145 ±799.8/hh/year forest contributed while forest away from settlement contributed INR 8506.04 ±397.7 /hh/year (Table 3.3 and 3.4).

Mixed conifer – less degraded

Households were sampled of the villages located near mixed conifer-less degraded forests. Every year 3192.28 ±155.67 kg per household of fuelwood and 3950.95 ±138.9 kg/hh of fodder has been contributed to the local economy from mixed conifer –less degraded. The extraction of fuelwood and fodder contributed INR 4788.4 ±233.5 and INR 7816.94 ±282.24 to the economy of dependent households per year, respectively. People also use 2253.48 ±69.62 kg of leaf litter/ hh/year collected from mixed conifer forest contributing economic value of INR 3380 ±104.4/hh/year. Mixed conifer- less degraded forest also contributes to thatching (51.87 ±3.27 kg/hh/year) and food needs of the dependent households (vegetable- 2.43 ±0.07 kg/hh/year, fruits- 5.83 ±0.15kg/hh/year). Thatching has contributed INR 10375 ±654.3/hh/year while vegetables and fruits have contributed INR 121.64 ±3.8/hh/year and INR 291.7 ±8/hh/year, respectively. In total less degraded mixed conifer contributed INR 15344.8 ±679.5/hh/year (Table 3.3 and 3.4).

Mixed conifer- degraded

Extraction of fuelwood is more in mixed conifer degraded forest located near villages than the forest located away from forest (2483.34 ±108.56 kg/hh/year and 1640.13 ±104.46 kg/hh/year respectively) and this contributed INR 3725 ±162.8/hh/year and INR 2460.2 ±156.7/hh/year to the economy of households living close to and away from forest, respectively. Same pattern have been observed for fodder collection also (4625.80 ±99.26 kg/hh/year from forest located near villages; 2282.14 ±137.45 kg/hh/year from forest located away from human settlement) which added INR 9251.6 ±198.5/hh/year (household close to forest s) and INR 4564.3 ±274.9/hh/year (household located away from forest) to the household earnings. The leaf litter is also provided more by the forest close to villages (2951.61 ±90.35 kg/hh/year, economic value INR 4427.5 ±135.5/hh/year) than the forests located away (1358.82 ±67.16 kg/hh/year, economic value INR 2038.2 ±100.7/hh/year). Degraded mixed conifer provided about 20 ±0.01 of thatching/hh/year and less degraded contributed 3.94

±0.12 kg vegetable/hh/year which contributed INR 4000 ±100.1/hh/year and INR 197.14 ±6.5/hh/year, respectively. In total degraded mixed conifer close to village contributed INR 15695.8 ±741.1 /hh/year forest contributed while forest away from settlement contributed INR 8372.7 ±505.2 /hh/year (Table 3.3 and 3.4).

Moist temperate deciduous forest - less degraded

Data was collected only for the households using moist temperate deciduous forest-less degraded located near their villages. Less degraded moist temperate deciduous forest provided 2328.57 ±113.76 kg of fuelwood and 3278.04 ±146.72 kg of fodder annually to each dependent household. The provision of fuelwood and fodder has contributed INR 3492.8 ±170.6/hh/year and INR 6556.1 ±293.4/hh/year, respectively. 2056.09 ±101.75 kg of leaf litter (economic value- INR 3084.14 ±152/hh/year), 27.5 ±1.5 kg thatching (economic value- INR 5500 ±316.8/hh/year) and 2.85 ±0.13 vegetables (economic value- INR 142.5 ±6.5/hh/year) were also being used annually per household extracted from less degraded moist temperate deciduous forest. In total less degraded Moist temperate deciduous. In total less degraded moist temperate deciduous contributed INR 13437.2 ±633.6 /hh/year (Table 3.3 and 3.4).

Moist temperate deciduous forest -degraded

Degraded moist temperate deciduous forest located near villages provide higher amounts of fuelwood (2237.74 ±152.50 kg/hh/year), fodder (3247.35 ±141.86 kg/hh/year), leaf litter (2189.42 ±77.98 kg/hh/year), thatching (125 ±2.80 kg/hh/year), vegetable (2.52 ±0.10 kg/hh/year) and fruits (5.75 ±0.20 kg/hh/year). Provision of these natural resources contributed as, fuelwood- INR 3356.6 ±228.7/hh/year, fodder- INR 6494.7 ±283.7/hh/year, leaf litter- INR 3284.13 ±116.9/hh/year, thatching- INR 25000 ±555.6/hh/year, vegetables- INR 126.2 ±5.2, fruits- INR 287.5 ±10.3/hh/year.

Forest located away from the human settlement provided 2139.70±131.531 kg/hh/year of fuelwood- (INR 3209.6 ±197.3/hh/year), 3452.89 ±174.6 kg/hh/year of fodder- (INR 6905.7 ±348.5/hh/year), 2419.73 ±68.75 kg/hh/year of leaf litter- (INR 3577.2 ±104/hh/year), 3.27 ±0.12 kg/hh/year of vegetable- (INR 163.2 ±6.3/hh/year) and 11.18 ±0.43 kg/hh/year fruits- (INR 559.2 ±21.7/hh/year) to the local communities annually. Households located near forest avail more thatching and food material than households located away from forest. In total degraded moist temperate deciduous close to village contributed INR 13786.9 ±811.9 /hh/year forest contributed while forest away from settlement contributed INR 11582.7 ±697.9 /hh/year (Table 3.3 and 3.4).

Deodar forest

Households were sampled only for the Deodar forests which were located near the villages for both less degraded and degraded conditions. Less degraded Deodar forest (located near villages) contributes 1925 ±146.65 kg of fuelwood and 2321.87 ±154.62 kg of fodder annually to per dependent household this provided economic input of 2887.5 ±219.9 and 4643.7±309.24. While degraded Deodar forest contribute 2488.34 ±108.36 kg of fuelwood (economic value INR 3725 ±162.8/hh/year), 4625.8 ±99.26 kg of fodder (economic value- 9251.6 ±198.5/hh/year), 2951.61 ±90.35 kg of leaf litter (economic value- INR 4428.4 ±135.6/hh/year) and 3.94 ±0.12 kg of wild vegetable (economic value- INR 197.1 ±6.4/hh/year) to the dependent household every year. In total less degraded Deodar contributed INR 5364.2 ±587.5 /hh/year while degraded Deodar contributed INR 15695.8 ±741.1/hh/year (Table 3.3, Table 3.4). Spatial distribution of provisioning services (biomass) provided by different LULC of NDBR is depicted in figure 3.2.

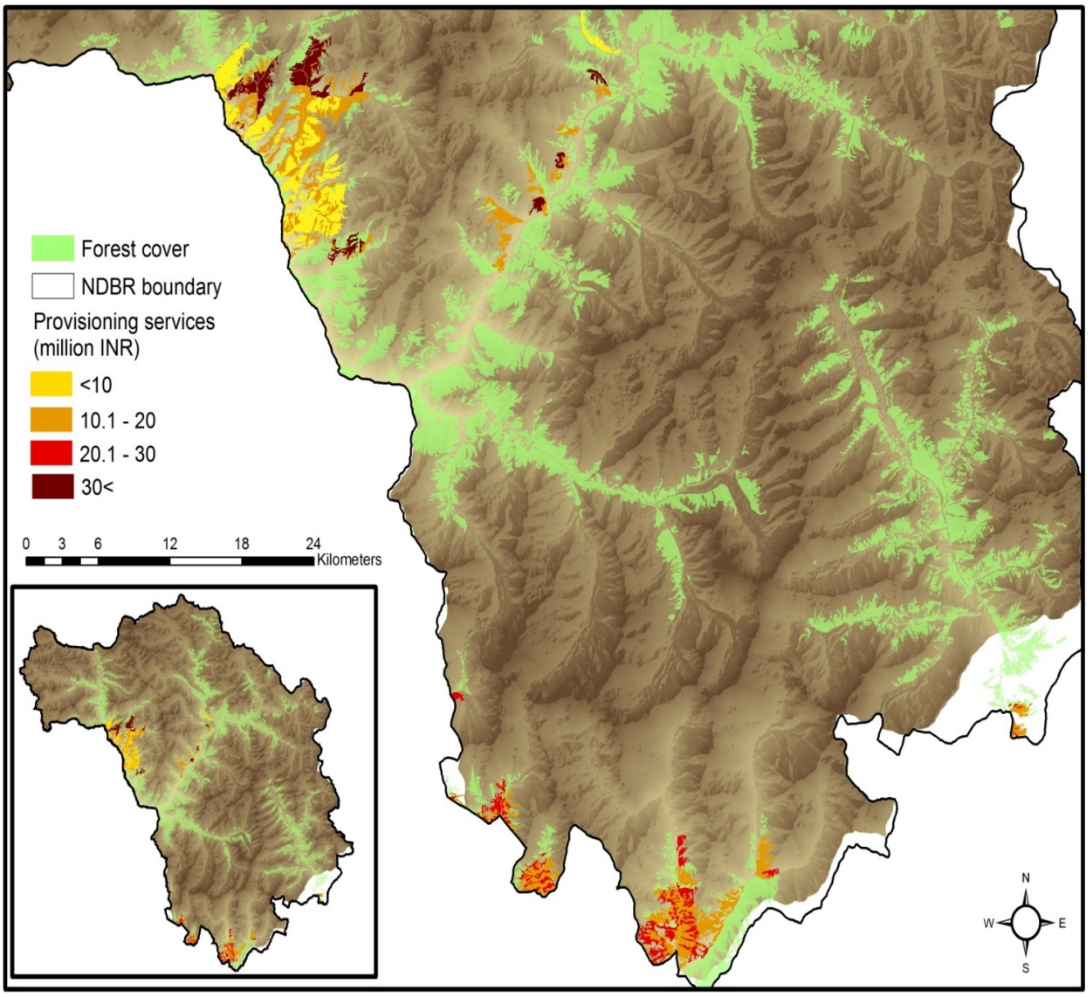


Figure 3.2. Spatial distribution of biomass provided by different NDBR

Table 3.3. Contribution of different forest types to household requirement (kg/household/year)

Forest type	**Fuelwood**	**Fodder**	**Leaf litter**	**Thatching**	**Vegetable**	**Fruit**
Oak LD (500-2500m)	2113.13 ±72.41	3433.16 ±106.7	2527.04 ±85.41	76.29 ±4.23	2.64 ±0.08	6.02 ±0.14
Oak D (500-2500m)	6150 ±247.18	5925 ±182.12	2700 ±208.44	0	2.0 ±0.00	0
Oak D (3000m<more)	1480.76 ±78.84	2514.58 ±106.9	1381.13 ±54.50	30 ±1.04	0	0
Mixed conifer LD (500-2500m)	3192.28 ±155.67	3950.95 ±138.99	2253.48 ±69.62	51.87 ±3.27	2.43 ±0.07	5.83 ±0.15
Mixed conifer D (500-2500m)	2483.34 ±108.56	4625.8 ±99.26	2951.61 ±90.35	0	3.94 ±0.12	0
Mixed conifer -D (3000m <more)	1640.13 ±104.46	2282.14 ±137.45	1358.82 ±67.16	20 ±0.01	0	0
Moist temperate deciduous forest -LD (500-2500m)	2328.57 ±113.76	3278.04 ±146.72	2056.09 ±101.75	27.5 ±1.5	2.85 ±0.13	0
Moist temperate deciduous forest -D (500-2500m)	2237.74 ±152.50	3247.35 ±141.86	2189.42 ±77.98	125 ±2.80	2.52 ±0.10	5.75 ±0.20
Moist temperate deciduous forest -D (3000m<more)	2139.70 ±131.531	3452.89 ±174.6	2419.73 ±68.75	0	3.27 ±0.12	11.18 ±0.43
Deodar-LD (500-2500m)	1925 ±146.65	2321.87 ±154.62	0	0	0	0
Deodar-D (500-2500m)	2488.34 ±108.36	4625.8 ±99.26	2951.61 ±90.35	0	3.94 ±0.12	0

Table 3.4. Economic contribution of different forest types to household requirement (INR/household/year)

Forest type	Fuelwood	Fodder	Leaf litter	Thatching	Vegetable	Fruit	Total
Oak LD (500-2500m)	3169.68 ±108.6	6866.32 ±213.4	3790.56 ±128.1	15258.1 ±847.7	132.45 ±4.4	301.16 ±7.2	15959.1 ±757.05
Oak D (500-2500m)	9225 ±370.7	11850 ±364.2	4050 ±312.6	0	100 ±0.0	0	25145 ±799.8
Oak D (3000m<more)	2221 ±118.3	5029.2 ±213.8	2071.7 ±81.7	6000.0 ±209.1	0	0	8506.04 ±397.7
Mixed conifer LD (500-2500m)	4788.4 ±233.5	7816.94 ±282.24	3380 ±104.4	10375 ±654.3	121.64 ±3.8	291.7 ±8	15344.8 ±679.5
Mixed conifer D (500-2500m)	3725 ±162.8	9251.6 ±198.5	4427.5 ±135.5	0	197.14 ±6.5	0	15695.8 ±741.1
Mixed conifer -D (3000m <more)	2460.2 ±156.7	4564.3 ±274.9	2038.2 ±100.7	4000 ±100.1	0	0	8372.7 ±505.2
Moist temperate deciduous forest -LD (500-2500m)	3492.8 ±170.6	6556.1 ±293.4	3084.14 ±152	5500 ±316.8	142.5 ±6.5	0	13437.2 ±633.6
Moist temperate deciduous forest -D (500-2500m)	3356.6 ±228.7	6494.7 ±283.7	3284.13 ±116.9	25000 ±555.6	126.2 ±5.2	287.5 ±10.3	13786.9 ±811.9
Moist temperate deciduous forest -D (3000m<more)	3209.6 ±197.3	6905.7 ±348.5	3577.2 ±104	0	163.2 ±6.3	559.2 ±21.7	11582.7 ±697.9
Deodar-LD (500-2500m)	2887.5 ±219.9	4643.7 ±309.24	0	0	0	0	5364.2 ±587.5
Deodar-D (500-2500m)	3725 ±162.8	9251.6 ±198.5	4428.4 ±135.6	0	197.1 ±6.4	0	15695.8 ±741.1

3.3.2. Difference between the contributions of different forest types

Condition of forest determines the availability of the resources to the dependent community. I quantified the dependence on different forest types on the basis of condition of forest and distance from the dependent villages. It was found that dependence on the natural resources not only depends on the condition of a particular forest type but distance from the forest also play a major role in determining the extent of the dependence on forest resources. The dependence was also found to be determined by the distance between dependent household and forest. Differences were found in the dependence of households using same type of forest with similar condition but were located at different distances from it.

The average annual income per household was calculated as INR 95646.4 ±3332.4/hh/year which included income from agriculture, floriculture, horticulture, bee keeping, dairy, pack animal and other livestock, jobs in government and private sector, business and forest products. Natural products that people collect from forests contributed INR 15315.1 ±495.7/hh/year and this contribution was found to be 15.6% of the total household income of the dependent households.

It was observed that there was a significant difference in resources provided oak less degraded and oak degraded forest (distance category- 500 to 2500m) (fuelwood- $U=45$, $Z= -9.39$, $p<0.000$; fodder- $U=534$, $Z=-7.456$, $p<0.000$; thatching material- $U= 2595$, $Z = -2.28$, $p<0.05$, fruits- $U=2415$, $Z= -2.76$, $p<0.005$; vegetables- $U= 1872$, $Z= -3.68$, $p<0.000$). There was no significant difference in the provision of leaf litter from degraded and less degraded forest.

Significant difference was observed between the provision of forest resources by mixed conifer less degraded and mixed conifer degraded (distance category- 500 to 2500m). The provision of fodder ($U= 6361$, $Z= -1.93$, $p<0.05$), thatching material ($U= 6912$, $Z= -2.42$, $p<0.05$), fruits ($U= 6840$, $Z= -2.57$, $p<0.05$), vegetables ($U= 1100$, $Z= -11.63$, $p<0.000$), leaf litter ($U= 4893$, $Z= -4.432$, $p<0.000$) was found significantly different while there was no difference in the provisioning of fuelwood.

Contribution of degraded and less degraded moist temperate deciduous forest was found significant only for thatching material ($U=4192$, $Z= -2.44$, $p<0.05$) and wild fruit ($U=2408$, $Z= -7.393$, $p<0.000$). While there was no difference in the contribution to the fuelwood, fodder, leaf litter and vegetable requirements of dependent households.

When I quantified contribution of forests to local economy on the basis of distance between village and forest, I found a significant difference in the contribution of fuelwood, fodder, leaf litter and vegetables provided by the degraded oak forest to the households located close to and away from it (fuelwood- U=0, Z= -9.181, $p<0.000$; fodder- U=48, Z=-8.456, $p<0.000$; leaf litter- U=517.5, Z= -6.266, $p<0.000$; vegetables- U= 1464, Z= -5.024, $p<0.000$). There was no difference found in the input of thatching material and fruits to households located at different distances from the degraded forest. Same pattern was observed in the households located close to and away from degraded mixed conifer forest (fuelwood- U=1568, Z= -5.253, $p<0.000$; fodder- U=1026, Z=-6.849, $p<0.000$; leaf litter- U=1.026E3, Z= -6.801, $p<0.000$; vegetables- U= 78, Z= -11.224, $p<0.000$).

A significant difference was found in the contribution of fuelwood, fodder, leaf litter and vegetables provided by the degraded moist temperate deciduous forest to the households located close to and away from it (fuelwood- U=1568, Z= -5.253, $p<0.000$; fodder- U=1026, Z= -6.849, $p<0.000$; leaf litter- U=1026, Z= -6.801, $p<0.000$; vegetables- U= 78, Z= -11.224, $p<0.000$). No significant difference was found in the contribution of the thatching material and fruits to household located at different distances from the degraded moist temperate deciduous forest.

For the Deodar forest the households were located only near Deodar less degraded forest and near Deodar degraded forest while none of the household was using Deodar located away from the village. The difference was significant between the input of fuelwood, fodder, leaf litter and vegetables by degraded (fuelwood- U=1156, Z= -3.013, $p<0.005$; fodder- U= 432, Z= -6.880, $p<0.000$; leaf litter- U= 45, Z= -9.242, $p<0.000$; vegetables- U= 225, Z= -8.322, $p<0.000$).

3.3.3. Association between alternative livelihood and forest dependence

The dependence on forest's direct services found to be decreasing with the income from other sources (jobs in government and private sectors) ($r(764)= -0.088$, $p<0.05$). The dependence on natural resources was positively contributing to the total household income (income from forest and non-forest sources) ($r(764)= +0.214$, $p<0.005$). The dependence on direct services decreased with availability of other sources of income as it improve the ability of community to avail the alternatives modern resources e.g. sources of the energy, food, fertilizer etc. The relation is not very strong since the dependence for the resources to be used in agriculture increases with the increase in agriculture. Use of natural resources directly and indirectly contribute to the average income of the dependent household hence, total household income increases with increase in the use of natural resources.

3.4. Discussion

Forests are the major source of fuelwood, fodder, and food for the communities of Himalayan region. Here, dependence of human population on the forest biomass for sustenance is tremendously high and it is a century old practice. My results indicate that the ability to provide these resources differ with the type and condition of forests, and availability of alternative livelihood options as it provide them capability to purchase the alternative resources. Similar findings have been made by Sati and Song (2012) who studied dependence of the people in montane mainland of the Indian Himalaya. Their results established that the pine and oak forests contribute to local requirements of fuelwood differently. Results of my study show similar pattern, where contribution to local livelihoods varies across the forest types. Present results establish relation between provisions of ecological goods not only with the forest types, but I have explored these relations on the basis of distance to forests and condition of forests as well.

The overall magnitude of anthropogenic pressure is lower in the buffer zone of NDBR compared to other parts of the India as the restricted use of natural resources, sparse distribution of human settlements with low population density and declining trends of human population due to out-migration of people over the years have kept the biotic pressure under check in the NDBR (Silori, 2001). Due to adverse environmental conditions, the dependence for firewood has been part of the life of local people traditionally and fodder forms a large part of the overall dependence. Study conducted by the Awasthi et al. (2003) and Singh et al. (2010) in other parts of the Garhwal Himalaya show higher resource dependence than the present study (14.65 kg of fuelwood/household/day and 20 to 25 kg of fuelwood/household/day respectively) which indicate that dependence on fodder resources has been lowered in recent past due to accessibility to alternative sources. However, the value are higher than the ones estimated for lower altitudinal villages of western Himalaya (1.49 kg/capita/day) by Bhatt et al. (1994), for southern India (1.9–2.2 kg/capita/day) by Reddy (1981) and the Himalayan range of Nepal (1.23 kg/capita/ day) by Mahat et al. (1987). The difference in the resource use pattern is due to difference in the environmental condition and harsh winter in the area (Bhatt and Sachan, 2004).

Natural ecosystems provide a wide range of assets, including household goods, cultural values and physical and biological products to the human societies (Daily, 1997; Wackernagel and Rees, 2013) and form base for the livelihood of a major population of the developing world (Sunderlin et al., 2005). It is now widely recognized that economically unstable and weak rural households in developing countries depend to a momentous degree on local common-pool resources such as forests and grazing lands to meet their day to day requirements (Beck and Nesmith, 2001; Vedeld et al., 2004; Kuik, 2005). Though dependence is always because of unavailability of alternative resources but communities living in close proximity with forest also use forest resource because they are freely available to them. It has been observed that the main reason for the collapse of sustainable forest management, or the cause of deforestation and change of forested land to various land use categories, is the inadequate recognition and underestimation of the value of many goods and services provided by the forests at the local, national, regional and global scales (UN, 1996). Provisioning services provided by the forest have not received much importance as a service but only in terms of dependence for timber and have been labelled as ‘minor forest products’ (Shylajan and Mythili, 2003). In last few years, there has been increasing interest in the input of natural forests to local rural employment and economy (Mamo et al., 2007).

There is a growing interest about the sustainability of forests and ability of forest dependent communities to sustain themselves through unpredictable political and environmental conditions (Nadeau et al., 2003; Sunderlin et al., 2005). Because community stability primarily evolved with an economic implication, more inclusive terms such as community capacity, well-being, and community pliability are now more useful replacements. These concepts include the previous elements expressed by the notion of stability, but also provide means to integrate other current concerns and values held by community residents. These concepts also possess several common features, the most understandable being that community capacity is an important element of community well-being (Nadeau et al., 2003).

COLLECTION OF BIOMASS BY LOCAL PEOPLE

Leaf litter collection

Fuelwood collection

Fodder collection

Spices collected- *Faran* (*Allium sp.*)

***Kira jari* (*Cordyceps sinensis*) collected**

PLATE 3

Chapter 4. Provision of freshwater by forests

SUMMARY

The object of the present chapter was to assess the provision of freshwater by the different stream originated from the forests of NDBR and its economic contribution to the local communities. Stream flow was monitored using timed volume method (TVM) to quantify the functional output of streams originated from forested landscapes of the area. To explore the reliance of local communities on natural sources of water, personal structured questionnaires were used and data was verified using TVM. Six streams for monitoring were selected on the basis of forest type (oak forest, moist temperate deciduous forest, conifer mixed forest), distance from villages and use of stream by the villagers for different purposes. To assess the economic value of water used by local communities, market price method was used.

Average functional output was found to be more for streams originating from moist temperate deciduous forest (4.8 ±0.5 m^3/hr) than oak (2.3 ±0.5m^3/hr) and mixed conifer forest (0.92 ±0.06 m^3/ hr). This provided opportunity to the local communities to avail the services worth INR 9209.1 ±914.9/day (moist temperate deciduous forest), INR 4375.1 ±976.8/day (oak forest) and INR 1776.05 ±117.5/day (mixed conifer forest). These selected streams altogether provided freshwater services of economic value INR 5120.1 ±595.42/day (with total functional output- 64001.1 ±7442.8 m^3/day). It was found that every household (hh) uses 217.78 ±20.32 lts of water/day (39.6 ±3.7 lts/capita/day) of which 116.67 ±14.81 lts/day/hh (21.2 ±2.7 lts/capita/day) was being used to meet the domestic needs while 101.12 ±9.34 lts/day/hh was being used for livestock. For the irrigation purposes every household which is extracting water from selected streams was found to be using 826.06 ±33.71 m^3 water/year. The total economic value of overall household water consumption was INR 627.2 ±55.5/hh/year (INR 114.03 ±10.6 per capita/year) while it was INR 336 ±40.4/hh/year (INR 61.1 ±7.5 per capita/year) for the domestic consumption of the water. The value of water used for livestock and agricultural purposes was INR 291.2 ±25.5/hh/year and INR 132170.4 ±269.7/hh/year, respectively.

4.1. Introduction

Integral and complex aquatic ecosystems endow with many short and long term services to the humankind. The short-term benefits are ecosystem goods and services, such as drinking water, food supply, flood control, purification of domestic and industrial wastes, and habitation for flora and fauna (Daily, 1997; Wilson and Carpenter, 1999; Baron et al., 2002). Long-term benefits include sustaining the provisioning services and improving pliability of ecosystems to environmental change (Baron et al., 2002). Of all the water forms available, freshwater's availability and distribution is the greatest concern, since freshwater comprises a small proportion (2.5%) of the total water covering earth's surface, of which only 0.3% is the renewable and most easily accessible from lakes, reservoirs and river systems (Shiklomanov, 1998). This freshwater plays multiple roles as supporting, regulating, provisioning and recreational services (MA, 2005; Smith et al., 2006; Greiber, 2009; Mayers et al., 2009) (Table 4.1) and is thus critical for aquatic ecosystems (Shiklomanov, 1998). With rising demands of the growing population and development needs, water is becoming increasingly scarce and vulnerable, compromising its environmental functions. Considering the importance of freshwater systems to human survival and well-being, natural processes and properties that maintain freshwater ecosystem should be identified and monitored on both local and global scales (Karr, 1991; UN, 2011) and all water resources should be treated as an ecological and economical commodity.

Table 4.1. Water related ecosystem services (Modified from: Smith et al., 2006 and Greiber, 2009)

Type of service	Description	Examples
Provisioning services	Direct supply of food and non-food products depending on water flow	1. Access to freshwater 2. Agricultural production 3. Livestock production 4. Fisheries and marine products 5. Production of hydro-electric power 6. Water transport trade

Type of service	Description	Examples
Regulating services	Related to regulating flows and reducing hazards	1. Buffering of runoff soil water infiltration ground water, maintenance of base flows 2. Regulation of soil nutrient 3. Prevention of disaster i.e. landslide, flood, land erosion drought (Risk management) 4. Regulation of surface and ground water 5. Regulating micro-climate
Supporting services	Support to habitats and ecosystem functioning	1. Stabilizing wildlife habitats 2. Upholding flow required to maintain downstream habitat and uses
Cultural services	Related to reservation and human inspiration	1. Aquatic recreation 2. Landscape aesthetic 3. Cultural heritage and identity 4. Religious value (Sacred pond, rivers)

The river runoff representing 0.006% of the available renewable freshwater resources is most widely distributed over the land surface and provides the major volume of water consumption in the world (Herschy, 2009). Globally, the value of river runoff or stream flow is commonly used for estimating water availability and/or deficit in water resources for a region. Climate change has affected the stream flow directly by altering the trends of precipitation, temperature and evaporative demand (Stern, 2006; Alavian et al., 2009) resulting in dryer dry seasons, wetter rainy seasons and degradation of water resources (IPCC, 2007). This phenomenon can reduce minimum flows in rivers, affecting quality and availability of water for various purposes (Stern, 2006; FAO, 2008). Climate change also creates variations in water storage and fluxes at the land surface further threatening local biodiversity (Rounsevell and Reay, 2009). Climate changes aggravate pressure on water resources especially in areas where water resources are scarce affecting human well-being (Bates et al., 2008). There is significant ambiguity in trends of hydrological variables due to large regional differences and limitations of the spatio-temporal monitoring networks (Bates et al., 2008; Baltas, 2009). Monitoring stream flow can potentially be used to monitor impact of the climate change on water resources and can be applied for the assessment of freshwater services or water retained by different landscapes (Huntington, 2006).

Regular monitoring of water resources can determine the optimum extraction levels and its sustainable allocation. Monitoring of water resources can enhance the understanding of climatic conditions, availability of water resources in the region, melting and other flow-generation processes, sediment transport processes, and can help understand trends of natural hazards, e.g. flash floods, cloudbursts, landslides, rockslides and avalanches (Naithani et al., 2001; Mazari and Sah, 2004; Haritashya et al., 2006). It can also be used as a tool to understand contribution of water to economic development and human well-being (Acreman, 2001), enabling societies to allocate water to its highest social value (Moran and Dann, 2007). Stream flow (discharge) data are vital in most water quality sampling and water resource conservation programs.

Natural stream and water sources are used for irrigation and domestic use. Mountains are considered as water towers and are source of water not only for the local communities but also for the communities living downstream. Forested catchments are the source of water for domestic, agricultural and industrial requirements of a large population (Ernst et al., 2004). The availability of water is influenced by forests (Jackson et al., 2005). Water-related problems as scarcity, pollution, floods and drought are important challenges to sustainable development (Morrison et al., 2009). Climate change also increases the complication and affects the dynamics of the forest-water relationship (Kundzewicz et al., 2007). Modern forest hydrology has focused policy-making, advantages and disadvantages of forest cover in maximizing downstream water yields and role of upstream forests in maintaining water flows for downstream and water-quality preservation (Hamilton, 2005). To achieve this, water resources should be monitored regularly (Sharma and Rai, 2004).

Stream discharge or flow

Stream flow or discharge (Q) is the flow of water in streams. Specifically, it is the amount of water passing a point at a given time, and comprises base flow and storm flow (Boman and Shukla, 2009). In all types of streams the upper surface velocity is higher than the mean velocity and does not adequately represent mean velocity. To overcome this challenge, a correction coefficient is used (Vogel et al., 1998). The commonly used coefficient is 0.85 (Costa et al., 2000; Douglas et al., 2002). However, for mountain streams, Jarrett (1988) calculated the value of coefficient as low as 0.67. Stream flow is affected by both natural and anthropogenic activities.

Monitoring stream flow can provide baseline information about the status and effects of water resource degradation on natural habitat. The identification, monitoring and valuation of stream flow are vital for human well-being, locally and downstream (Sharma and Rai, 2004). Since effective management practices at smaller and larger areas can restore degraded ecosystems, measuring flow is significant as it provides information to policy makers and natural resource managers for effective policy and management interventions for efficient economic and financial water allocation (Fig. 4.1) for e.g. allocation of resources for agriculture and domestic uses and relief management during landslide, land erosion, flood, drought. Literature on methods to monitor water as provisioning service is mostly scattered. Most of the studies on stream monitoring are focused on run-off and soil erosion estimation. However, studies on the importance of water resources in relation to the ecosystem services provision are few.

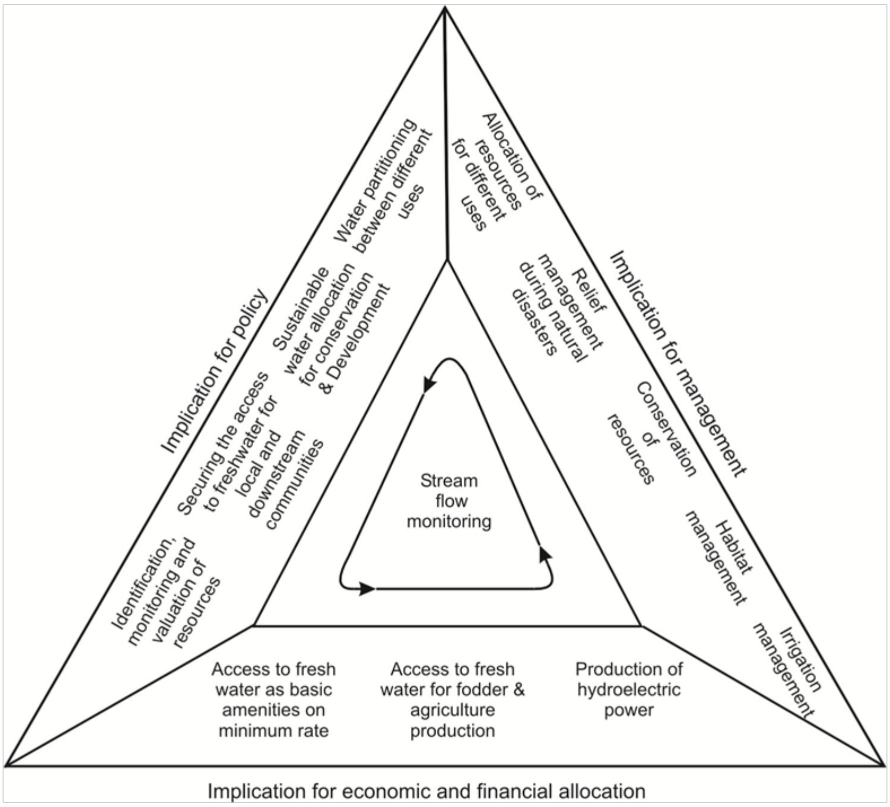


Figure 4.1. Effective policy and management interventions for efficient economic and financial water allocation

In Indian Himalayan Region (IHR), a fragile and dynamic ecosystem, dependence on natural resources for water provisioning is very high. Although, most of the functional output of streams originated from IHR is either being used for industrial purposes or by downstream communities for developmental work, thereby making local communities more vulnerable to the loss of basic facilities. Local communities mainly use the stream originated from forest as bigger streams and rivers are inaccessible due to rough terrain of the mountain. To understand the role of forest in providing these services to human communities stream flow monitoring is a very useful tool and can be used to quantify the contribution of forest to local requirements in terms of provisioning of freshwater.

The object of the present chapter was to assess the contribution of the freshwater provisioned by the different stream originated from forests of NDBR is its economic contribution to local communities.

4.2. Methodology

Stream flow was monitored using timed volume method (TVM) to quantify the functional output of streams originated from forested landscapes of the area. To explore the reliance of local communities on natural sources of water, personal structured questionnaires were used and data was verified using TVM. Six streams for monitoring were selected on the basis of forest type (oak forest, moist temperate deciduous forest, conifer mixed forest), distance from villages and use of stream by the villagers for different purposes (Table 4.2). Accessibility and convenience in reaching the streams were also kept in mind while selecting the stream. Streams were selected by referring the soil moisture distribution results of Badola et al. (2014), which shows that soil moisture is higher at high altitude area due to closeness to snow and glaciers than soil moisture at lower altitudinal forested area. Although, the people are dependent more on the stream nearby villages which mainly originate from forests (Figure 4.2).

4.2.1. Timed volume or Volumetric stream flow method

Timed volume method is used for the streams where the entire flow converses into a single descend (Hauer and Lamberti, 2007). The time required to fill a container of a known volume is recorded, and later used to calculate the average flow rate (Gunn, 1974; Lawson, 1995). For reliable and accurate results, container must be of a large size and the flow rate measured at least five times while more than three replicates for the stream width and depth should be recorded (Ely, 1994; Pfeffer and Wagenet, 2007). Cross-section area can be calculated using average depth and width (USEPA, 1997). The flow rate is the fraction of average stream cross-section area and average time taken to fill the container. This method is accurate, both cost and time effective, non-polluting, and requires limited resources and technical knowledge (Friederich and Smart, 1982). Human error may occur in measuring velocity, stage height and cross-sectional area. To minimize such errors, a high number of trials are required (Weight and Sonderegger, 2001).

Selected streams were monitored in every 10 days for two and half years. Monitoring was avoided during monsoon and after one month of monsoon, and snowfall as during this period the flow in streams is influenced with the rain water and snow. Flow of streams was calculated at a place with a waterfall so all the flow can be captured. A 20 lts bucket was used to calculate the flow and time taken to fill the bucket was recorded using a stop watch. At least 10 replicates of flow measurement were recorded to verify the readings (Plate 4). 10 replicates of width and depth of streams were measured with measuring tape. 10 replicates of width were recorded at different segments of stream. To measure the depth of the stream three reading were recorded at one point; depth at both the sides and depth of water in the middle of the stream at that particular point. This has been replicated for 10 times before calculating the final depth for the particular day.

Table 4.2. Different purposes of water use by villagers from selected streams

Forest type	**Stream ID**	**Purpose of water use**			
		Drinking	**Other domestic works**	**Livestock**	**Agriculture**
Oak forest	1	✓	✓	✓	✓
	2	✓	✓	✓	✓
Moist temperate deciduous forest	1	×	✓	✓	✓
	2	×	✓	✓	✓
Mixed conifer forest	1	✓	✓	✓	✓
	2	✓	✓	✓	×

4.2.2. Interview based questionnaire method

To assess the dependence of people on natural water resources (selected streams), an interview based structured questionnaire was used (n=764). Questions about consumption of water for domestic and agricultural use were asked. To calculate the dependence for water for agricultural use, timed volume method was used. This data was collected only for the households (hh) extracting water from the aforementioned six various streams selected for the water flow monitoring (n=50). The dependence for water for agricultural purposes was quantified by taking representative readings in different crop seasons.

4.2.3. Data analysis

The functional output (stream flow) of the selected streams was calculated using average cross section area of the stream and average velocity of the stream (i.e. time taken to fill the water container). Average of time taken was calculated by recording the replicates of the readings. The economic output was calculated using market price method.

Cross section (a) = average width of stream (w) × average depth of stream

Stream flow= average cross section area (a) × average velocity × 0.67(correction coefficient)

Economic output = stream flow per unit of time × market price (government rate)

Total water use = water used for {domestic purpose (drinking + sanitation + cleaning) + livestock use + agriculture use}

Economic contribution = total water used × market price (government rate)

4.3. Results

4.3.1. Functional and economic output of selected streams

A total of six streams were selected on the basis of forest type (oak forest, moist temperate deciduous forest, mixed conifer forest; two streams in each forest type) and dependence of local people on them. The flow of selected stream (after every 10 days) and contribution of these streams to the requirements i.e. agricultural and domestic, of villagers were monitored. In compared to results of Badola et al. (2014) of soil moisture content in NDBR area, it was found that soil moisture content was higher for high altitude areas due to presence of glaciers than the forested areas.

Although, most of the villagers were found to dependent on the natural streams originating from forests (Figure 4.2 and Figure 4.3).

Average functional output was found to be more for streams originating from moist temperate deciduous forest (4.8 ±0.5 m^3/hr) than oak (2.3 ±0.5m^3/hr) and mixed conifer forest (0.92 ±0.06 m^3/ hr). This provided opportunity to the local communities to avail the services worth INR 9209.1 ±914.9/day (moist temperate deciduous forest), INR 4375.1 ±976.8/day (oak forest) and INR 1776.05 ±117.5/day (mixed conifer forest). These selected streams altogether provided freshwater services of economic value INR 5120.1 ±595.42/day (with total functional output- 64001.1 ±7442.8 m^3/day).

Oak forest

Average depth of the first stream in oak forest was found to be 0.08 ±0.01 m while the average width was calculated as 0.82 ±0.16 m. Cross section of the stream was calculated as 0.07 ±0.02 m^2. Total water flow of the stream was 3.40 ±0.85 m^3 per hour. While for the second stream the average depth and average width were measured as 0.06 ±0.01 m and 0.95 ±0.06 m, respectively. The cross section area of the second stream was calculated as 0.06 ±0.01 m^2. The total water flowing in the stream was measured as 1.09 ±0.25 m^3 per hour. The economic value the services provisioned by these two streams was found to be INR 6653.9 ±162.8/day and INR 2096.2 ±47.5/ day, respectively (Table 4.3).

Moist temperate deciduous forest

Average depth of the first stream in moist temperate deciduous forest was found to be 0.14 ±0.02 m while the average width was calculated as 1.25 ±0.11 m. Cross section area was calculated as 0.19 ±0.04 m^2. Total water flow of the stream was 5.99 ±0.80 m^3 per hour. While for the second selected stream the average depth and average width were measured as 0.09 ± 0.001 m and 1.46 ± 0.002 m, respectively. The cross section area of the second stream was calculated as 0.13 ± 0.001 m^2. The total water flowing in the stream was measured as 3.60 ±0.08 m^3 per hour. The economic value of the freshwater provisioned by the two streams originated from moist temperate deciduous forest was calculated as INR 11500.6 ±153.4/day and INR 6917.6 ±12.2/day (Table 4.3).

Mixed conifer forest

Average depth of the first stream in mixed conifer forest was found to be 0.07 ±0.003 m while the average width was calculated as 0.60 ±0.05 m. Cross section was calculated as 0.04 ±0.005 m^2. Total water flow of the stream was 0.86 ±0.08 m^3/hr. While for the second selected stream the average depth and average width were measured as 0.07 ±0.004 m and 0.62 ±0.05 m, respectively. The cross section area of the second stream was calculated as 0.05 ±0.005 m^2. The total water flowing in the stream was measured as 0.99 ±0.08 m^3 per hour. The economic value of functional output of these streams was found to be INR 1659.6 ±16.3/day and INR 1892.4 ±16.9/day (Table 4.3).

Table 4.3. Functional output of streams originated from different forest types

Forest type	**Stream ID**	**Average depth (m)**	**Average width (m)**	**Cross section area (m^2)**	**Water flow (m^3/ hr)**	**Economic output (INR/day)**
Oak forest	1	0.08 ±0.01	0.82 ±0.16	0.07 ±0.02	3.40 ±0.85	6653.9 ±162.8
	2	0.06 ±0.01	0.95 ±0.06	0.06 ±0.01	1.09 ±0.25	2096.2 ±47.5
Moist temperate deciduous forest	1	0.14 ±0.02	1.25 ±0.11	0.19 ±0.04	5.99 ±0.80	11500.6 ±153.4
	2	0.09 ±0.001	1.46 ±0.002	0.13 ±0.001	3.60 ±0.08	6917.6 ±12.2
Mixed conifer forest	1	0.07 ±0.003	0.60 ±0.05	0.04 ±0.005	0.86 ±0.08	1659.6 ±16.3
	2	0.07 ±0.004	0.62 ±0.05	0.05 ±0.005	0.99 ±0.08	1892.4 ±16.9

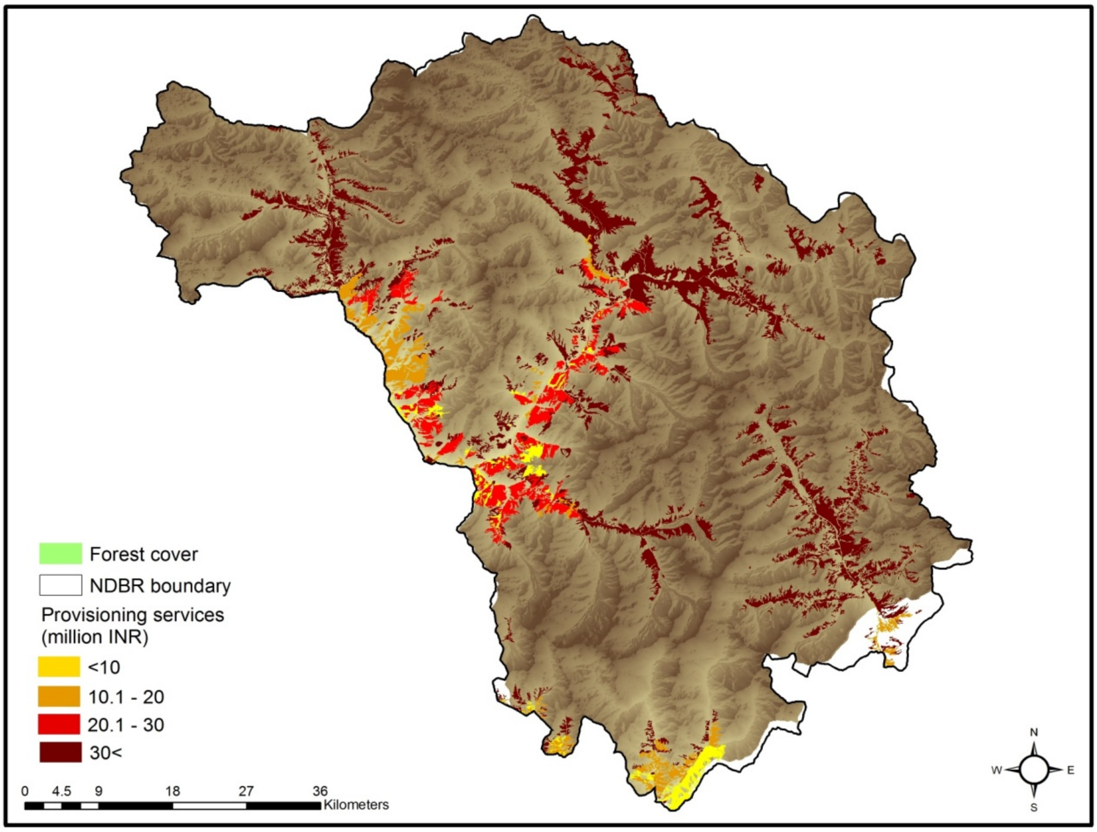


Figure 4.2. Availability of soil moisture content in NDBR (Badola et al. 2014)

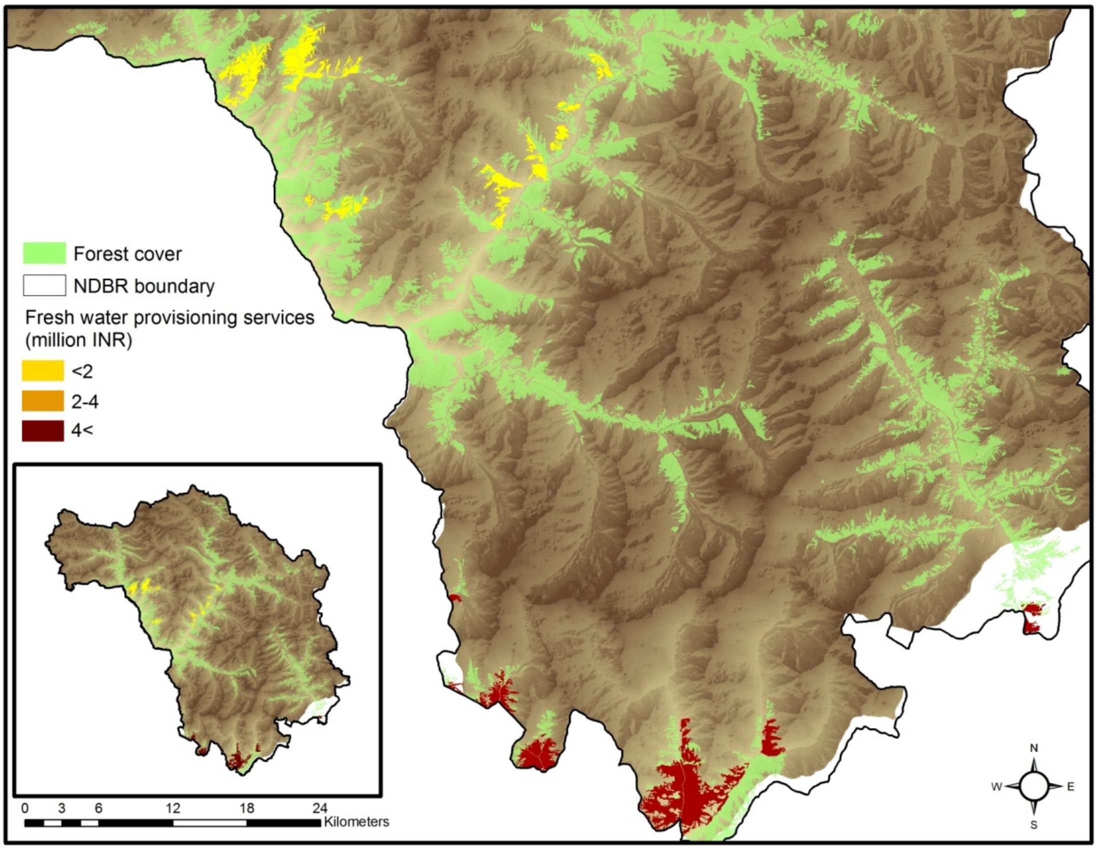


Figure 4.3. Spatial distribution of economic value of contribution of freshwater services

4.3.2. Contribution of natural water resources to local economy and daily requirements

All the respondents surveyed (n=764) said that they use water from natural source originated from forest and snow fed areas located nearby their villages. 20.02% of the respondents said that they use the water from natural resources for irrigating the vegetable crops. Only 16.75% respondents (respondents from Dhak and Lata villages) said that they face shortage of water in summers due to lack of proper arrangement to supply the water for domestic use. It was found that every household uses 217.78 ±20.32 lts/hh/day (39.6 ±3.7 lts/capita/day) of which 116.67 ±14.81 lts/day/hh (21.2 ±2.7 lts/capita/day) was being used to meet the domestic needs while 101.12 ±9.34 lts/ day/ household was being used for livestock. For the irrigation purposes every household which is extracting water from selected streams was found to be using 826.06 ±33.71 m^3 water/year. The total economic value of overall household water consumption was INR 627.2 ±55.5/hh/year (INR 114.03 ±10.6 per capita/year) while it was INR 336 ±40.4/hh/year (INR 61.1 ±7.5 per capita/year) for the domestic consumption of the water. The value of water used for livestock and agricultural purposes was INR 291.2 ±25.5/hh/year and INR 132170.4 ±269.7/hh/year, respectively (Table 4.4).

Table 4.4. Economic contribution of freshwater provisioned by forests of Nanda Devi Biosphere

	Consumption /hh/day	Economic contribution /hh/year	Consumption per capita/day	Economic contribution /hh/year
Total household consumption	217.78 ±20.32 lts/hh/day	627.2 ±55.5	39.6 ±3.7	114.03 ±10.6
For domestic purpose	116.67 ±14.81 lts /hh/day	336 ±40.4	21.2 ±2.7	61.1 ±7.5
For livestock use	101.12 ±9.34 lts//hh/day	291.2 ±25.5	-	-
For agricultural use	826.06 ±33.7 m^3/hh/year	132170.4 ±269.7	-	-

4.4. Discussion

The functional output was found higher for the streams originated from Oak and Moist temperate deciduous forests than the streams originated from mixed conifer forest. As the tree diversity was higher for the first two forest types which increase their ability to restrain more moisture content resulting in supplementary surface flow. Jackson et al. (2005) and Sun et al. (2010) have also observed similar results, they have concluded that a less diverse or monoculture forest may capture more carbon but have adverse effects on the ground water of the area. The freshwater services of forested areas have found to contribute to the day to day requirement of the local communities, significantly, although, the economic contribution is not much, as the prices of water in the rural area are subsidized. However, if considered the expenditure Government and people pay at other places (cities and towns) for safe drinking water and for agricultural other domestic purposes, the economic value of the freshwater provided by forests of the study area, will be remarkably higher than the present values.

Local communities of NDBR are completely dependent on natural streams for water related requirements. As villages are mainly situated at staying at higher elevations, they do not have access for rivers; also as rivers are fast flowing and bring debris/ rocks during monsoon cannot be trusted for water supply, thus increase the need for maintaining the stream as source of water supply for the area.

The dependence is not only for the household need but also to meet the requirements of livestock and for agriculture. Conservation and maintenance of the natural water resources, which is mainly surface flow, is an important task for the natural resource managers as supply of water from other sources is affected due to difficult terrain. At times, alternatives are either unavailable or unsuitable for use. Our results are similar to the estimates of Howard and Bartram (2003) who quantified the per capita requirement of water for household needs. However, our results are higher than the estimates of WHO and UNICEF (2000) as they estimated the water use for domestic health and hygiene activities only while present study has included drinking and cooking also (Table 4.5). Per capita water requirement estimated from the present study is higher than other studies, as we have considered water needs of human, livestock and agriculture. The results for household water requirement per capita suggest that use of water by communities of NDBR is similar to the amount recommended by WHO and UNICEF (2000), which suggested availability of at least 20 lts per person per day from a source within one kilometer of the users dwelling.

Table 4.5. Minimum per capita water requirement estimates of different studies (source: http://epubs.surrey.ac.uk/7676/49/minimum_water_requirement7.pdf)

Study	Water requirement (lts/capita/day)	Basis of estimate
WHO and UNICEF (2000)	20	Basic domestic health and hygiene needs
Gleick (1996)	50	Basic domestic health and hygiene needs
Howard and Bartram (2003)	100	All domestic health and hygiene needs
Shuval (1992)	342	Non-agricultural requirements plus water for essential fresh food production
Falkenmark (1986)	1369	Requirement to run a modern society
World Water Assessment Programme (2003)	4654	Drinking water for active and healthy human life
Present Study	21.2 ± 2.7	Domestic use
	101.12 ± 9.34 lts/day/hh	For livestock use
	826.06 ± 33.71 m^3/yr/hh	Agricultural use

In the Millennium Declaration of the UN General Assembly in 2000, a commitment was made to halve the global proportion of people without access to safe drinking water by 2015 (http://www.un.org/millennium/declaration/ares552e.htm). The international community both confirmed and extended this commitment in the 2002 Johannesburg Declaration on Sustainable Development (UN, 2002). The goal of provision of basic amenities can be achieved only by maintaining the natural sources of water which can be done by regularly monitoring the resources and assessing their sustainability and ability to provide services to the future generations. Forests play crucial role in storing the rain water and slowly releasing surface water in the form of large and small water bodies, including streams, ponds and springs. Maintenance of forests for the provision of freshwater can be an effective management strategy to achieve the goal of ‘access to safe drinking water’.

In addition to the direct impacts of climate change on crop production (Fischer et al., 2005; Tubiello et al., 2007), there is concern about future agricultural water requirements vis-à-vis water availability under the combined effects of climate change, growing population demands, and competition from other economic sectors under future socioeconomic development. Renewable water resources are being increasingly recognized as being essential for the sustainability of human societies in coming decades, just as increasing numbers of people live in water scarce conditions (Fischer et al., 2005). Maintained and properly managed watersheds provide valuable services to society, including the supply and purification of freshwater. Because these natural ecosystem services lie outside the traditional domain of commercial markets, they are undervalued (Postel and Thompson, 2005).

In the next half century, global population is projected to rise at least three times faster than accessible freshwater runoff (Postel et al., 1996; UN, 1998). As a consequence, improving the efficiency of water use will be important for balancing supply and demand for freshwater and for protecting water resources.

Restoration and plantation of forest with ability to retain water especially the rain water in the areas with scarcity could solve the water issues and will lessen the dependence on rain water and ground water. Present study found that in the Himalayan region (with no access to stream generated from glacier), oak and moist temperate deciduous forest are the main source of water but degradation of these forests in lieu for development activities could affect their ability to maintain and provide water for agricultural and household use. Various studies have addressed the stipulation of freshwater resources, and stated that water resources have been significantly tainted (NRC, 1992; Gleick, 1993; Jackson et al., 2005) and aquatic biota negatively affected (Dobson, 1997; Ricciardi and Rasmussen, 1999). The services and functions of freshwater ecosystems are determined by watershed (Hynes, 1970; Likens, 1984). But these services and functions are influenced by terrestrial processes which include changes in land use and land classes by human activities (Moyle and Leidy, 1992).

Stream flow monitoring can be a valuable tool to monitor the impact of climate change at local level. Governments and water resource managers can use stream monitoring using prioritized methods for gathering information needed to plan and assess possible adaptations to a changing climate (Nilsson, 2003; Woodward et al., 2010; CCME, 2011) and valuation of freshwater services. Greater efficiency could be encouraged through economic incentives and a more realistic valuation of water and freshwater ecosystem services. For this, new and site suitable methods should be developed and water resources should be monitored. More complete monitoring of the components of hydrological and biogeochemical cycles, including measuring water quantity and quality at the same spatial and temporal scales, would also provide better data for allocating water resources efficiently among competing needs (Rodda et al., 1993). This emphasis is especially important, because in the last three decades, more than one-fifth of flow gages on small, free-flowing streams have been eliminated (USGS, 1999). Though few studies suggest that afforestation is increasingly considered as a land use activity that threatens water resources security but they also mentioned that at the same time, afforestation is advocated for a wide range of other water-related benefits (Van Dijk and Keenan, 2007). Achieving sustainable water use in the future will also depend on conservation of forest resources (Jackson et al., 2002) and practices used for water resources management (National Research Council, 1999).

STREAM MONITORING PROTOCOL

Selected stream in the study area

Monitoring of the stream flow

PLATE 4

Chapter 5. Interaction among local communities and wildlife

SUMMARY

The purpose of the present chapter was to examine the status and pattern of conflict between wildlife and agro-pastoralist communities of NDBR and economic loss caused by it. Hierarchical cluster analysis was performed to get the clusters of homologous village sets using secondary information. A total of 11 clusters were generated and from each cluster, representative villages were selected for extensive primary data collection. Interview based semi-structured questionnaire were conducted in 411 randomly selected households (hh). The information on status of human wildlife conflict is collected for three years, thus the loss occurred is for three years for all types of conflicts. Economic loss was calculated using market price of the damaged crop. Economic loss due to livestock lifting was calculated using value of the livestock species in the local market. The average land holding for surveyed household was found to be 0.48 ±0.02 ha while total land raided was calculated as 0.16 ±0.007 ha per household. The crop raiding caused economic loss of INR 3179.5 ±102.7/hh. Out of 411 respondents, 107 (26.03%) families reported loss of oxen (1.46 ±0.05 individuals per household in last three years) by wild animals while 113 (27.49%) reported loss of cows (1.45 ±0.04 individuals per household in last three years, 2007-2009). Only seven families have reported loss of a pack animal (mule). 12% families' representatives said that they have lost goats and sheep; one of the household lost 10 goats in one night to an unknown animals. Average monetary loss due to livestock depredation was calculated as INR 6177.27 ±166.7/hh. A significant difference was found in the number of incidences which occurred in different season (χ^2 = 32.35, df = 2, $p < 0.005$). Livestock killed by the wild animals were from different age classes with average age of 4.76 ±0.076 years (χ^2 = 10.72, df = 5, $p \leq 0.05$). Status of the HWC was found to be negatively associated with the average years of schooling (r, 411)= -0.098, $p<0.05$) and household income from sources others than forest products (r, 411)= -0.136, $p \leq 0.005$). As the educational status and higher household income from alternative is an indicator of stable and secure livelihood which makes people less dependent on livestock and agricultural production, and more tolerant towards loss caused by wildlife. There was no significant relation was found between conflict and benefits from forest.

5.1. Introduction

The intimate interspersion of people residing inside forests and nearby areas often results in negative interaction between humans and wildlife (Mishra, 1997a). Human-Wildlife Conflict (HWC) or negative interface between people and wildlife has become one of the primary factor of wildlife management as it represents the most extensive and complex challenge currently being faced by the conservationist (Woodroffe et al., 2005). HWC is a result of actions which degrade and fragment habitats of wild population (e.g. logging, animal husbandry, agricultural expansion and developmental projects; Fernando et al., 2005; Graham et al., 2005) and impede the economical and social security of people (e.g. attack on livestock and human and crop raiding; Graham et al., 2005). Due to high intensity and frequency of HWC, both the marginal human societies and wild population face vulnerability. Intensity and frequency of conflict also determine and frame the attitude of people towards wildlife which directly affects the survival of many populations (Manfredo & Dayer, 2004; Woodroffe et al., 2005). Incidences of livestock lifting, Crop raiding and attack on human reduce tolerance of human societies towards wildlife (Linkie et al., 2007; Campbell-Smith et al., 2010). Conflict and attitude of people are mainly area specific and influenced by personal experiences, socio-economic and political conditions (Messmer, 2000; Graham et al., 2005). HWC confront human welfare, health and security, and have economic and social costs (Ogra, 2008; Ogra and Badola, 2008) and has become a threat to many endangered wild species (Woodroffe et al., 2005).

Understanding and awareness about the complexity of the interaction between human and wildlife can be used as a tool to manage the existing conflict, as impact of conservation strategies on human wellbeing is critical to the amalgamation of poverty alleviation and biodiversity conservation (Barua et al., 2013).

Managing and reducing negative interaction between wildlife and people is top conservation priority in countries like India where high densities of people and wildlife share same resources (Karanth et al., 2012). Communities inhabiting Indian Himalayan region are completely dependent on forest resources which put an extra pressure on fragile ecosystem. These communities share limited resources and space with wildlife which creates a condition. Modern life-style, growing population and unplanned developmental activities has degraded the forest resources up to the extent that they are not enough to support the wildlife population. These developmental activities also have adverse impacts on human population of the area as they have to share the limited natural resources with the workers from outside. Conversion of natural ecosystem to human modified ecosystem has contributed significantly to increase the frequency and intensity of incidences of conflict. Rich and easy food sources in form of crop and livestock attract wild animals which sometimes also leads to attack on human (Gordon, 2009). Newly built roads and other communication facilities have increased the accessibility to the remote areas (Miller and Hobbs, 2002) and have provided probability of interference from outsiders.

In Nanda Devi Biosphere Reserve (NDBR) the local economy is dependent on forest resources and marginal farming. NDBR was famous as a tourist destination to nature, adventure and cultural tourism which has provided an alternative livelihood opportunity to the local communities but had also affected the natural resources. Ban on tourism in the NDNP has diminished the local economy and people are forced to survive on marginal agricultural activities. This sudden but drastic change has negatively changed people's attitude and tolerance level towards forest and wildlife. Earlier local communities had enough of resources to bear the loss to wildlife and population was less, to survive on limited resources. But as the scenario has changed, the interaction between wildlife and people has changed to the status of conflict only.
In NDBR, it is a local belief that population of wild animals (i.e. Black bear, porcupine, wild pig, ungulates etc.) has increased in last few years as the hunting has been prohibited by the government. This has created competition for livestock and human life, and threat for local economy. Due to this particular belief and ban on hunting, the tolerance among people for the wild animals has been condensed. This has also been encouraged by the new market based economy and increased awareness about the monetary value of the livestock and crops.

The purpose of the present chapter was to examine the status and pattern of conflict between wildlife and agro-pastoralist communities of NDBR and economic loss caused by HWC. The results will also provide an assessment of degree of HWC with respect to forest type and socio-economic condition. The study can be used as a tool for proper distribution of the compensation among affected communities which will lessen the tension between human societies and wildlife.

5.2. Methodology

Secondary data regarding HWC and demographic information was collected from the government sources for the period of 2007 to 2009 (Uttarakhand Forest department and Block development office, Census office) to get the overview and assess the nature and the pattern of HWC in the NDBR (Mishra, 1997a). Hierarchical cluster analysis was performed to get the clusters of similar behaving village sets (Gavin and Anderson, 2007) using secondary information. "Cluster Analysis is a set of methods for constructing a sensible and informative classification of an initially unclassified set of data, using the variable values observed on each individual " (Hastie et al., 2000).

A total of 11 clusters were generated and from each cluster representative villages were selected for extensive primary data collection. Collecting primary information is vital in managing the HWC by understanding the timing and locations of conflict, and attitude and behaviour of the involved human communities (Treves et al., 2006). Households were sampled randomly in the selected representative villages. Interview based semi-structured questionnaire (Rigg et al., 2011) and informal discussions (Bagchi and Mishra, 2006; Ogra and Badola, 2008) were conducted in randomly selected households in selected representative villages (Kumssa and Bekele, 2013). Information on compensation, livestock population and species of livestock and extent of crop damage was collected (Karanth et al., 2012). Semi-structured questionnaires are mixture of closed and open questions which enables a mix of qualitative and quantitative information (Barriball and While, 1994; Bryman, 2012). Questionnaire method was used to get responses in a standardized and cost-effective way (Fowler, 2008). Questionnaires were used to collect information of patterns amongst large number of respondents (Harris and Brown, 2010). Personal interview were conducted to overcome the poor response rates of a normal questionnaire survey (Austin 1981). Personal interviews provide opportunity to evaluate the validity of the respondent's answers by observing non-verbal indicators as HWC is a very sensitive issue (Gordon, 1975) and researcher could make sure that respondent is not being influenced by other people (Bailey, 1987). The questionnaire had both open and close ended questions (Holmern et al., 2007). Closed-ended questions were used to get quick information and because of simplicity of analysis of the data while open-ended questions were used to get the unique responses and exploratory data about the subject (Gurung et al., 2008). The questionnaire was pre-tested on 25 people of varying ages, sexes and economic background to ensure clarity and effectiveness of the questions before use.

A total of 411 respondents were interviewed from 12 selected villages. Respondents were selected from different sex, age group, educational and economical classes. The study covered all the main issues i.e. socio-economic characteristics e.g. land holding, livestock owned, annual household income, attitude towards wild animals and forest resources. Questions were not focused on particular wild species to get the information about the actual condition of the area. To assess the crop damage questions related to name of crop, type of crop (weather cash or traditional crop) wild species involved, season, land sown, loss in output of crop and monetary loss were asked. For livestock depredation questions on type of livestock, wild animals, place, season and time were asked. To get the information on attacks on human questions about wild animals, place, season and time were asked. All the respondents were asked whether they have reported the case to Forest Department or not.

The information on status of human wildlife conflict is collected for three year, thus the loss occurred is for three years for all types of conflicts.

5.2.1. Data analysis

Loss incurred by the people was calculated using total land raided under a crop and production per unit. Economic loss was calculated using market price of the lost crop. Economic loss due to livestock lifting was calculated using value of the livestock species in the local market. Chi-square test was used to know the difference in the seasonality of the livestock lifting. To assess the loss occurred due to attack on human was calculated using number of working days lost due to injury, expenditure of treatment, expenditure of travel to hospital and number of lost working days of one care taker (as one member of the family has to stay at home to take care of the injured person mainly affecting agricultural and livestock related work). For the data analysis, program SPSS v16 was used. To understand the seasonality of livestock loss Chi-square test was used. To know the association between socio-economic factors and status of HWC, correlation analysis was done.

Following equations have been used to calculate loss due to wildlife:

$$\text{Crop damage} = \text{Area raided under crop} \times \text{production of crop per hectare}$$

$$\text{Economic loss} = \text{total crop damaged} \times \text{market price of the crop}$$

$$\text{Total agricultural loss} = \text{loss to crop}_1 + \text{crop}_2 + \text{crop}_3 + \ldots\ldots\ \text{crop}_n$$

Loss due to livestock lifting = number of the individual × market price of a species and variety of livestock

Loss due to attack on human = number of working days lost due to injury × expenditure of treatment × expenditure of travel to hospital × loss number of working days of one care taker

Total loss = loss due to (crop damage +livestock loss +human attack)

Annual income for the households was calculated by following equation:

Average Income/household/year = Average {*Income from (forest products + livestock + agriculture + salaries/wages and government schemes/labour)*}

5.3. Results

A total of 12 villages were selected to assess status of human wildlife conflict in the area. A total of 599 households (hh) were surveyed but only 411 households reported any kind of conflict or loss of crop, livestock and human life due to presence of wild animals. For the 411 sampled households, average annual income per household was found to be INR 86642.07 ±5191.15/hh, while land holding was 0.48 ±0.02 ha per household. 96.59% households were practicing agriculture with other livelihood activities having 1.78 ±0.05 person per family engaged in agricultural work. Only 3.41% said that they do not practice agriculture anymore and have left it due to various reasons i.e. old age, insufficient land, loss of crop by wild animals, other livelihood opportunities (Plate 5).

5.3.1. Livestock holding pattern

Of total 411 households, 90.75% had at least one of the livestock while only 9.25% didn't have any livestock holding. Average livestock holding per household was found to be 5.23 ±0.36. Local communities of NDBR mainly rear cattle, goats and sheep along with pack animals especially mules. 72.51% households had one or more cows of local breed while only 16.06% had hybrid varieties of cattle. Buffaloes are not very common and are not preferred in the area hence only 9.25% families reported to own buffaloes of local variety while less than 1% said that they have hybrid variety of the livestock. Only few families were having goats (2.68%), sheep (9.25%) and mules (2.25%) while no one had any pony or horses. 58.15% households owned oxen and 80.54% had cattle calves. As the agriculture in the area is dependent more or less on the cattle. Cattle dung being the main source of fertilizer and oxen used in ploughing. Milk is one of the main sources of direct income and nutrition. Hence the livestock holding per family is higher for these than other livestock species (cow local, 1.06 ±0.04; oxen local, 1.16 ±0.05; calves, 1.17 ± 0.05) (Table 5.1). Representative of the households were asked about the livestock holding and loss of livestock for last three years to pledge the reliability of the information.

Table 5.1: Mean livestock holding per household

Sl. No.	Livestock	Mean holding/hh
1	Cow local	1.06 ±0.04
2	Cow hybrid	0.20 ±0.02
3	Ox local	1.16 ±0.05
4	Calves	1.18 ±0.04
5	Buffalo local	0.09 ±0.01
6	Buffalo hybrid	0.01 ±0.004
7	Goat	0.47 ±0.15
8	Sheep	1.03 ±0.23
9	Mule	0.04 ±0.01

5.3.2. Damage to crops by different wild species

All the 411 families surveyed were also interviewed for the crop depredation by different wild animals. The average land holding for surveyed household was found to be 0.48 ±0.02 ha while total land raided was calculated as 0.16 ±0.007 ha per household. The crop raiding caused economic loss of INR 3179.5 ±102.7/hh. Questions related to crop raiding focused on the incidences occurred in last three years. *Rajma* (*Phaseolus vulgaris*), cabbage (*Brassica oleracea*), and potato (*Solanum tuberosum*) are the main cash crops of the NDBR, and apple (*Malus domestica*) and apricot (*Prunus armeniaca*) are the most grown orchard species. Among traditional crops, people grow wheat (*Triticum aestivum*), *Fafar* (*Fagopyrum tataricum*) and *Ogal* (*Fagopyrum esculentum*), Foxtail millet (*Setaria italica*) and Finger millet or *Mandua* (*Eleusine coracana*). Few household also grow *Cheena*, Maize and pulses.

Triticum aestivum (Wheat)

Out of 411 households sampled, 77.37% said that their wheat fields were raided by wild animals. A total of 0.07 ±0.003ha/hh land under wheat crop was raided which caused loss 185.6 ±8. kg wheat/hh and INR 2227.7 ±105.4/hh. Black bear, Goral, Langur, Rhesus macaque, porcupine and wild boar were found responsible for major loss of the wheat crop in the area. Black bear was held responsible for 11.94% (n=318) of the incidence. All the raiding by Black bear took place during the night and 0.061 ±0.004 ha/household wheat fields were raided which caused loss of 155.56 ±12.4 kg wheat/household. The total monetary loss was calculated as INR 1866.62 ±148.89 per household. Of the observed cases, 78.94% were reported to Uttarakhand Forest Department, Joshimath (UFD) while 21.05% cases were not reported by the affected families. In 2.83% cases, attributed to the Goral, all the incidences occurred in the afternoon raiding on an average 0.091 ±0.021 ha/hh and caused loss of 231.14 ±55.52 kg of wheat per household. A loss of INR 2773.68 ±666.28/household by the crop raiding by Goral was calculated. About 50% of the cases were reported to the UFD. In 14% cases Langur was attributed to the loss of crop and had raided 0.07 ±0.007 ha land per household. This resulted in loss of 185.3 ±17.78 kg of wheat yield per household and loss of an amount of INR 2223.65 ±213.46 per household. All the incidences occurred in afternoon and 80.43% were reported to UFD. 1.88% of cases were caused by Rhesus macaque which raided 0.03 ±0.004 ha land per household and caused loss of 84.56±10.7 kg of wheat per household. Loss of INR 1014.76 ±128.35 per household was calculated. All the incidences occurred in the morning and were not reported to UFD. Porcupine raided 0.08 ±0.002 ha of wheat crop per household and has been involved in 3.14% of the cases. Porcupine caused a loss of 192.65 ±10.18 kg of wheat per household which had a monetary value of INR 2313.65 ±121.77. All the incidences occurred in the night and were not reported to UFD. Wild boar was found to be involved in maximum cases of wheat field raiding (0.075 ±0.004 ha per household) and destroyed the crop in about 65% cases. Loss of 191.78 ±12.27 kg of wheat crop was attributed to wild boar and loss of INR 2301.42 ±147.24 was calculated. All the incidences occurred in the morning and only 28.22% were reported to UFD.

Hordeum vulgare (Barley)

Four wild species, *i.e.* Black bear, wild boar, Goral and Langur, were reported to be involved in cases of raiding of Barley (*Jau*) fields. 115 (36.16%) households reported that they have lost their *Jau* crop due to these wild species. A total of 0.067 ±0.005 ha/hh land under *Jau* crop was raided which caused loss 201.2 ±15.6 kg *Jau*/hh and

INR 2011.7 ±151.7/hh. Black bear was involved in the incidences (13.04%) occurred during the night and raided 0.05 ±0.006 ha land per household and had destroyed 2317.77 ±19.07 kg of wheat per household which had a monetary value of INR 23177.7 ±190.6. All the cases were reported to UFD. Goral and Langur were involved in only 3% of the incidences and reported to raid 0.07 ±0.01 ha/hh and 0.11 ±0.09 ha/hh, respectively. Goral raided the fields in the early morning while Langur raided crops in the afternoon. 70% cases of raiding by Goral were reported to UFD while all of the cases by Langur were reported. Like in wheat, *Jau* fields were also raided maximum times by the wild boar (82.6%) that had raided a total 6.65 ha of *Jau* field (0.07 ±0.005 ha/hh). This has caused loss of 208 ±17.7 kg/hh with a market value of INR 2080.05 ±176.65/hh. All the raiding by wild boar took place during night. More than 75% of the cases were not reported to UFD.

Amaranthus sp. (*Ramdana*)

A total of 13 incidences of *Ramdana* crop raiding were recorded and all were attributed to the Black bear (0.06 ±0.01 ha/hh). All the cases happened in the night. This raiding caused loss of 62.12 ±10.22 kg of *Ramdana* which had value of INR 1863.55 ±306.83/hh. More than 50% of the cases were not reported to UFD.

Pisum sativum (Pea)

A total of 59 households (18.5%) reported that their pea crop was raided by Langur and Rhesus macaque. A total of 0.04 ±0.003 ha/hh land under pea crop was raided which caused loss 131.6 ±11.9 kg pea/hh and INR 3289.8 ±297.5/hh. Both the species had raided the field in afternoon. Langur was reported to raid 0.05 ±0.006 ha of pea fields and caused loss of 151.11 ±19.25 kg of yield which had a value of INR 3777.78 ±483.83 in the market. Rhesus macaques were involved in the 27% of the cases and had raided 0.03 ±0.002 ha of land where pea crop was growing. This has caused loss of 105.86 ±8.24 kg of yield per household which was worth of INR 2646.61 ±20616 in the local market. All the incidences by Langur, Rhesus macaques and wild boar were reported to UFD while none of the cases by porcupine got reported.

Oryza sativa (*Dhan*)

20 households reported that they have lost their *Dhan* yield to crop raiding incidences by wild animals and said that all the raiding occurred in the night time. All the loss of

Dhan crop was attributed to wild boar which had raided 0.043 ±0.001 ha of crop field and destroyed 179.54 ±6.84 kg of yield. This has resulted in the loss of INR 3052.29 ±116.29/hh. None of the incidence was reported to UFD.

Eleusine coracana (Finger millet)

A total of 8.4% of household representatives responded that they have lost the yield of Finger millet (*Mandua)* due to wild animals. Of these cases 25.92% were attributed to Black bear while 74.07% were caused by wild boar. A total of 0.04 ±0.001 ha/hh land under *Mandua* crop was raided which caused loss 102.05 ±2.9 kg *Mandua*/hh and INR 1530.8 ±44.7/hh. Black bear raided 0.04 ±0.002 ha of the *Mandua* fields and had caused loss of 103.58 ±6.9 kg of the crop per household. The lost crop had market value of INR 1553.78 ±103.58. Wild boar had raided 0.04 ±0.001 ha of fields per household. Each affected household had lost crop (101.51 ±3.32 kg/hh) of worth INR 1522.71 ±49.9. None of the cases were reported to UFD by affected families.

Coriandrum sativum (Coriander)

A total of 0.03 ±0.003 ha/hh land under Coriander (*Dhania*) crop was raided which caused loss 65.6 ±7.6 kg *Dhania*/hh and INR 2624.1 ±303.2/hh. Langur and Rhesus macaque were attributed to the raiding of coriander crop with both being involved in 82.6% and 17.4% of the cases respectively. Rhesus macaques raided 0.05 ±0.005 ha of the coriander fields and had demolished 101.95 kg/hh which had caused loss of INR 4078 ±470.8/hh. Langur had raided 0.02 ±0.003 ha of crop fields. Each household had lost 57.95 ±7.83 kg/hh of coriander crop which had a market value of INR 2018.02 ±313.48/hh. Affected households had not reported these cases to the UFD.

Solanum tuberosum (Potato)

A total of 278 families out of 411 families said that they have lost their potato crop due to wild animals. Black bear, porcupine, wild boar and Goral were reported to be involved in the raiding of the potato fields. A total of 0.08 ±0.004 ha/hh land under potato crop was raided which caused loss 818.5 ±41.8 kg potato/hh and INR 4092.6 ±209.2/hh. 63.3% cases, attributed to wild boar occurred during the night and each affected household lost 979.56 ±58.5 kg of potato which was grown on 0.09 ±0.005ha of land/hh. This had resulted in the loss of INR 4897.84 ±292.98/hh. 63.64% cases were reported to UFD and compensation was claimed. 27.33% cases were caused by porcupine and all happened in the night time. Porcupine raided 0.04 ±0.002 ha of potato fields and caused loss of 457.58 ±28.01 kg of yield/hh. Market value of loss per household was INR 2287.89 ±140.05/hh. In about 8% of the cases the crop was raided by Black bear and 809.59 ±143.6 kg of yield/hh diminished which was grown on 0.08 ±0.01 ha/hh. The lost crop had market value worth of INR 4048 ±718/hh. None of the raiding case by porcupine was reported to UFD while all the incidences involving Black bear got reported. 1.43% cases involved Goral as the problem animal which raided 0.06 ±0.02 ha of potato fields and have caused loss of 639.62 ±202.86 kg of yield/hh. The lost crop had a market value of INR 3198.13 ±1014.32/hh. Affected household did not report the incidences to the UFD.

Red kidney bean *(Phaseolus vulgaris)*

A total of 59 households reported loss of Red kidney bean (*Rajma*) crop due to wildlife and mainly Black bear, Rhesus macaques and porcupine were attributed for the losses, only in two cases it was caused by wild boar. A total of 0.06 ±0.004 ha/hh land under *Rajma* crop was raided which caused loss 3827.14 ±7.9 kg *Rajma*/hh and INR 7557.4 ±616.8/hh. In more than 67% cases, Black bear was the problem animal which raided 0.07 ±0.005 ha of crop field and destroyed 117.48 ±9.03 kg of yield/hh. The lost amount of yield was worth INR 9163.73 ±704.04/hh. 77.5% cases were reported to the UFD. 20.33% cases were attributed to the Rhesus macaques, which raided 0.01 ±0.001 ha of land with *Rajma* crop and caused loss of 29.2 ±1.8 kg of *Rajma*/hh. This has resulted in loss of INR 2278 ±139.62/hh. Porcupine was attributed to the *Rajma* crop raiding in 5 cases in which 0.06 ±0.004 ha land was raided by the animal. This has resulted into loss of 94.58 ±1.0 kg yield per household which was worth of INR 7377.24 ±78.0/hh. Not any case involving Rhesus macaque and porcupine was reported to the concerned department.

5.3.3. Loss of livestock due to wild animals

Out of 411 respondents, 107 (26.03%) families reported loss of oxen (1.46 ±0.05 individuals per household in last three years) by wild animals while 113 (27.49%) reported loss of cows (1.45 ± 0.04 individuals/hh in last three years). The killed individuals were reported to belong to different age categories, more than 67% being more than 5 years old. This is because cattle of this age group are generally send to and left unsupervised in the forest while younger ones are stall fed. 24.33% households have reported that they have lost one or more individuals of both the sexes. Only seven families have reported loss of a pack animal (mule); as people generally do not leave mules and horse unsupervised in grazing areas and forests. 12% families' representatives said that they have lost goats and sheep; one of the household lost 10 goats in one night to an unknown animals. Average monetary loss due to livestock depredation was calculated as INR 6177.27 ±166.7/hh while due to lifting of oxen and cows, the loss was INR 7336.45 ±251.5 per household and INR 5079.64 ±164.6/hh, respectively.

Loss of cattle

Causes of cattle loss

Two species of the wild animals; Himalayan Black bear (*Ursus thibetanus*) and leopard (*Panthera pardus*) were reported to be involved in livestock lifting cases. 84.1% cases of cattle lifting were attributed to Black bear while only for 15% cases leopard was held responsible.

Place and seasonality of cattle loss

It was found that more incidences of cattle lifting occurred in winter season (82.72%) than in summer season (17.28%). As there is resource deficiency in forests during winter therefore wild animals come closer to human settlements for easy resources. More female livestock (51.36%) were reported to be killed by wild animals than the male (48.64%) but the difference was not significant (Fig. 5.1).

Death of oxen: seasonality and place

A total of 107 male individuals were killed by wild animals of which 75.7% were killed in winters while 24.30% were killed in summer. It was reported that all the male cattle (n=26) killed in summer were attributed to Black bear, where 30.77% cases took place in agriculture field closer to human settlement while 69.23% incidences occurred in forests; all the incidences took place in the evening time when cattle were returning to the villages. Leopard was involved in cattle lifting only in winters (22.2% of the cases), however, Black bear was responsible for higher percentage of livestock depredation (77.8%). 35% incidences occurred in agricultural fields as during winters the livestock graze in nearby areas of human settlement. All the incidences happened in the evening time. 79.31% of the total deaths of winter season in agriculture fields were credited to Black bear while only 20.69% were attributed to leopard. 64% of the total cases that occurred in winter season took place in forests, of which 59.62% attacks occurred in evening while 40.38% occurred in morning. 85.71% of the incidences that occurred in the morning were caused by Black bear while only 14.29% individuals were killed by leopard. Black bear was involved in 70.97% of total evening incidences while in 29.03% cases, cattle were killed by leopard. No incidences were reported in afternoon and night.

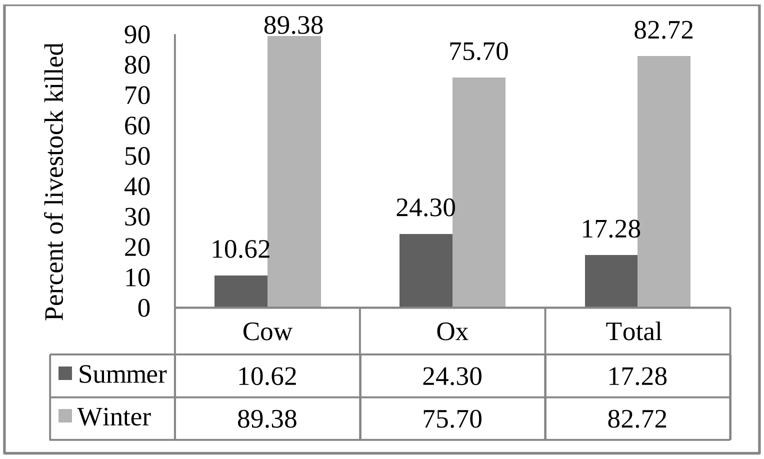


Figure 5.1. Seasonality of cattle lifting by wild animals

Death of cow: seasonality and place

A total of 113 female cattle were killed by wild animals. 89.38% were killed in winters while 10.62% attacks occurred in summer. In summer all the incidences took place in forests in evening and all the cases were attributed to Black bear. In winters, no incidence occurred in the morning, 78.21% happened in afternoon, 15.84% occurred in evening while rest of the 5.9% took place in the night. In all the cases that occurred in evening, cattle were lifted (n=16) from the cow shed; of which 81.25% were killed by Black bear and 18.75% cows were lifted by leopard. In the cases that occurred during night time (people leave their cattle in the forest), all cattle were killed in forest (n=6). Of the incidences that occurred in evening, 77.22% happened in forest, 21.52% occurred in cowshed and 1.27% took place in the agriculture field. Only one case occurred in agriculture field in afternoon which was attributed to Black bear. Of the cases which occurred in forest during afternoon, 81.97% were by Black bear while 18.03% were credited to leopard. Of the cattle killed in or lifted from cowsheds, 88.24% were killed by Black bear while 11.76% were killed by leopard. In all the cases reported for livestock loss in forest and agriculture fields, grazing was unsupervised.

Report to forest department about cattle loss

Out of total 220 cases recorded during the present survey, 73.64% cases were reported to the Forest department and compensation was claimed while 22.43% cases went unreported. In case of oxen, 77.6% cases were reported to the Forest department while in case of cow lifting only 69.9% cases were reported by the affected families.

Loss of goat/sheep

About 12% (n= 411) household representative reported the loss of either goat or sheep, or both the livestock. Most of the cases (81.40%) occurred during summer while grazing in the alpine grasslands. The predator animal were snow leopard, leopard, Black bear and wolf, although respondents were not sure about the predator involved in particular kill and reported that either of the above mentioned wild animals may be involved in the loss of goats and sheep. Rest of the cases (18.6%) occurred during winters while grazing in nearby forests under supervision. Death of goat/sheep due to wildlife has caused economic loss of about INR 4936.7 ±198.15/hh. Only about 20% of the cases were reported to the Forest department as the compensation for the loss of goat and sheep is less than the actual market price.

Loss of pack animal (mule/horse)

Only seven families have reported loss of a pack animal (2%, n= 411). All the cases occurred during winters; of which two of the cases occurred while the livestock were grazing in the barren/common land near villages while rest of the cases occurred in forests. The loss was attributed to leopard and Black bear. This has caused economic loss of INR 35714.3 ±4144.5/hh which is higher than the economic loss caused by loss of other livestock as the market price for the pack animal is high because of its use in tourism and transportation to the remotely situated villages.

Difference in the incidences in different seasons and age classes of livestock

None of the respondent reported any incidence of livestock depredation during rainy season. A significant difference was found in the number of incidences which occurred in different season (χ^2= 32.35, df = 2, p<0.005). Livestock killed by the wild animals were from different age classes with average age of 4.76 ±0.076 years (χ^2= 10.72, df= 5, p≤0.05).

5.3.4. Attack on human

Out of 411 families, only one household reported an attack by Black bear on an elderly person leaving him injured. In this case, bear attacked the victim near the agriculture field. In informal discussions, three other cases of attack on human were reported. In one case a women working in a wheat field was attacked and killed by the Black bear in the morning. In two other cases, leopard attacked and killed two women while they were collecting fodder in forest. Other than the specific villages which were selected to study conflict extensively, four more cases were found where person was killed in the attack. A minor injury causes loss of INR 41666.6 ±1667/ person to the injured person while a major injury cost INR 92500 ±2500/person. This loss include loss of working days, expenditure of treatment, expenditure of travel to hospital and number of working days lost, of one care taker (as one member of the family has to stay at home to take care of the injured person mainly affecting agricultural and livestock related work).

5.3.5. Factors affecting status of human wildlife conflict

Status of the HWC was found to be negatively associated with the average years of schooling (r, 411)= -0.098, p<0.05) and household income from sources others than forest products (r, 411)= -0.136, p≤0.005). As the educational status and higher household income from alternative is an indicator of stable and secure livelihood which makes people less dependent on livestock and agricultural production, and more tolerant towards loss caused by wildlife. There was no significant relation was found between conflict and benefits from forest.

5.4. Discussion

The results of present study identified the main factors of self-reported household crop raiding and livestock predation and their impact on the local economy. Only few studies have been conducted to assess the perceived and self reported human wildlife conflict (Siex and Struhsaker, 1999; Karanth et al., 2012). Most of the work has been done by direct assessment and estimation of human wildlife conflict and losses, but the losses perceived by the affected household have often been ignored. Understanding and acting upon such information are the necessary steps to reduce the conflicts between people. As HWC is a local phenomenon, it should be dealt by understanding the local factors well. People do not report all the cases to the concerned department or the government offices leading to under estimation of the actual loss to people and wildlife both. Many people do not report the conflict cases due to lack of awareness, less or no compensation and sometimes due to procedure of compensation mechanism. This knowledge and understanding of perceived conflict can be used to minimize the level of conflict in affected areas.

It was found that there were more incidences of livestock predation in forest than the agriculture fields and human settlement; and all the livestock killed were unsupervised. The area experience a harsh winter and limited resources which also leads to a competition between human and wildlife. Survey respondents clearly regarded wildlife in this area as causing significant problems, with varying conflict levels (Maddox, 2002). People although leave cattle are often left in rangelands during summer and early rain without supervision but have reported the loss more due to more compensation than goat, sheep. During the personal conversation it was found that people can bear the loss of a goat and sheep while they are most confounded with the loss of a pack animal as the owner household is completely dependent on the animal for livelihood. As the main occupation of the area, agriculture is dependent on the availability and quantity of the cattle manure, cattle play a major role in the local economy and loss of cattle affects the whole economical setup of a household. During non-formal discussions respondents and members of local community said that the frequency and intensity of conflict (affecting human economy and well-being) have increased, which also has been observed by Conover and Decker (1991), Conover (1994, 1997, 1998), Mishra (1997a) and Messmer (2000). People also reported that cases exterminating wildlife have decreased due to ban on hunting. According to local people, increased protection to wild animals has resulted in increased frequencies of crop raiding and livestock depredation. Mishra (1997a), in contrast to this stated that high protection plays less significant role in high frequency of conflict. In an unpublished report submitted to Wildlife Conservation Society, Bronx (Mishra 1997b) related it to increase in livestock holdings and change from subsistence to commercial agriculture and animal husbandry.

Human-wildlife conflicts, such as crop-raiding, increase as people expand their agricultural activities into or closer to wildlife habitats. Crop-raiding reduces lenience toward species that are already threatened, whereas potential dangers posed by conflicts with large-bodied species may also negatively influence local attitudes (Campbell-Smith et al., 2010). According to Turner et al. (2003), three main factors affect the level of vulnerability, namely entitlement, coping and resilience. Entitlement, whether through legal or customary means, involves the ability to access resources needed in times of hardship (Hazzah, 2006), and in traditional societies this is often achieved through systems of social reciprocity between households, particularly among extended families (Bell, 1984; Naughton-Treves and Treves 2005; Dickman, 2008). Conflicts between humans and predators are the product of socio-economic, political and geographical landscape. They arise mainly because of struggle between people and predators for shared, limited resources. The conflicts can be predominantly controversial when the resources concerned have economic value (Graham et al., 2003).

The link between higher conflict and higher levels of livestock depredation seen here is also completely understandable and echoes the results of other studies around the world, where high depredation results in intense human-wildlife conflict (Thirgood et al., 2005). Livestock predation by mammalian carnivores is one of the most recurrent reasons of conflict between humans and wildlife globally (Cozza et al., 1996; Kaczensky, 1996; Pedersen, 1999; Mazzoli, 2002). Perceived economic losses due to livestock depredation often lead to penalizing responses by agro-pastoralists (Graham et al., 2005). Improving the direct economic linkages between the protected area and local communities is therefore something that must urgently be addressed to help redress the cost-benefit balance of living adjacent to the protected area and to reduce conflicts.

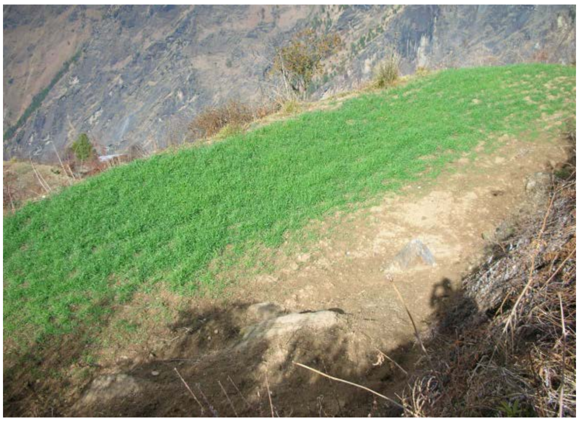
Conflict has characterized the linkage between humans and wildlife rights through history (Heydon et al., 2010). Though, the alteration of global landscapes from predominantly wild to predominantly anthropogenic over the last three centuries (Ellis et al., 2010) has seen rivalry between humans and wildlife for space and resources reach unparalleled levels (Siex and Struhsaker, 1999; Bulte and Rondeau, 2005; Woodroffe et al., 2005). There is no single way out to reduce HWC (Distefano, 2005). A methodical understanding of wildlife ecology is essential for the advancement of management and conservation plans (Sinclair et al., 2006; Hoffman and O'Riain, 2012). With increased human population, biodiversity conscious management strategies need to be made after concerning and understanding the perception of the local communities towards wildlife and conflict between two societies.

LOSS DUE TO HUMAN-WILDLIFE CONFLICT

Livestock predation

Agricultural field damage by wild pig

Crop depredation by Goral



Crop depredation by wild pig

PLATE 5

Chapter 6. Recreational value of the Reserve

SUMMARY

This study aims to evaluate the recreational service provided by the landscape of Nanda Devi Biosphere Reserve (NDBR) and its contribution to the livelihood of the local communities. The zonal approach travel cost method was used to collect data for evaluating recreation value in the NDBR. Awareness and attitude of tourist towards the Reserve and its protection status were also assessed using semi-structured questions. To calculate the contribution of tourism sector to the economy of local community 12 villages were surveyed. People directly involved with tourism sector i.e. shopkeeper, tourist guides, tour operators, porters, mule owners; and people indirectly involved (people selling products to local shopkeeper instead of selling directly to the tourists) were interviewed (n=200). The recreational value of the NDBR was estimated to be INR 963819.54 and consumer surplus was INR 43.71/visit/year. The value of NDBR for religious tourism was derived as INR 9840231.35 while the consumer surplus was 15.01/visit/year. Average household income for the households involved in tourism was estimated as INR 155454.56 ±15083.8 per year/hh and contribution of tourism was found to be INR 82133.33 ±10168.9 per year/hh. The recreational tourism in the area was more elastic than the religious tourism, hence religious tourism provide a continuous source of income for local communities. It was found that the contribution of tourism to the households ranges from 2% (mainly indirectly involved household) to 93%. Although, the religious tourism is providing livelihood to more people but the average household contribution was higher for the households involved in recreational tourism. It was found that recreational tourist were more aware about the conservation status of the area than the religious tourism.

6.1. Introduction

Cultural and natural tourism can be used to generate employment, combat poverty and achieve sustainable development. Recreation is one of the copious services provided by ecosystems. The users attach a value to nature recreation that is substantial and is not reflected by market prices and is provided as a quasi-public good (Zandersen and Tol, 2009). Considering these values can result in better management, conservation and planning activities for nature recreation. The recognition of economic benefits of recreation has provided a sound business rationale globally and has been identified a tool for biological conservation (Ahmed et al., 2007).

Natural areas are frequent focus of recreational trips but seldom command a price in the market. Tourism in Natural areas, particularly mountains is increasing at a rapid pace, as many tourists are attracted to the scenic beauty, culture, history, and adventure-recreational opportunities that it offers. This growth provides benefit to local communities and national economies, but on the other hand also poses a potential threat to the health of their natural and cultural resources. Inadequately addressed and implemented tours and activities can have a serious impact on fragile mountain ecosystems, as well as on the local communities (UNEP and CI, 2007). It put extra pressure on the ecosystem if not managed and leads to the inequitable benefit sharing. The value of a service may change due to change in climate, land use conversion and other natural and anthropogenic causes, it is necessary to allocate and value these services for their continued supply in the future. Allocation and valuation of recreation services will help managers to develop better policies and implementation strategies. Understanding potential value of forest recreation and other non-marketed benefits and quantification of such values are not new (Willis and Benson, 1989; Chaudhry and Tewari, 2006) but attempts to implement the finding of these studies are comparatively few.

Nanda Devi Biosphere Reserve (NDBR) gets visits for different purposes (Plate 6). Most of the tourists visit the place for the religious purpose as the Hindu and Sikh shrines are located near one of the core zones in the Reserve. The Niti valley hosts mainly adventure and nature tourists and the volume of tourists is low. The Nanda Devi peak was a key tourist attraction in the 1970s-80s, but the area was subsequently declared a National Park, and tourism was banned; but later, a stretch of 17 km was declared open to regulated tourism. The facility of traditional homestay is available in the peripheral villages of the Nanda Devi National Park (NDNP) that provides monetary benefits to the communities. Majority of the tourists in Mana valley are religious tourists, visiting Badrinath and Hemkunt Sahib, the Hindu and Sikh pilgrimage destinations. Visitors to these religious sites do not require permit from the government agencies, resulting in a high volume of unregulated tourists. However, visits to the nearby Valley of Flowers (VoF) are strictly controlled.

Tourism can potentially open up new vistas when it comes to livelihood opportunities for the communities residing NDBR (Plate 7). The tourism is ambivalent, and this may be particularly striking in those small island states where tourism contributes to the annual revenue. Here, growth in tourism sector raises several problems and difficulties such as conflicting demands on limited resources e.g. water, open lands, energy and waste disposal. Despite of important role in local economy and its impact on biodiversity recreational value of the NDBR has not been studied before.

This study aims to evaluate the recreational service provided by the landscape of NDBR and its contribution to the livelihood of the local communities and to assess the tourists' preferences and their willingness to pay of NDBR. Valuation of recreational use of the area will help the management in developing a sustainable ecotourism model for equity in benefit sharing.

6.2. Methodology

6.2.1. Travel cost method

The zonal approach travel cost method (ZTCM) was used to collect data for evaluating recreation value (Clawson, 1959; Moeltner, 2003; Badola et al., 2010) in the NDBR. The Travel cost method (TCM) estimates use values for site-specific amenities, specifically the use values that can be obtained by visiting a site. TCM models are based on the premise that individuals choose their trip pattern (number of trips and destination) so as to maximize their utility subject to their income (Tisdell and Wilson, 2002). The fundamental principle behind the TCM is the direct relation between distance and number of trips to a particular recreational site, i.e., number of trips will be more from places close to the recreational site than place far from the recreational site (Ahmed et al., 2007). The Zonal travel cost model was first applied and developed by Clawson at Resources for the Future (Clawson, 1959; Clawson and Knetsch, 1966). In ZTCM the whole area of origin of visitors is divided into zones. Zones can be circular where center will be the study site. Zones can also be selected using geographical or administrative units of the area. Identification of the origin of visitors is important to note to estimate the number of visitors per year from each origin zone. The population of each origin zone used to calculate visitation rate for the zone. This visitation rate is explained by two factors: the travel cost from the origin to the site and the demographic/income characteristics of the population of the origin zone (English and Bowker, 1996).

The ZTCM approach redefines the trip generating function (tgf) as;

$$V_{hj} / N_h = f\,(C_h, X_h)$$

where, V_{hj} = Visits from zone h to site j;

N_h = Population of zone h;

C_h = Visit costs from zone h to site j;

X_h = Socioeconomic explanatory variables in zone h.

The visitor rate, V_{hj}/N_h, is often calculated as visits per 1000, 1000000 population of zone h (Chaudhry and Tewari, 2006).

The individual approach is based on annual trips, trip costs and socio-economic variables of individual or micro data. Direct estimates of price-quantity relationship for a particular individual can be calculated. Economic theory shows individual models to be superior to zonal models (Fletcher et al., 1990). Though, in cases where households or individuals take only one or at most a few trips per year, individual models may not be applicable, for such situation zonal models are better substitute (Guha and Ghosh, 2009; Ward and Loomis, 1986).

Two alternative methodologies exist to estimate the recreational value, the Contingent Valuation Method (CVM) and the travel cost method (TCM). CVM asks potential visitors what they are willing to pay to visit a recreational site. However, this method does not record visitors' actual behaviour (Guha and Ghosh, 2009). In a developing country such as India the contingent valuation method (CVM) cannot always correctly evaluate the recreational value of an environmental resource because of parallel economy involving different categories of middle to upper income groups of visitors (Chaudhry and Tewari, 2006). Existing literature show that when there is a market for the service to be valued, CVM should be avoided (Guha and Ghosh, 2009). I used the travel cost method (TCM) to overcome this impede, which is a more acceptable methodology for valuing recreational services. I used the zonal approach for the study as most of the tourists do not repeat their trip to the NDBR. It estimates the recreational demand for the site based on visitors' 'revealed' - as opposed to 'stated' – preferences (Guha and Ghosh, 2009).

A multisite destination model based structured questionnaire was developed in accordance to UNESCO's manual "Managing Tourism at World Heritage Sites"

(Pedersen, 2002) as ignoring the multi destinations leads to overestimation of the consumer surplus (Kuosmanen et al., 2004). A survey was pre-tested and carried out at sampling sites (Ahmed et al., 2007). Sampling sites were selected on the basis of the visitation rate (Petrosillo et al., 2007). Personal interviews with tourists were conducted at all the selected sites. Tourists representing different socio-economic and occupational groups (Akhter et al., 2009) and with different profile (e.g. local resident, foreign tourist and tourist on independent holiday or on package tour) and purpose of visit (e.g., skiing, religious purpose, trekking, expedition, holiday, business and visiting friends and relatives etc.) were interviewed (Badola et al., 2010). The sampled population was divided into zones on the basis of the state of origin of the tourists. Areas of origin of tourist were not divided into circular zones as getting population estimation for these zones was difficult. For the visitors from other countries the state of origin was taken as a zone (English and Bowker, 1996).

Tourist visit NDBR for various purposes in different seasons, religious tourists visit in summers while nature-based and recreation tourists visit the place throughout the year. Adventure tourists visit the Reserve for trekking in summers and for skiing in winters. To reduce the seasonal effect and bias of data towards tourists of a particular type of profile, sampling was done for the whole year (Guha and Ghosh, 2009). To normalize information on the different variables utilized in the study, distance was measured as the distance (in kilometers) between the capital of the state of origin and the sampling site. For tourist profile information about income, age, education status and state of origin was collected. Reason for trip was asked to find out most attractive cultural services of the study area. To calculate the travel cost information about mode and cost of travel, group composition, and cost of stay, food and expenditure on services provided by local people were gathered. Time spent on travel (both side) and time of stay in the area was evaluated on the basis of hourly wages (Mcconnell and Strand, 1981). Recreational value for religious and recreational function was calculated separately as both the functions behave differently. Recreational visits highly depend on access to basic amenities, weather and road accessibility to the place while religious tourism is not affected by such factors.

Awareness and attitude of tourist towards WHS and protection status Biosphere Reserve were also assessed using semi-structured questions. To estimate the contribution of tourism to the local economy, people engaged in tourism related activities (tourist guide, porter, owners of home-stay and hotel and lodge owners) were interviewed.

The total cost of travel is calculated for each visit by using the total cost of travel, the monetary value of the time spent in travel to get to site and at site and money spent at the site for stay, food, hiring of guides and procurement of local products. The cost of time spent is estimated using the wages per hour for the particular visitor. Cost of travel to NDBR was considered for round trip and was calculated by summing cost of distance traveled, and fare paid for journey and maintenance cost for vehicle used, it was calculated per km per visit. Maintenance cost included cost of fuel, money spent to refurbish or other maintenance work of the vehicle. These clubbed together gives the total cost of travel. The regression analysis between visits and travel cost was done to get an equation that relates visits per capita to travel costs (Badola et al., 2010).

To calculate the contribution of tourism sector to the economy of local community 12 villages were surveyed. People directly involved with tourism sector i.e. shopkeeper, tourist guides, tour operators, porters, mule owners; and people indirectly involved (people selling products to local shopkeeper instead of selling directly to the tourists) were interviewed (n=200). Questions regarding employment type and annual income were asked.

6.3. Results

A total of 693 tourists at three selected sites (Auli, Badrinath, Hemkunt and Valley of Flowers) were interviewed using structured questionnaire. An average six to seven lacs tourists visit NDBR every year. VoF receives tourism related to nature only while Auli receives nature tourism along with adventure tourism. Badrinath hosts mainly cultural tourism while Hemkunt receives some nature tourism with high percent of cultural tourism (Table 6.1). Auli and Badrinath have metalled roads while one has to walk 17 km and 19 km to reach VoF and Hemkunt respectively. Because of high cultural value in Hindu and Sikhism beliefs, Hemkunt and Badrinath attract more visitors than other two sites.

Table 6.1. Tourism profile of NDBR

Place	Type of tourism	No. interview conducted	Season of maximum visits	Season for visit
Auli	Nature & Adventure	242	Winter	Throughout the year
Valley of flowers	Nature	119	Rainy	July-October
Badrinath	Cultural	220	Summer	May-Mid November
Hemkunt	Nature & Cultural	112	Summer	June-October

6.3.1. Nature based recreational value of the NDBR

6.3.1.1. Profile of tourist

A total of 361 respondents from 22 different zones were interviewed (Table 6.1; Table 6.2) of which 79.78% were male while 20.22% were female. 307 people said that they are visiting the place for the first time while 54 had visited the area earlier. Among repeat visitors 55.6% were visiting the place for the second time while 18.5% had more than 10 visits in previous years. Mean age of respondents was 36.80 ±0.60. Most of the tourists were on independent holidays (58.73%) while 16.62% were on package tour provided by different non-governmental organizations. 15.79% were international tourists. For recreational activity the least number (8.86%) was observed for local residents (Fig. 6.1). Group size of the tourist was observed ranging between 22 to single individual (mean=6.36, SE= 0.31).

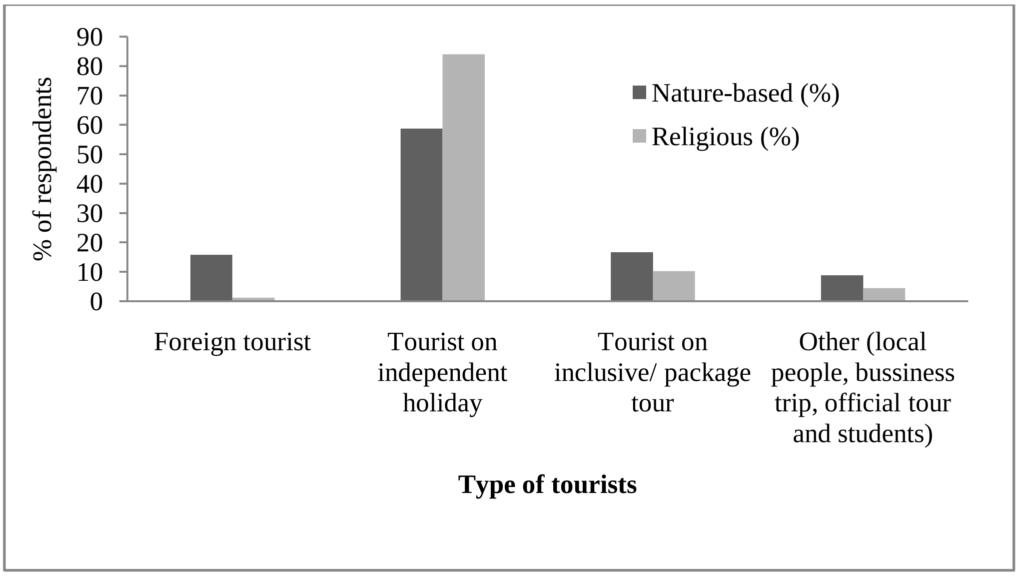


Figure 6.1. Type of tourist visiting NDBR

Respondents were categorized into different educational, occupational and income groups and classes. 48.5% respondents were graduates followed by the post graduates (34.63%). Least percent (1.39%) of respondents were from sixth educational group (Ph.D.) (Fig. 6.2).

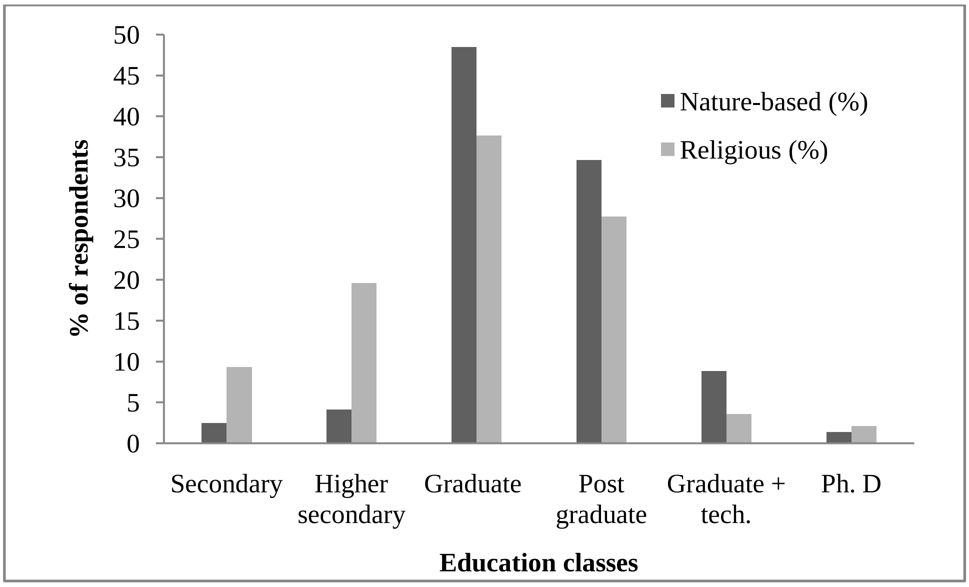


Figure 6.2. Educational status of tourists visiting NDBR

Table 6.2. Profile of tourists visiting NDBR for recreational purposes

Zones	Interview conducted	Total visit	Population	Visit/1000	Total expenditure
Arunachal Pradesh	3	9	84655533	0.000106313	98597.92
Austria	3	21	8414638	0.002495651	437092.67
Belgium	2	8	11041266	0.000724555	440836.67
Chennai	3	8	72138950	0.000110897	58331.25
Delhi	44	161	11007839	0.014625941	1049407.76
England	3	15	53012456	0.000282952	546762.33
France	3	21	65350000	0.000321347	320087.50
Germany	8	37	81799600	0.000452325	1253396.94
Gujarat	9	24	60383628	0.000397459	224831.25
Haryana	6	38	25353081	0.001498832	193115.93
J&K	3	23	12548926	0.001832826	67062.50
Karnataka	21	96	61130704	0.001570406	1348323.14
Madhya Pradesh	3	13	72597565	0.000179069	153520.84
Maharashtra	57	213	112372972	0.001895474	2674824.25
Punjab	3	8	27704236	0.000288765	124875.00

Zones	Interview conducted	Total visit	Population	Visit/1000	Total expenditure
Rajasthan	13	13	68621012	0.000189446	190341.41
South Africa	5	10	51770560	0.00019316	2031613.42
South Korea	1	11	50004441	0.00021998	175982.00
Tamil Nadu	3	9	72138958	0.000124759	52312.50
Uttar Pradesh	19	138	199581477	0.000691447	447499.31
Uttarakhand	42	255	10116752	0.025205718	229617.42
West Bengal	43	146	91347736	0.001598288	1188953.89

Respondents are reported to belong to eight different occupational backgrounds. More than half of respondents were working in private sector (53.74%) while 17.73% were self employed and had their own business. 12.47% were working with different government agencies while 8.59% were students (Fig. 6.3).

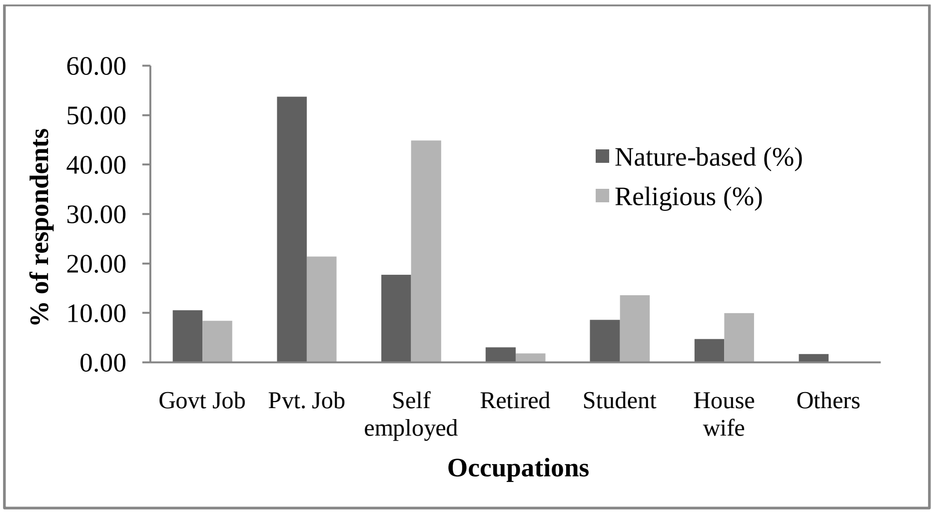


Figure 6.3. Occupational pattern among tourist visiting NDBR

Further respondents were sorted into seven different income classes. Highest number of respondents were from the income class third (INR 21000-40000/month) followed by the group first (not earning, which included elderly, house wives and students), and fourth (INR 41000- 60000) and sixth (INR 81000-100000). Least number of respondents was observed for the income class (INR 1000- 20000) (Table. 6.3).

Table 6.3. Income classes of respondents visiting NDBR

Income class	Nature-based (%)	Religious (%)
Not earning	15.79	24.40
1000-20000	10.80	31.02
21000-40000	22.16	25.90
41000-60000	15.24	8.13
61000-80000	11.63	6.93
81000-100000	14.13	1.81
> **100000**	10.25	1.81

When asked about the sponsor of the present trip 95.29% respondents were on self paid visits while for 3.05%, government was paying. For 1.66% respondents, a private firm or company (one they employed with) was sponsoring the trip. Many hotel, lodges and guest houses are available in the buffer zone of NDBR along with few home-stays. It was found that about 87% of respondents preferred staying in a hotel or lodge than staying in a home-stay which was preferred by only 1.66% of visitors (Table 6.4).

Table 6.4. Type of stay preferred by the visitors

Type of stay	Nature-based (%)	Religious (%)
Hotel/lodge	87.26	87.35
Guest house	3.05	0.90
Home stay	1.66	-
With friends and relatives	1.39	-
Ashrams	-	5.72
Didn't stay	-	6.02

When asked about the source of information from which they heard about the NDBR, more than 30% respondents said that they plan the visit to NDBR because of suggestion of their friends and relatives who have visited the place earlier. Internet was found to be an important source of information to the tourist as 27.15% people got the information about the place from internet followed by tourist guidebook

(17.17%). TV programme and Newspaper were found the least used information source by the visitors (Table 6.5).

Table 6.5. Source of information about NDBR

Source of information	Nature-based (%)	Religious (%)
A previous visit with advice from friends/ relatives	32.69	88.86
Advice from a tourist information centre with brochure	11.36	3.31
Tourist guidebook	17.17	2.71
Internet	27.15	2.41
TV program	7.48	-
Others (including newspapers, magazines etc.)	4.16	2.71

As the Biosphere Reserve has potential to provide recreational services to a large number of tourists, about 50% of the tourists said that it is very likely that they will visit the place again while about 23% said that they do not want to visit the Reserve again. When these 23% respondents were asked about the reasons for not visiting the area again about 75% said that it is because of poor infrastructure of the area while about 10% said that it is too far and it is difficult to travel. About 11% of the visitors said though they liked and enjoyed the natural splendor of the NDBR they would like to visit some other place instead to repeating their visit to NDBR.

It was observed that scenic beauty and adventure activities provided by the area were the main reason for the visit of about 90% of the tourists. About 2% of the respondents said that they did not like anything in the area (Table 6.3). 54% of the visitors are satisfied with the facilities present in the area and do not want any change while 19.67% said though they would like to have better access to the basic amenities. About 6% said that they would like to change the negligible attitude and negative behavior of other tourist towards the environment (Table 6.3). When asked about their recommendation to improve the quality of recreational services provided by the area about 50% recommended that basic infrastructure (accessibility to basic facilities such as, drinking water, sanitation and health facility) should be improved while 30% said that everything is good and it not new should be constructed, 15% said the in the area conservation and protection of the environment should be given the top priority (Table 6.6).

Table 6.6. Attitude of tourists towards attraction provided by NDBR and issue to be dealt with to improve the quality of recreational services

	Nature based respondents (%)	**Religious respondents (%)**
Most Enjoyed attraction of the place		
Adventurous games	14.13	0
Scenic beauty	75.62	66.87
Scenic beauty + adventurous games	8.31	0
Cultural heritage	0	9.94
Scenic beauty + Culture	0	21.99
Nothing	1.94	1.2
Attraction Enjoyed least		
Everything is good	54.02	68.98
Absence or poor maintenance of basic facilities	19.67	15.36
Travel	14.13	6.33
Attitude of other tourists towards nature	5.82	3.61
Others	6.37	5.72
Recommendation for improvement of the area		
Better basic facilities	50.42	67.17
Everything is very good should be protected	29.64	22.29
Tourists should be educated about environment	14.96	3.61
Tourist friendly environment	4.99	6.93

In spite of being one of the most visited places for religious and recreational especially for mountaineering and expeditions tourists are not aware about the conservation and world heritage site status of the area. 43.49% respondents were about that area has been declared biosphere reserve but about 48% respondents were unaware of the fact that NDBR is a UNESCO natural world heritage site while only 45.71% knew that the Reserve has two core zones but only 41.55% were aware about their conservation status (national parks) (Table 6.7).

Table 6.7. Awareness among tourists towards conservation and world heritage site status of NDBR

	WHS (%)		PA (%)		BR (%)		Two core zone (NDNP, VoF) (%)	
	Nature-based respondents	Religious respondents	Nature-based respondents	Religious respondents	Nature-based respondents	Religious respondents	Nature-based respondents	Religious respondents
Know	51.25	22.59	41.55	18.37	43.49	18.67	45.71	13.25
Do not know	48.75	77.41	58.45	81.63	56.51	81.33	54.29	86.75

About 60% of the respondents were aware about the objective of the protected areas while more than 50% were about the objectives and criteria of the world heritage site (Table 6.8). When asked whether it is justifiable to declare the NDBR as a world heritage site 73.68% respondents replied affirmatively while less than 1% disagreed with it. More than 25% of the respondents were indifferent of the fact. 71.19% respondents were aware that protected area status of the two core zones will help in conserving the natural capital of the area. 28.81% respondents did not know how the conservation status of the area is going to benefit (Table 6.8).

Table 6.8. Awareness among tourist about objective of protected area and world heritage site

	Nature based respondents (%)	Religious respondents (%)
Protected Area		
Protection to flora and fauna	46.26	46.26
Less human interference	6.37	6.37
Both	9.14	9.14
Do not know	38.23	38.23
World Heritage Site		
Popular across the world	4.16	4.16
to protect environment against degradation	1.66	1.66
Unique, world famous, protection for nature declared by UNESCO	48.48	48.48
Place with special natural and cultural beauty	1.39	1.39
Do not know	44.32	44.32
Benefits by declaring place a protected area		
It will improve the condition of natural wealth of area by protecting it	71.19	42.47
Do not know	28.81	57.53

6.3.1.3. Demand curve and consumer surplus for recreational value

As secondary data about the total visits from the zone was not available, observed numbers of visits per zone were used to calculate the proportion of visits in each zone through dividing the number of visits in that zone by the total number of visitors. The proportion was calculated for three consecutive years to overcome wrong estimation of the visits. Actual number of visits was estimated by multiplying respective zonal proportions of visits with number of visitors that year. Visitation rate (VR) for each zone was calculated by dividing estimated visits from the zone by total population of the particular zone. To calculate the recreational value of NDBR a regression analysis was done to know the visitation rate at different travel costs. Curve estimation was used and non-linear inverse curve fit was obtained through the equation VR= -13.015 + (3.67*10^5)/ travel cost. The plot of the fitted model of the demand curve generated through regression (Fig. 6.4) represent the whole experience demand curve. Various models were applied on the data and were tested for their predictive ability (based on R^2), the inverse model (V/P = a+ b/C) of the fitting was finally selected as the coefficient of determination was found to be highest ($R^2 = 0.688$) for this model. From the plot of the curve, it is observed that visitation rate becomes almost constant travel cost of INR 24000. The above whole-experience demand curve has been used for creating a 'net recreational demand curve' by adding a hypothetical increment in the travel costs, INR 1000, 2000, 3000 etc., and forecasting the number of tourists. To estimate the consumer surplus, a regression was again carried out with visitation rate as the dependent variable and added travel costs as the independent variable. The curve was fitted through non-linear curve estimation and the logarithmic model (VR= $4681.7e^{-2E\text{-}04\ (\text{travel cost})}$) was found to be more appropriate (R^2= 0.998) (Fig. 6.5). The area under this curve represents the consumer surplus per year i.e. INR 963819.54 for recreational use of the NDBR. Dividing this figure by average number of visit (n= 22048 per year; for recreational purpose) gave the consumer surplus per visit per year (INR 43.71).

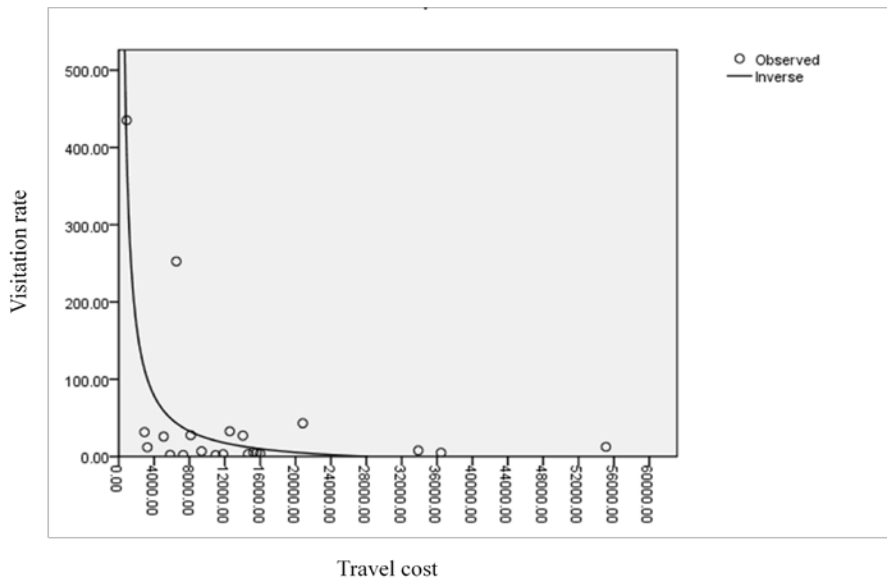


Figure 6.4. Whole experience demand curve for recreational use

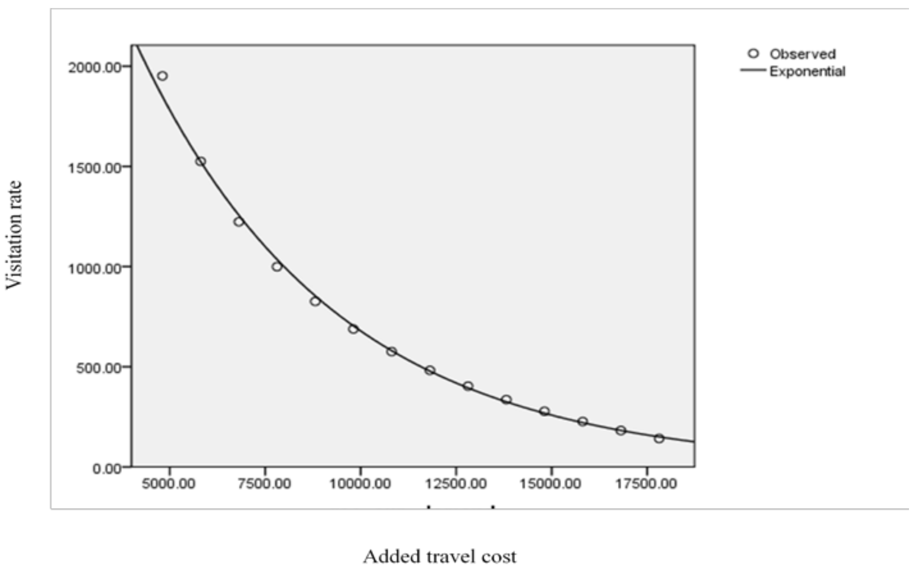


Figure 6.5. Net recreational demand curve for recreational use

6.3.2. Cultural value of the NDBR: Religious tourism

6.3.2.1. Profile of tourist

A total of 332 respondents from 16 different zones were interviewed (Table 6.1; Table 6.9) of which 76.8% were men and 23.19% were women. 227 people said that they are visiting the place for the first time while 105 had visited the area earlier. Among repeat visitors 41.90% were visiting the place for the second time while 38.10% were visiting the place for the third time and 7.62% have visited the area for more than ten times before. Mean age of respondents was 34.16±0.59. Most of the tourists (84.04%) were on independent holidays while few (10.24%) were on package tour provided by different governmental and nongovernmental organizations. Only 1.20% of the total religious visitors were international visitors (Fig 6.1). Group size of the tourist was observed ranging between 73 to single person (mean- 6.98, SE- 0.52).

Respondents were categorized into different educational, occupational and income groups and classes. 37.65% respondents were graduates followed by the post graduates (27.71%). Least percent (2.11%) of respondents were observed from sixth educational group (Ph.D.) (Fig. 6.2).

Table 6.9. Profile of tourist visiting NDBR for religious purposes

Zones	Interview	Total visit	Total population	Visits/1000	Expenditure/ visit
Athens	3	18	10815197	0.0017	74236.34
Belgium	4	24	11041266	0.0022	10347.57
Bihar	3	9	103805637	0.0001	5033.33
Delhi	53	412	11007839	0.0374	2225.12
Gujarat	3	11	60383628	0.0002	9048.30
Haryana	36	165	6856509	0.0241	5473.40
Himachal Pradesh	10	94	12548926	0.0075	4396.81
Jharkhand	3	25	32966238	0.0008	7025.50
Madhya Pradesh	8	26	72597565	0.0004	189569.10
Maharashtra	27	198	112372972	0.0018	4991.87
Punjab	61	547	27704236	0.0197	2065.03
Rajasthan	20	95	68621012	0.0014	5327.32
Tamil Nadu	6	126	72138958	0.0017	9180.43
Uttar Pradesh	57	265	199581477	0.0013	3585.29
Uttarakhand	34	273	10116752	0.0270	1200.36
West Bengal	4	30	91347736	0.0003	4772.57

Respondents are reported to belong to seven different occupational backgrounds. 44.88% respondents had were self employed and were running their own businesses, 21.39% were working with private firms and organizations. 12.47% were working with different government agencies while 8.59% were students. 13.55% respondents were studying and were not working. Least representation was found from government job and others. Others included farmer, part time employed (Fig. 6.3).

Likewise for recreational tourists religious tourists were also divided into seven different income classes. Most number of respondents (31.02%) were from the income class second (INR 1000-20000/month) followed by the group third (INR

21000-40000). Least number of respondents was observed from the higher income classes (INR 81000- 100000 and more than 100000) (Table 6.3). When asked about the sponsor of the present trip 95.18% respondents were on self paid visits while 1.81% was government sponsored. For 2.11% respondents, a private firm or company (one they employed with) was sponsoring the trip. About 1% of the visits were partially sponsored by the government and private firms.

There are numerous hotels, lodges and guest houses are available at Badrinath and Hemkunt but no homestay facility is available due to which no respondent was staying in a homestay owned by a local resident. It was found that 87.35% of respondents used hotel or lodge services during their stay in NDBR, 1% stayed in a guest house, about 6% stayed in a community ashram while rest of the 6% did not stay and left on the same day of arrival (Table 6.4).

When asked about the source of information from which they heard about the NDBR, 88.86% respondents said that they plan the visit as suggested by their friends and relatives who have visited the place earlier and is their family tradition. Only 3.31% used tourist information service to get the information about NDBR while only 8% of the visitors used other information facilities (Table 6.5). Though Nanda Devi area has been visited by the people across the country for religious purposes since a long period of time 35.54% respondents do not want to visit the area again. Only 28.01% respondent wanted to repeat their visit to NDBR. More the 50% of the respondents who refused further visits to the area said they would like to visit some other religious places in future in spite of repeating their present visit.

Scenic beauty and religious value (cultural importance) of the area were the main reason for the visit of most of the tourists. 66.87% respondent enjoyed scenic beauty most while about 10% gave more value to the cultural activities. 22% respondents said that natural and cultural offerings of the place were equally good and satisfactory (Table 6.8). Most of respondents (68.98%) do not want to change anything about the place. 15.36% said the infrastructure in the area needs to be improved while 3.61% did not like the attitude and behaviour of other tourists towards nature and religious monuments (Table 6.6). When asked about their recommendation to improve the quality of recreational services provided by the area about 67.17% recommended that basic infrastructure (accessibility to basic facilities such as, drinking water, sanitation and health facility) should be improved while 22.29% said that everything is good and it not new should be constructed, 3.61% said the in the area programme to educated and sensitize the tourist about nature and environment should be introduced. 329 out of all 332 respondents said they will recommend the place to other while rest of the 3 respondents said that they will not recommend the place to other as is not clean (Table 6.6).

Only 22.59% respondents were aware while 77.41% were unaware of the fact that NDBR is a UNESCO natural world heritage site while 18.37% were aware that there are two protected areas in the biosphere reserve but only 13.25% knew about these conservation categories (Table 6.7). About 60% of the respondents were aware about the objective of the protected areas while about 50% were about the objectives and criteria of the world heritage site and only 48.47% were aware about the benefits declaring a place as protected area. When asked whether it is justifiable to declare the NDBR as a world heritage site only 50.09% respondents replied affirmatively while less than 49.10% were ignorant about the issue (Table 6.8).

6.3.2.3. Demand curve and consumer surplus for religious value of the NDBR

To calculate the religious value of the NDBR regression analysis was done to know the visitation rate at different travel costs. Visitation rate was calculated following same method as used for recreational value calculation. Curve estimation was used and non-linear inverse curve fit obtained through the equation VR= -527.815+ (1.193*10^7)/ travel cost. The plot of the fitted model of the demand curve generated through regression (Fig. 6.6) represent the whole experience demand curve. Various models were applied on the data and were tested for their predictive ability (based on R^2), the inverse model (V/P = a+ b/C) of the fitting was finally selected as the coefficient of determination was found to be highest ($R^2 = 0.526$) for this model. From the plot of the curve, it is observed that visitation rate becomes almost constant travel cost of INR 20,000. The above whole-experience demand curve has been used for creating a ‘net recreational demand curve’ by adding a hypothetical increment in the travel costs, INR 1000, 2000, 3000 etc., and forecasting number of tourists. To estimate the consumer surplus, a regression was again carried out with visitation rate as the dependent variable and added travel costs as the independent variable. The curve was fitted through non-linear curve estimation and the exponential model (VR= $= -105.42e^{-1E-04(\text{travel cost})}$) was found to be more appropriate ($R^2 = 0.999$) to fit the curve (Fig. 6.7). The area under this curve gives the consumer surplus per year, i.e. INR 9840231.35 for religious use of the NDBR. Dividing this figure by average number of visit (n= 655431, for religious purpose) gave the consumer surplus per visit per year (INR 15.01).

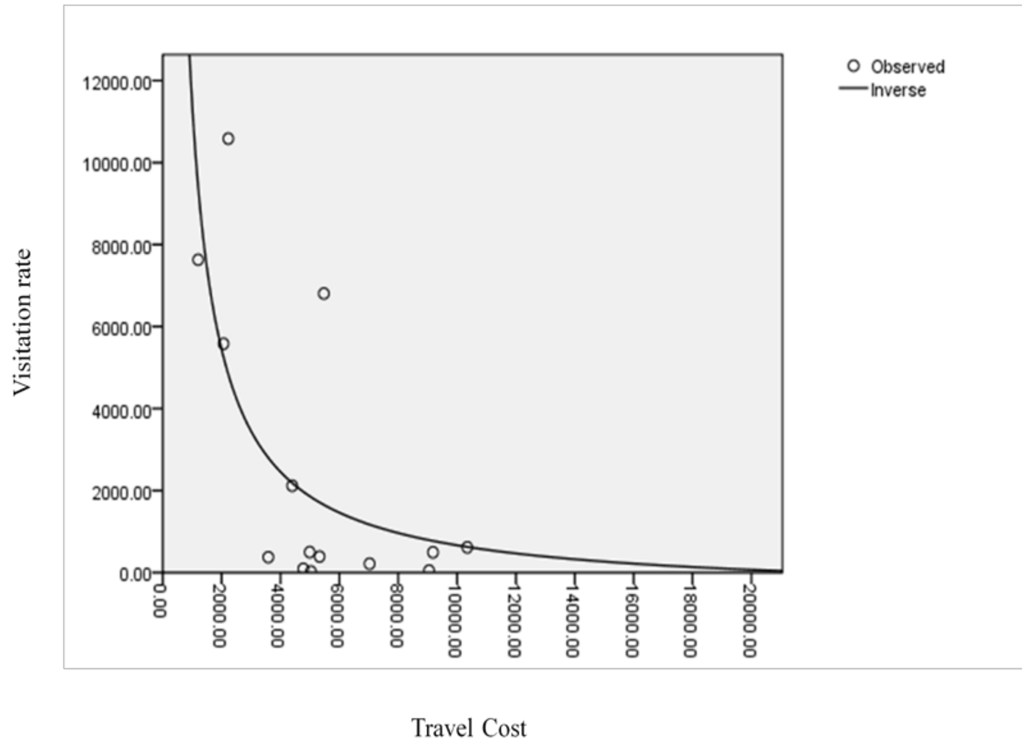


Figure 6.6. Whole experience demand curve for religious use

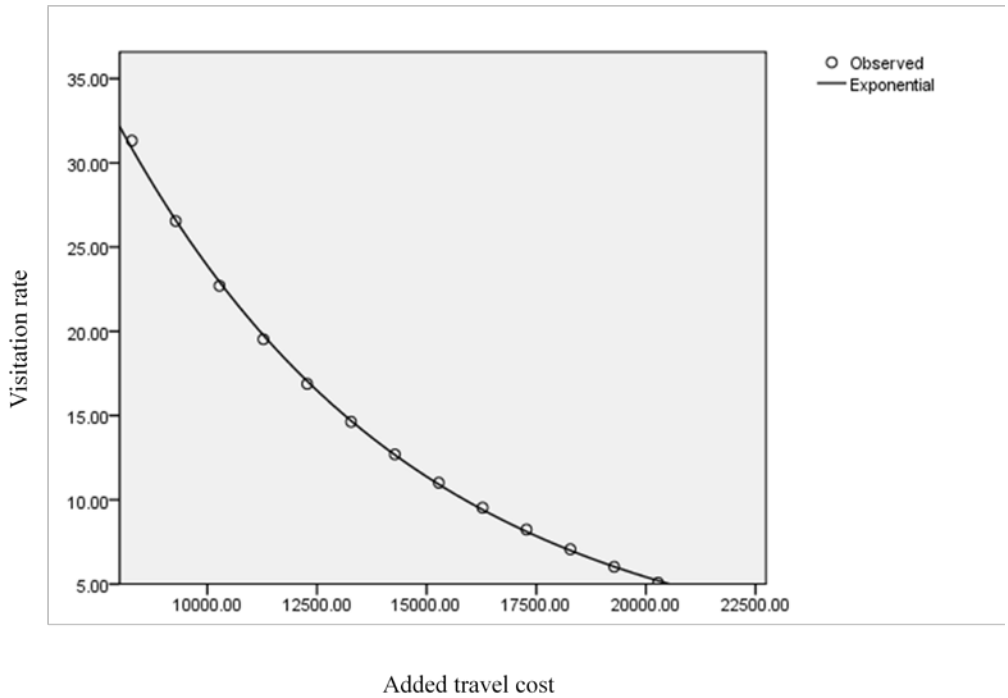


Figure 6.7. Net recreational demand curve for religious use of NDBR

6.3.2.4. Nature of tourism

The recreational tourism was found to be elastic in nature as tourists showed their willingness to visit other areas (except NDBR) if the quality of nature and basic amenities depletes in the future. Whereas, religious tourists; although paying less money to visit the place and were found to opting for cheaper services (ashrams, guest houses etc.); were found to willing visit the area again for the same religious purpose. Both type of tourism was found to generate niche based jobs, providing opportunities only to the households in close proximity of the tourist attraction site.

6.3.3. Contribution of tourism in the local livelihoods

A total of 200 household were sampled, those involved and dependent on tourism related activities for their livelihood. 130 were directly working (shop, milk product selling, photography, making garlands to be used at Badrinath, working in temple committee on monthly wages, taxi, guide, porter, travel agent, homestay and mule owner) with the tourism sector while 70 were indirectly (selling herbs to the local garland seller and shopkeeper, making woolen products for local shopkeeper on order, renting land or shops to outside business men) earning money from the tourism. Average household income for the households involved in tourism was calculated as INR 155454.56 per year/hh (SE= 15083.8, range= 677145, median= 154150) and contribution of tourism was found INR 82133.33 per year/hh (SE= 10168.9, range= 382000, median= 60000). It was found that contribution of tourism to the economy of households involved ranges from 2% (mainly indirectly involved household) to 93%. Contribution of tourism to local household income was found higher for the directly dependent households. It was found that the in all the 12 villages surveyed and 180 to calculate the contribution of tourism to annual household income, average annual households INR 155454.56 per year (SE= 15083.8, range= 677145, median= 154150) was higher to the households involved in tourism than the households not involved in tourism related activities (average annual household income= INR 78256.5, SE= 3402, range= 687345, median= 50750). Contribution of different tourism based profession to dependent households has been summarized in table 6.10. It was found those travel agents are being benefited most followed by shop owners and vehicle owner (vehicle used by tourists).

Table 6.10. Contribution of tourism to local livelihood

Profession	No. of interviews	% of interviews	Income (INR/ hh/year)	Income from tourism (INR/ hh/year)	% of hh income
Tourist guide	14	7.0	107606.07 ±10430.45	8608.5 ±834.4	8
Homestay + Porter	20	10.0	137162 ±18606.8	20574.3 ±2791.02	15
Work at Badrinath	12	6.0	112674.03 ±7501.3	104001.6 ±6942.8	78
Milk + Garland	26	13.0	133335.4 ±8901.1	15774.4 ±1050.2	14
Mule	30	15.0	135737 ±7534.5	81442.2 ±4520.7	60
Photography	16	8.0	82287.5 ±5804.7	53486.8 ±3773.1	65
Shop owners	16	8.0	198540 ±13175.0	158832 ±10540.0	80
Travel Agency + tourist guide	8	4.0	442977.5 ±92362.2	411969.1 ±85896.8	93
Vehicle owner	38	19.0	139990.5 ±12402.9	88194.03 ±7813.8	63
Indirectly involved	20	10.0	52404 ±5226.04	26202 ±2613.02	50

It was found that more families were dependent on religious tourism than nature-based tourism. Any change in pattern and type of tourism will affect different occupations differently. Change or loss in nature-based tourism will mainly affect tour guides, homestay owners, porters and big-hotel owners while small hotel owners, mule owners, small shop keepers, photographers, handicraft workers and other people working with minimal investments and specific market accessibility will get affected by loss of religious tourism.

6.4. Discussion

The results show that there is a significant difference in economical values of recreational and religious tourism in NDBR. Religious value is more than recreational value due to presence of two main Hindu and Sikh shrines (Badrinath and Hemkunt) and many less known pilgrim sites. The visitation rate for the religious purpose is about three times more than visitation rate of recreational visitors. The consumer surplus is higher for the recreational tourism as tourist visiting for recreational purpose, willing to pay for to attain the available services and they stay for longer period at the site while people coming for religious purpose though appreciate the natural and cultural beauty of place but do not stay longer and often do not spend on things as copiously.

More than half of the respondents were not aware about the conservation and WHS status of the area as most of the people got to know about the area from family and friends while only few have searched for any information from other sources. The exclusive cultural and natural diversity have been ranked as the most important attraction of the site by most of the people but only few were about the threats place is facing due to developmental activities. Average annual household income was found higher for the households involved in tourism related activities than the households not engaged in tourism sector. Same pattern was observed by Emptaz-Collomb (2009) in Namibia.

The United Nations World Tourism Organization declared poverty reduction as one of its primary themes for tourism development, and its Sustainable Tourism-Eliminating Poverty (ST-EP) initiative (http://www.unwto.org/step/) focuses on supporting the goals of sustainable tourism activities to alleviate poverty. Union (1998) noted that lack of economic data on the usage of parks has resulted in an information blind spot and natural areas which provide numerous economical and social benefit have been assigned a zero price (In Prideaux & Falco-Mammone, 2007). This has resulted in destruction and degradation of many natural sites as their true economic significance has not been estimated.

Nature-based recreation and tourism is publicized as a sustainable way to preserve nature while providing economic benefits to communities (Gossling 1999, Wunder 2000, Wood, 2002). Usually, many factors with specific significance, affect the economic issues related to recreational value. Other affecting conditions are typically considered constant when investigating a specific variable’s effects. In the curve related to a recreational site’s demand, so many visitors’ reactions would be thus ignored to specify the relation between the cost and the amount of uses. The cost measures not only user’s behaviour, but it is an effective factor. Clawson (1959), Yachkaschi (1975), Cooper (2000), Kavianpour & Esmaeili (2002) have already studied this topics, observing a direct relation between the cost and the number of visitors.

Tourism is emerging as the second largest foreign exchange earner for the country even though the mainstay of the tourism industry in India continues to be domestic travellers (Government of India, 2002). The barriers to improved performance of the tourism industry in India include its distance from affluent tourist markets, lack of facilities, relatively limited professionalism in the industry and the ‘image’ of the country (e.g. it is not a holiday location, it poses safety concerns and it has inadequate services) (Government of India, 2002). As well, the emphasis of the central government on other development issues has left many regions to plan for tourism with little central help or coordination. Cultural heritage sites typically possess public goods characteristics, and thus nonmarket valuation methods must be employed to measure the benefits that they provide to visitors (Poor and Smith, 2004). Nature-based tourism, particularly in protected areas, can create uneasy interfaces between the business models of the tourism industry and the “business models” of natural resource managers (Fennell & Smale, 1992; Shultis & Way, 2006). As a direct result of these interfaces, formal and informal relationships are created between tourists, tour operators and natural resource managers. These relationships, sometimes described in the literature as public–private partnerships, form frameworks around which tourism is often organised, again formally and informally, in protected areas (Buckley, 2002).

Visitor satisfaction is a particularly important consideration in protected area tourism as satisfaction scores are used as a measure of success, or failure, of a protected area to deliver a high quality visitor experience. Examples where the discourse of valuing protected areas for their economic benefits via tourism (and thus the importance of satisfactory visitor experiences) are frequently noted in public policy statements and documents released to the public.

Our results suggest that tourism positively contributes to economy of the local communities and affects the culture heritage of any tourism site. Although, these impacts are limited to certain villages and people those are directly involved in the tourism industry. As the tourism industry will develop in a sustainable way it not only reduce the direct dependence on forests by providing alternative livelihood but also will lead to improved basic infrastructure of the area. The power of local community to attain the resources (alternative resources from market) will improve and lead to self sustenance (Lindberg 2003; Scheyvens 1999). Being employed in tourism sector provides a regular source of income to many households, and thus economic security. It helps people meet basic financial needs, as well as acquire additional assets or livestock investments.

RECREATIONAL AND RELIGIOUS VALUE OF NDBR

Religious visitors at Hemkunt and Badrinath shrine

Adventure tourism at Auli

Nature based tourism at Valley of flowers and Auli

PLATE 6

CONTRIBUTION AND IMPACT OF TOURISM


Livelihood for local community

Leakage of tourism benefits due to high end affluent stakeholders

Improper solid waste management at Badrinath

Opportunities for homestay owners


Market for local products

PLATE 7

Chapter 7. Attitude and perception of user groups towards benefits provided by forest

SUMMARY

For the present chapter the attitude of local community towards ecosystem services provided by NDBR was evaluated. For the present study, services were divided into two categories; direct which included provisioning services and tourism (cultural; particularly economic benefits from tourism were considered), and indirect services which included regulating and supporting services. A total of 11 clusters were formed using hierarchical cluster analysis using secondary information- demographic parameters, development parameters, distance from forest and condition of forest. , and 22 villages were selected for intensive study and 764 interviews were conducted from randomly selected households. Respondents were asked to value the services on the scale of 4 to 1 (4 is the highest value and 1 is the lowest). In cases where respondent did not give any value to a service, it was marked as '0'. The study revealed that the people assigned more values to the services such as fodder, fuelwood, leaf litter, water and nutrient retention which contribute to their day to day life and livelihoods. The services which do not contribute directly such as prevention of landslide, aesthetic value, etc. have been given less values. The difference was significant between the values assigned by the people living close to forest and away from forest ($p<0.000$). People living close to less degraded forest assigned more values than the people living close to degraded forest ($p<0.000$). There was significant difference in the attitude of men and women towards conservation practices in the area. The attitude of respondents towards conservation practices was found to be positively correlated with, average years of schooling of households and contribution of direct and indirect benefits. The perceptions of people were significantly positive towards the conservation of the wildlife and forest resources. Although, the attitude of people was found to be associated negatively due to human wildlife conflict {$r(763)= -.206^{**}$, $p< 0.05$}.

7.1. Introduction

Ecosystem services provided by the natural ecosystems play an important role in social and cultural associations (Lindemann-Matthies et al., 2013). Different communities with specific social and cultural practices, value nature differently and have different attitudes toward it (Johnson et al., 2004). The attitude of user towards services is mainly predicted by the extent of direct dependence of people on nature and the contribution of natural resources to the economy of people (Sarwono, 1992; Inglehart, 1995; Ignatow, 2006). Attitudes, knowledge, behaviors, and concerns of local communities and other stakeholders directly and indirectly affect the environment and future decisions concerning natural resources and their allocation and conservation (Meinhold and Malkus, 2005). According to Deng et al. (2006), environmental problems are mainly embedded into the traditional values, attitudes, and beliefs of a given society. Maloney et al., (1975) stated that “we must determine what the population knows, thinks, feels, and actually does regarding ecology and pollution” (In Deng et al., 2006). According to Stern et al. (1995), this biospheric-altruistic value orientation is placed higher in a value-attitude-behavior hierarchy than the new environmental archetype, which “fits into a causal model between values and more specific beliefs, such as beliefs about specific environmental problems” (p. 725). However, members of different cultures value forest biodiversity and ecosystem services differently and may or may not support conservation goals set by governments for instance (Deng et al., 2006). Economic status also plays an important role in shaping the attitude of people towards nature and its services. Human psychological and socio-psychological values, perceptions and attitudes provide a feedback between structure of ecosystem and evaluation of the benefits, as the understanding of the attitudes can be used to achieve sustainable management and conservation of natural ecosystems (Nassauer, 2011; Nassauer et al., 2011).

A large number of studies have valued environmental preferences. The predilections for conserving and protecting environmental goods have been issues of concern in the last few years. Most of the studies have so far focused on specific and limited environmental goods e.g. air quality, fuel wood and fodder (Carlsson and Johansson-Stenman, 2000; Bulte et al., 2004; Dupont, 2004; Torgler and Garcia-Valiñas, 2005). However, limited peer reviewed studies are available which focus on attitude towards the environmental services (Badola and Hussain, 2005; Deng et al., 2006; Lindemann-Matthies et al., 2013).

Till now studies on ecosystem services focused on economic evaluation of services on the basis of local and global market values. Values assessed and perceived by local users (direct user) have been ignored. The values given by local community member and their attitude are important to conserve and use the natural resources sustainably as most of the ecosystems suffer from unsustainable utilization (DeFries et al., 2005) and the majority of these environmental services are now declining (MEA, 2005; Sodhi et al., 2010). To aggravate the environmental conditions, local communities are often not supportive of conservation practices due to limited access to natural resources (Sodhi et al., 2008). To resolve such anthropogenic pressure nature should be preserved for ecosystem services and not just for the conservation of biodiversity (Daily 1997; Kareiva and Marvier, 2007). It is equally important to consider perception of local community towards ecosystem services in decision making as it plays an important role in management and allocation of the natural resources. Most of the local people are not aware about the true value contribution of natural system in terms of the ecosystem services (Sodhi et al., 2010) but are aware of the direct and indirect benefits they get from the natural systems (especially from forest, freshwater system and rangelands).

For the present study, attitude of local community towards ecosystem services provided by NDBR have been evaluated. The present study assessed the values assigned to different ecosystem services provided by the Reserve to the people and how people see and assess the contribution of natural system services to their lives. For the present attitude study, services were divided into two categories, direct which included provisioning services and tourism (cultural; particularly economic benefits from tourism were considered), and indirect services which included regulating and supporting services.

7.2. Methodology

The data for attitude of local people towards ecosystem services and conservation practices was collected in three stages through review of secondary information, selection of villages for extensive survey and semi-structured questionnaire based interviews (Badola and Hussain, 2003; Harris and Brown, 2010); as interviews are considered as important tool to acclimatize planning to existing perceptions and attitudes (Buchecker et al., 2003; Höchtl et al., 2005). The first stage involved a rapid assessment of the study area in order to obtain an overall perspective of the villages. In the second stage secondary data about all the villages of NDBR was gathered and information on type of nearby forest and distance from nearby forest was collected. Hierarchical cluster analysis was carried out using secondary information-demographic parameters, development parameters, distance from forest and condition of forest. A total of 11 clusters were formed and representative villages were selected for intensive study. In third stage, the primary data for selected villages were collected (Torgler and Garcia-Valiñas, 2005; Sodhi et al., 2010). Households in selected villages were sampled on random basis. Head of the house or any family member older than 18 years was interviewed (irrespective of gender) to get reliable information. A structured interview based questionnaire was developed to assess the attitude of people towards services provided by the forest. The data were collected from both primary and secondary sources. Primary data were obtained through both formal and informal interviews. To avoid the personal and respondent biasness which occur by a propensity of people to tell us what we perceive (Sheil and Wunder, 2002), the questionnaire was first tested in the field with 25 interviews and slight modifications were made to suit the conditions of the study area.

A total of 764 interviews were recorded from 22 selected villages. Personal information of respondents was collected. Respondents were asked to value different direct and indirect services provided by their forest on the basis of importance of services in their economic and social well-being. They were asked to value the services on the scale of 4 to 1 (4 is the highest value and 1 is the lowest). In cases where respondent did not give any value to a service, it was marked as '0'. Technical jargons were avoided while framing the questions to make them easy for the respondents of rural background. The questions were asked in local language and were related to the respondent's daily interaction with natural resources. Questions were asked indirectly to avoid the tendency to pick the first option (Sodhi et al., 2010).

7.2.1. Data analysis

To know the difference between the values attached to ecosystem services provided by degraded and less-degraded forest Mann–Whitney U test was used. Mann–Whitney U test was also used to know the difference between values given to direct and indirect benefits. Spearman correlation was done to know the association that exists between average years of schooling of households and attitude. Kruskal-Wallis H test was used to know the difference between attitude of male and female member of the community.

7.3. Results

7.3.1. Direct benefits or provisioning and recreational services

Fuel wood

All 764 households reported that they use fuel wood from the nearby and accessible forest. Fuelwood is the main energy source for cooking and as the area experiences harsh winters and less warm summers therefore people use fuelwood for space heating also. Some of the households use wood just to keep their houses warm while for cooking and other purposes they use modern energy resources and appliances. A high percent of household representative (93.19%, n=764) gave maximum value to resource (4), while 6.81% (n=764) valued it as 3.

Fodder

Livestock rearing being one of the important livelihoods of the area, most respondents (93.06%, n=764) gave highest value to forest fodder as most important resource, 6.28% valued fodder as very important resource (value as 3). Less than 1% people did not give any value to the fodder provided by the forests. Some families which did not have livestock and were not using fodder in the present still valued fodder as most important and very important (by giving value of 4 and 3 to it) which shows that these families despite not using fodder from forest at present, consider its importance for future.

Leaf litter

70.29% respondents gave value of 4 to leaf litter and considered it as a very important forest product, 17.93% gave value of 3 to it while 8.64% and 2.23% gave it 2 and 1, respectively. Less than 1% of the respondents did not give any value to the provision of the leaf litter as these respondents either did not have or had very few livestock.

Material for construction

All respondents said that they have used some of the forest products while constructing a house and cowshed. But with the modernization of the building design in the area, the dependence on forest for construction material has reduced. More than 25% respondents gave a value of 4 to material of construction while 50.13% household representatives said that construction material provided by the forest is the very important resource and valued it 3 as all the people build the houses with the material provided by the forests. 21.33% valued it as 2 while 2.75% respondents did not give any value to the resource.

Medicinal plant

Most of the local residents do not follow the traditional medicinal practices, and use the services of modern health workers (trained doctors, nurses), hence do not feel any importance of the medicinal plants (50.26%, n=764). Only about 1% of the respondents valued medicinal plants as most important (valued 4) while 30.63% valued them as 3. Rest of the 17.8% said that medicinal plants are important and valued it as 2.

Tourism

More than 64.01% (n=764) respondents did not give any value to the tourism and recreation as it provides economical benefits to only few households. 12.43% valued the service as 4 while 9% valued it as 3. 10.60% and 3.93% valued it as 2 and 1, respectively.

7.3.2. Indirect services: regulating and supporting services

Water retention

All respondents, except one (99.61%, n=764), said that the most important indirect benefit they get from forests of NDBR is retention of fresh water and valued it as 4. This service not only supports the domestic needs of the local communities but also provide water for agricultural and local small level industrial use also.

Nutrient retention

About 90% (n= 764) household representatives gave maximum values to nutrients retention by different types of forest while 10.08% valued the service at 3 considering it as very important, as the nutrients provided by the forest play an important role in maintaining the agricultural productivity. 0.39% respondents said that the service is of less importance and valued it as 2 while 0.26% did not give any value to it.

Air purification

More than 72% (n= 764) of the respondents said that purification of the air is the most important service provide by the forests and without it their society have to live in ‘city like environment’. These respondents gave maximum value to the air purification service of forests. 18.19% and 8.64% household representative valued it as 3 and 2, respectively. Only 0.26% respondents did not give any value to the air purification.

Prevention of landslide

Being a landslide prone area, the service plays an important role in daily life and lifestyle of local residents. Prevention of landslide by the presence of forests and trees was valued as 4 and 3 by 47.51% and 42.54% respondents, respectively. About 2% of the respondents said that it is not a very crucial service but is an important one and value it at 2 while 7.85% said that this service do not have any value for them.

Prevention of land erosion

45.42% of the respondents put prevention of land erosion by different means (by natural: rain, snowfall; artificial: construction) in the category of most important services by giving it maximum value while 34% valued it as 3. 10.73% respondents value the service as 2, while rest of the 9.82% did not give any value to the service.

Genetic value

In spite of being a biologically diverse area, people are not much aware of the genetic resources and only 16.1% of the people gave maximum value (4) to the genetic resources of the area. 4.06%, 16.49% and 8.38% valued it as 3, 2 and 1, respectively. Most of the respondents (54.97%) did not give any value to the genetic resources provided by the NDBR.

Aesthetic value

Aesthetic pleasure provided by the nature is rated as one of the most important services of NDBR by only 4.58% who gave it maximum value while 12.70% and 15.18% of the respondents valued it as 3 and 2, respectively. 8.38% said that it does not have much value (valued as 1) while about 60% did not give any value to it.

Spiritual & religious

Spiritual & religious services provided by the NDBR was rated as one of the most important services of NDBR by only 3.8% of the respondents who gave it maximum value while 13.22% and 21.73% of the respondents gave it 3 and 2 value, respectively. 0.26% said that it has very less value (1) while more than 60% did not give any value to it.

7.3.3. Conservation of forest and its resources

Most of the respondents (99.73%, n=764) were positive about the conservation of forests and wanted to save it from further degradation. Only two respondents said that they do not want to have their area covered with forest and want to replace it with some developmental activities.

Reason for conservation of forests

Most of the livelihood practices in the area are directly and indirectly forest product dependent hence all the respondents wanted to save the forest. 99.87% (n=762) respondents said that forests provide products to meet their day to day needs while 100% of them said that forest products support their livelihood and hence should be preserved. 75.72% responded that forests retain water which is the basic need for survival. 62.86% said that forest should be conserved as it provide shelter to the wild species and in the absence of the forest and forest products, the conflict between human society and wildlife will increase. 67.98% respondents said that forest provides an aesthetic pleasure and they feel proud to have a forested landscape in their area (Fig. 7.1).

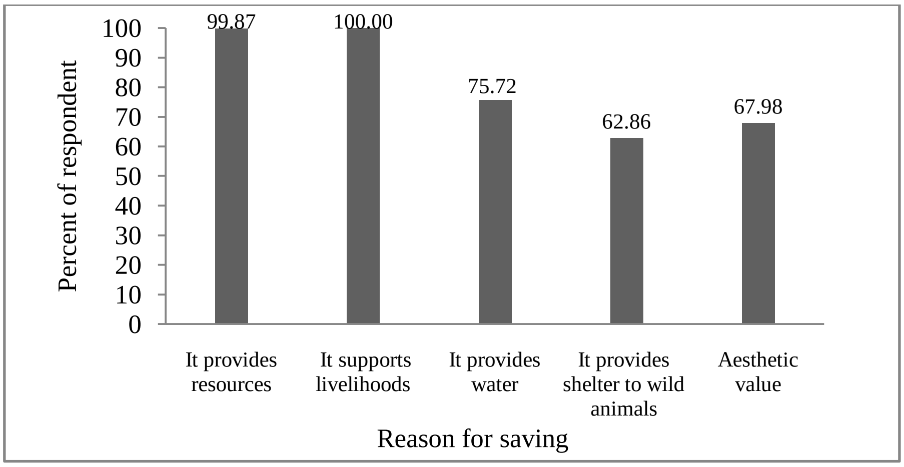


Figure 7.1. Reason for conservation of forest and forest products

7.3.4. Strategies suggested by local people to improve the forest condition

Respondents were asked to suggest a solution to improve the present condition of their forest, a total of six different strategies were suggested by them i.e. plantation (p), no felling (nf), fencing (f), prevention of forest fires (pf), training to local people (tp) and reduced dependence on forests (rd). Most of the respondents (76.05%; n=764) said new plantation should be done to improve the present condition of the forest while ban on felling was supported by 34.29%. 24.21% of the respondents said that trees and saplings should be fenced and saved from livestock and lopping. 31.68% said that more techniques should be introduced to prevent and manage the forest fires, as forest fires in the area damage the natural resources. 30.89% suggested that local people should be trained with different techniques to prevent forest resource loss and conservation of natural resources. Only 2.23% of the respondents said that forest can be conserved by reducing the direct dependence on forest products (Fig. 7.2).

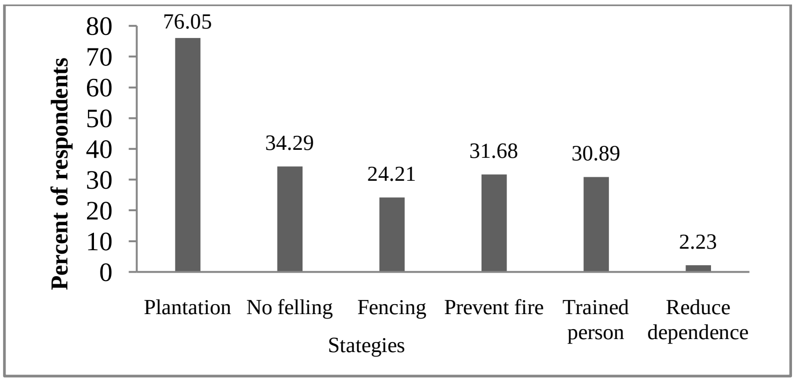


Figure 7.2. Strategies suggested by respondents to improve the condition of nearby forest

Most of the respondents suggested more than one strategy to conserve the natural forest conditions. 14.12% said that plantation and ban on felling are the combination of solutions to protect and improve the quality of forest resources. 19.76% respondents preferred plantation with fencing while 16.3% said plantation with prevention from forest fires is better solution. 13.06% said that plantation should be done and local people especially youngsters should be trained. 12.57% said that people should be trained to prevent forest fire which prevents the loss of natural wealth (Fig. 7.3).

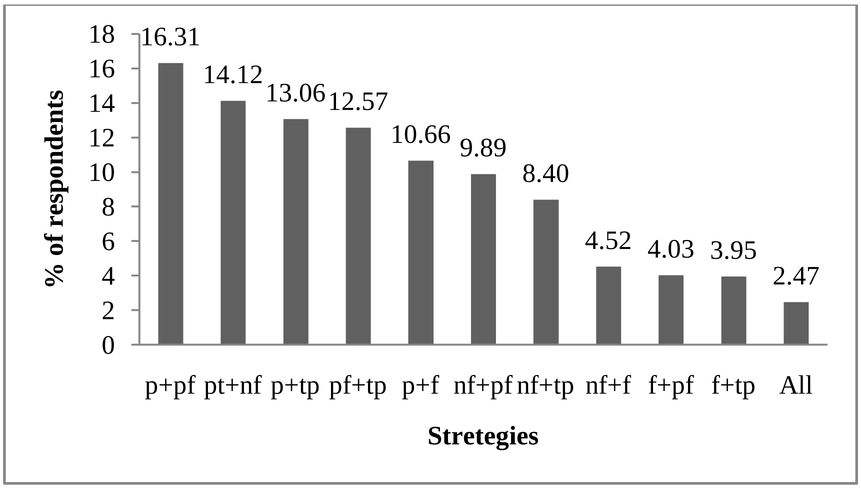


Figure 7.3. Combination of strategies suggested by respondents to improve forest condition

7.3.5. Conservation of wildlife

When asked about the reason for saving the wildlife in the nearby forest 50% (n=764) said they want the wildlife to be conserved while 49.48% (n=764) respondents do not want to conserve it. Very few respondents (0.52%, n=764) were not aware and did not know what should be done.

Reason for conserving wild animal

Those who said wild animals should be conserved (n=382), were given four options; (aesthetic value (av), recreational value (rc), right to live (rl), maintain balance in nature (mb); to choose why they want to save the wildlife. 67.54% said that wild animals should be saved because of their aesthetic value, while 62.30% said that they attract tourists and give an identity to the area. Most of the respondents (90.58%) said that the wild animals also have right to live as humans have. 6.02% respondents said that the wild animals maintain the balance of nature by preying upon species which otherwise will increase in number and hamper the agriculture output and put extra pressure on the available natural resources (Fig. 7.4). Of 382 respondents who supported conservation of wildlife, 62.3% chose aesthetic value and recreational value as reasons for conservation. 58.64% chose aesthetic value and right to live, 2.09% opted for aesthetic value and maintenance of the balance of nature and 54.45% opted for recreational value and right to live. Other most preferred combination of options given was aesthetic value with recreational value and right to live (preferred by 54.45%) (Fig. 7.4).

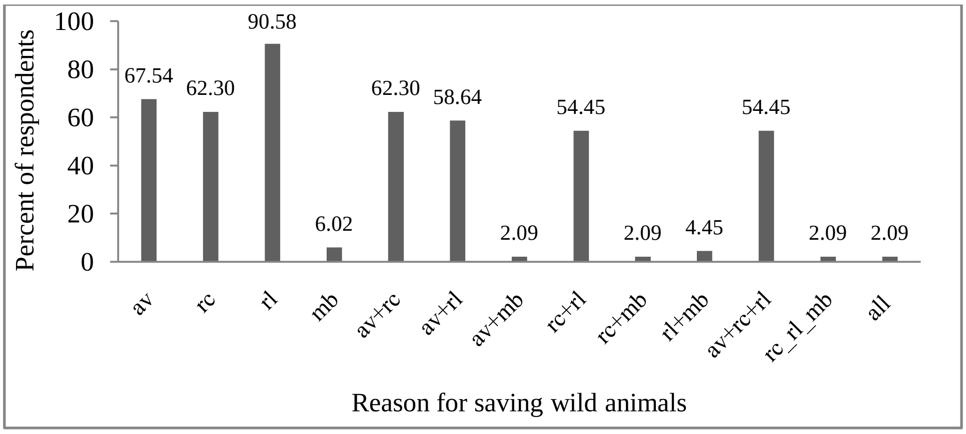


Figure 7.4. Reason for conservation of wildlife

Reason for not saving the wildlife

Question related to not saving wildlife was open ended and 4 major reasons were observed. Local residents (n=378) do not want to save the wildlife as they kill people (kp) and livestock (kl), damage crop (dc) and do not provide any benefit to the human society (nb). About 58.20% respondent gave all the four reason for not to save wild animals. 95.24% said that wild animals kill people and, livestock and raid the crop field and damage the economy and so should not be saved. 58.20% people said that wildlife does not provide any benefit to the society and so they should either be moved to some other place or killed; these respondents also gave others reasons (kill people and livestock, and damage crop). 98.97% respondents do not want wildlife in their area as because of wildlife their life and livestock are under threat (Fig. 7.5).

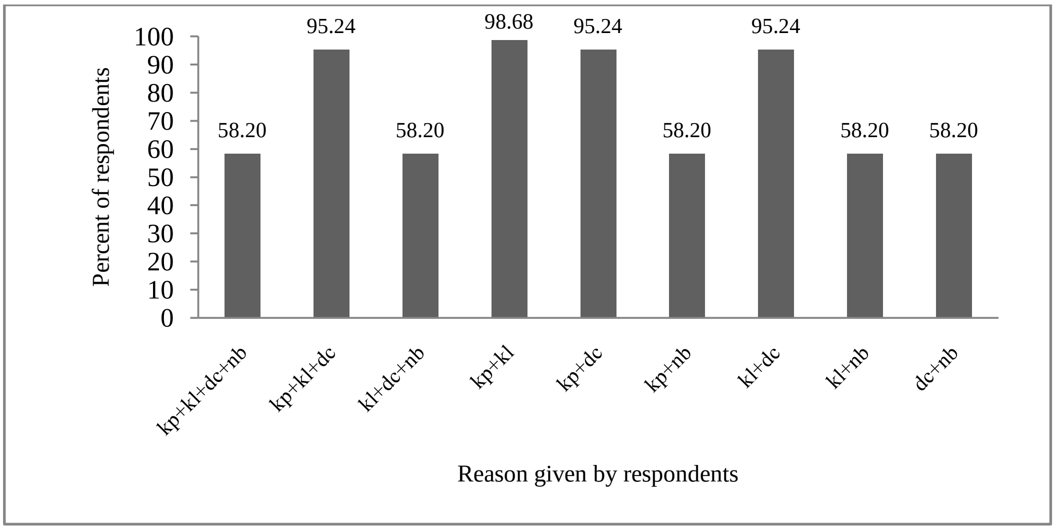


Figure 7.5. Reason for not conserving wildlife

7.3.6. Suggestion by people to improve the forest

Respondents were asked what they want to do with the forest near their village. When asked whether the forest should be cut 98.69% (n=764) disagreed while 50.52% said that they would like to remove the wild animals and keep the forest as it is while 49.21% disagreed and 0.26% were not sure. 99.74% do not like the present situation and 0.26% were not aware about it. 99.48% respondents said that they would like more plantations (Fig. 7.6).

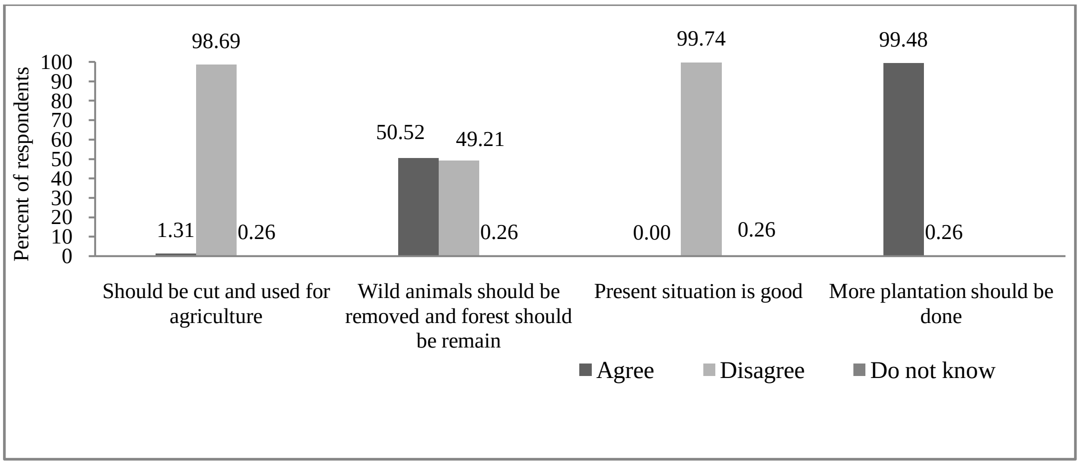


Figure 7.6. Views of people on nearby forested area

7.3.7. Benefits to agriculture from nearby forest

Most of the respondents (n=764) agreed that forest near their agricultural land contribute to the yield in many different ways. More than 66.88% respondents said that agricultural fields located near forests produce more yield than the fields away from forest (Table 7.1). Although most of them said that instead of better growth the crop is generally damaged by the wild animals. 12.04% responded that closeness to forest does not make any difference in the yield while 0.26% were not aware about it. 85.47% agreed that agricultural fields near forest require less fertilizer than the fields away from the forest while 11.39% disagreed to the given option and rest of the 3.14 (%) were not sure about it. More than 98% said that the soil of agricultural land near forest has more moisture content than the field away from forest while 1.57% found no difference in both the condition. 88.48% respondents said that forests regulate the local rain fall pattern thus contributing to rain fed agriculture and better production of the different seasonal crops (Table 7.1).

Table 7.1. Benefits from forest near agricultural fields

Benefits from forest near agricultural fields	Yes (%)	No (%)	Do not know (%)
Areas near the forest give more yield	87.70	12.04	0.26
Fertilizers required in less quantity near forest	85.47	11.39	3.14
Water table is high near forest	98.17	1.57	0.26
Regulates rainfall	88.48	11.13	0.65

7.3.8. Difference in the attitude

A significant difference was found between the values, given by people living close to forest and away from forest (U= 71169.5, Z= -3.486, p< 0.000). Although both categories understand the importance of the direct and indirect contribution of the natural resources (both directly and indirectly) to the local and regional economy and level of human wellbeing, it was found that the people living close to forest with better accessibility to high quality resources (less-degraded) appreciate contribution of nature more.

There was a significant difference between the values attached to ecosystem services provided by degraded and less-degraded forest (oak forest: U= 4672, Z= -11.345, p<0.000; mixed conifer forest: U= 10500, Z= -5.299, p<0.000; moist temperate deciduous forest: U= 47430, Z= -6.242, p<0.000); deodar forest: U= 0, Z= -12.725, p<0.000).

The attitude of respondents was found to be positively correlated with, average years of schooling of households, r(763)= + .114**, p<0.005, benefits (both direct and indirect contribution of the forest, r (763)= +.096**, p<0.005 and total income (earning from forest and other livelihoods), r(763)= +.218**, p<0.00).

The attitude towards indirect benefits was found to be positively correlated with, educational status of the individual and overall household, r(763)= + .131**, p< 0.005, benefits (both direct and indirect contribution of the forest, r (763)= +.149**, p<0.005 and total income (earning from forest and other livelihoods), r(763)= +.189**, p<0.005). Similarly, attitude towards direct benefit was found to be positively correlated with educational status of the individual and overall household, r(763)= + .080*, p< 0.05, benefits (both direct and indirect contribution of the forest, r (763)= +.077*, p<0.05 and total income (earning from forest and other livelihoods), r(763)= +.163**, $p<0.005$). The correlation between attitude towards overall benefit and indirect was found to be higher as the understanding towards these contributions are mainly not visible in the day to day life of dependent families. Contribution of direct benefits is visible and understood by the users irrespective of their educational or economical status.

Gender has also played an important role in structuring individual's attitude towards ecological services provided by natural land use type and there was significant difference between attitude of male and female member of the community ($H= 7.496$, $p\leq0.005$). Men gave more score to the total benefits provided by the nature than women and similar pattern was observed for direct and indirect benefits. This difference was found to be significant for direct and indirect benefits and total benefits together (indirect benefit-, $H= 9.471$, $p<0.005$, direct benefit- $H= 3.776$, $p\leq0.05$). The difference in the attitude of men and women can be attributed to the difference in the educational status of both and men get more chances to visit places, participate more in public meetings, get more time and chances to access media and other means of communication such as newspaper, television etc.

Attitude of people was also found to be associated with the extent of loss caused by wildlife. There was a negative relation between attitude and human wildlife conflict (r(763)= -.206**, $p< 0.05$).

7.4. Discussion

Results show that the attitude of people of NDBR is significantly positive towards the environment and its services. Respondents have given high values to all the services, though direct services (fuel wood and fodder) have been given maximum value (4) for highest number of times in comparison to indirect services. This is because the direct services contribute to the local livelihood and daily needs noticeably and provide a direct improvement in economy of local communities. The mountain communities of NDBR have traditionally been having the sustenance economy, where they used to consume what they grew and hence dependence on market was nil or negligible. However, this trend is changing (Pearce & Atkinson, 1993), despite this people give importance to the services which sustain their lives and secure their well-being (Daily et al., 2000; Newton and Newman, 2013).

While regulating and supporting services often contribute by enhancing quality and quantity of direct benefits, therefore, adding to the local economy and daily life, indirectly. Hence, indirect benefits of nature were given equal values but more focus was given to direct benefits which directly contribute to their daily needs and livelihood *viz.,* agriculture and livestock production in the area. The indirect services which contribute to the agricultural productivity and environmental security were valued more in comparison to others which do not contribute directly to local economy (Table 7.2). Most of the respondents support forest resource conservation and want to save it from further degradation, as forests provide main resources to meet their daily needs and support their livelihood. Local people of NDBR want more plantations of native species to be done in the area, they also suggest that the local people should be trained to take care of the plantations and to maximize the survival rate. About half of the respondents want to remove wild animals from the area as they cause loss of crops, livestock and human life every year. Loss of crop and livestock leads to an immense economical pressure on the affected families as agriculture and livestock raring are the main livelihood of the local people. Other half of the respondents wanted to protect the wild animals as they believe that animals also have a right to live and help in maintaining the balance in nature. Most of the respondents agreed that the agriculture fields located near the forest produce more yield than the field located away from forest. But the yield from these fields do not benefit the people as most of the crop is damaged by the wild animals (Table 7.1).

The significant difference in the values attached to the services by people living close to and away from forest is mainly due to more direct contribution to the livelihood of local communities and easy access to the important natural resources. As members of households situated closer to forest have to put less efforts and time to get the resources than the members of households located away from forest, they appreciate the contribution of forest more and want to conserve it and are willing to participate in improvement of the condition of the forest.

The conservation of biodiversity is crucial for the functioning of ecosystems and for continuous flow of their services (Hooper et al., 2005). The biological conservation is more or less influenced by the knowledge, attitude and behaviour of the local residents who live in the direct association with the natural systems (Bizerril, 2004; Barraza and Robottom, 2005; López-del-Toro et al., 2009). According to Gao et al. (2013) forest and other natural resources linked with traditional cultural practices and beliefs have been maintained for longer periods without much disturbance or change; as the cultural linkage makes the attitude of people affirmative towards conservation practices. At other times, however, human attitudes can be aggressive with respect to conservation practices and may lead to loss of biodiversity (Newmark et al., 1993). Usang (1995) observed that negative attitudes of the people resulted in forest destruction. Understanding the attitudes of dependent community help in identifying and realizing their ideas, opinions and suggestions regarding conservation and management of natural resources (Badola et al., 2012). Although the conservation with ecosystem approach is determined by bigger policy decisions, but the sustainable use of resources relies mainly on communities living in the vicinity of natural systems (Pyrovetsi and Daoutopoulos, 1997; Badola et al., 2012).

Local communities are often dependent (more directly) on the natural resources to meet their needs, financial benefits and subsistence and value the resources more than the communities indirectly and less dependent for basic amenities. Local communities' attitude towards conservation and management of ecosystem often differ with the external social and developmental agents (Matta and Alavalapati, 2006). In some cases people may appreciate benefits, but may not be aware of the supply (Archabald and Naughton-Treves, 2001). Ignorance towards the values that people put on the nature leads to the failure of acknowledgement and undervaluation of the benefits (Parry and Campbell, 1992; Gillingham and Lee 1999; Gadd, 2005). Introduction of modern technologies and life style have changed the behaviour and attitude of people towards natural system and some of them want natural resources be replaced by new developmental activities. As the dependence on natural system for daily needs is shifting towards substitutions (markets), people have started ignoring the importance of ecosystem services (Sandhu et al., 2008). Assessment of the attitude and behaviour of local communities can be used to understand the value local people put on flow of environmental services and their actual values.

Table 7.2. Values given by respondents to different ecosystem services

	Benefits	Values given by respondents				
		4	**3**	**2**	**1**	**0**
Indirect	**Water retention**	761	1	0	0	2
	Nutrient retention	682	77	3	0	2
	Air purification	557	139	66	0	2
	Prevention of landslide	363	325	16	0	60
	Prevention of land erosion	347	260	82	0	75
	Genetic value	123	31	126	64	420
	Aesthetic value	35	97	116	64	452
	Spiritual & religious	29	101	166	2	466
	Biodiversity value	27	57	203	2	475
Direct	**Fodder**	711	48	0	0	5
	Fuel	712	52	0	0	0
	Leaf litter	565	98	22	0	79
	Material for construction	195	383	163	2	21
	Medicinal plant	9	234	136	1	384
	Tourism	95	69	81	30	489

Chapter 9. Conclusions and recommendations

In the present study I assessed the value of the provisioning (biomass and water) and cultural (both recreational and religious) services provided by the forested ecosystem of Nanda Devi Biosphere Reserve (NDBR) and their contribution to human wellbeing. Biomass, provisioned by natural forests of NDBR and its use by local communities, has been quantified using questionnaire survey and entry point method. Provision of freshwater by natural forests and their quantity used by nearby local communities was quantified using timed volume method and questionnaire survey. Both the provisioning services were valued using market price method.

It was found that contribution of oak and moist temperate deciduous forests to the NTFP (kg/hh/year) was higher and hence these two forests contributed more to the direct household income (Chapter 3 and 4). The availability of forest resources and their contribution to local economy varied with the condition and type of forest, and distance between user household and of the source forest. It was observed that the dependence on resources was decreased with the increased household income. The high dependence on natural resources and high visitation rate to forests, often lead to the incidences of human-wildlife conflict in the area. The extent of human-wildlife conflict was found to be reducing with the increased in household income and level of education. As the NDBR hosts a large number of religious and recreational tourists, eco-tourism can be developed to generate alternative livelihood for local communities i.e. economically and educationally well-off households were found to be more tolerant towards the loss caused by wildlife. This will help in reducing the direct dependence on forest resources hence leading to restoration of degraded and restoration of less degraded forests.

To value recreational services, I used zonal travel cost method approach. Limited number of studies have linked forest conditions to human wellbeing, which has been addressed in the present study. It was found that the religious tourism create more livelihood opportunities than the nature based tourism as the religious tourism activity does not require much economic inputs and specific skills. The consumer surplus was lower for the religious tourism, although, it attracts more tourists and provides more opportunities to the local people, its less elastic nature affect the consumer surplus. It was also found that religious tourism was dominated by the affluent outsiders (especially large hotel owners and travel agents) and a larger part of the benefit of tourism goes outside of the area. Recreational and nature-based tourism, although, provide opportunities to few people but contribute more to average household income, by creating markets for local agricultural and livestock products.

Both types of tourism were found to be limited to the specific valleys and pockets of the areas hence generating only niche jobs for the local people. Channelizing the tourists flow to less known religious sites and nature-based attractions, will provide livelihood opportunities to the deprived villagers by involving them in tourism related activities and will ensure equitable benefit sharing. New attraction for nature-based and culture based tourism can be develop to involve more people. This will not only reduce the direct dependence but also will reduce the concentrated pressure of tourists and local people on natural resources.

It was found that people who are being benefitted more from the natural resources are supportive and willing to participate in conservation and management practices, but are unaware about the indirect contributions of natural resources. The attitude of people is found to be associated with their education which is shaping the attitudes positively. People were also found to be aware about the changes occurring in the environment of their area. They mainly attribute these changes to the unplanned and rapid developmental programs and were found to be affected by the consequences. It was observed that the environmental, health and social wellbeing depletes with degradation of the natural resources in the vicinity. Degradation affects the social relation in a village as people have to compete for the limited resources. It was found that, although, resources like *Cordyceps sinensis*, which have high market price and contribute significantly to the income of dependent household, often is a root cause of clashes between villagers and leads to economic discrepancy in the area.

Nature-based recreation and tourism is touted as a sustainable means to preserve natural resources while providing a diversity of economic benefits to local communities and national economies (Gossling, 1999; Wunder, 2000; Wood, 2002). Recreation is one of numerous services provided by ecosystems. The value that users attach to nature recreation can be substantial although it is not reflected by market prices and is provided as a quasi-public good. On a practical level, taking these values into account can make a significant difference in the management, conservation and planning options for nature recreation. On a research level, gaining knowledge on the range of values attributed to ecosystems, dependent on population characteristics, quality and quantity of the natural resource as well as specification of demand models, are essential when assessing general trends and impacts on the use of forests for recreation. Tourism is emerging as the second largest foreign exchange earner for the country even though the mainstay of the tourism industry in India continues to be domestic travelers (Government of India, 2002). The barriers to improved performance of the tourism industry in India include its distance from affluent tourist markets, lack of facilities, relatively limited professionalism in the industry and the 'image' of the country (e.g. it is not a holiday location, it poses safety concerns and it has inadequate services) (Government of India, 2002). As well, the emphasis of the central government on other development issues has left many regions to plan for tourism with little central help or coordination. Cultural heritage sites typically possess public goods characteristics, and thus nonmarket valuation methods must be employed to measure the benefits that they provide to visitors (Poor and Smith, 2004). Nature-based tourism, particularly in protected areas, can create uneasy interfaces between the business models of the tourism industry and the "business models" of natural resource managers (Fennell and Smale, 1992; Shultis and Way, 2006). As a direct result of these interfaces, formal and informal relationships are created between tourists, tour operators and natural resource managers. These relationships sometimes described in the literature as public–private partnerships, form frameworks around which tourism is often organized, formally and informally, in protected areas (Buckley, 2002).

The continuous provision and quality of the ecosystem services is determined by the ecological health of the source ecosystem (Fig. 9.1). The ecosystem's health is governed by bio-physical processes and affected by land use policies, affecting the economy and development. Ecosystem, economy and societal structures are three main components that form the mainstay of the sustainability debate. Of these, economics – the study of how humanity provides for itself (Heilborner, 1968), is the most critical factor undermining the sustainability of the natural resources, since humanity provides for itself by standing on the shoulders of natural systems (Fisher et al., 2008). Thus, integration of economic and ecological sciences into operational decision support system is fundamental for global conservation and sustainability (MEA, 2005a). Ecosystem degradation is argued to be linked with combination of information, market and policy failures, since these failures results in under pricing of scarce resources and environmental assets. The provisioning services provided by the ecosystems have been central to economic and financial decisions and transactions whereas the services, which cannot be translated into direct tradable goods have largely been ignored by the policy planers, till recently. As ecosystem services are neither fully captured by the markets nor adequately valued in monetary terms, they do not receive due importance in policy decisions (Costanza et al., 1997; Costanza et al., 1998; Bernard et al., 2009; TEEB, 2008, 2009, 2010). Provision of assigning market value for ecosystem services proves to be useful while measuring trade-offs between society and the nature when natural resources can enhance human welfare in a sustainable manner (Pagiola et al., 2004; Dasgupta, 2009, 2010; DEFRA, 2010; United Kingdom National Ecosystem Assessment, 2010). Existing markets have ‘failed’ to conserve ecosystem services because they lack mechanisms to compensate resource users and thus do not send signals that encourage participants to use and manage natural resources sustainably (Whitten and Shelton, 2005; Arifin and Hudoyo, 1998). There are many other proximate factors such as, demand on existing services, the opportunity costs of conserving services and unclear property rights, which add to the complexities of understanding of the value of ecosystem resources and results in over use of the common property resources (Gunningham and Young, 1997; Collins and Whitten, 2007; Bromley, 1990; de Groot et al., 2009). As a result, there is suboptimal investment in conservation and management leading to ecosystem deterioration (MEA, 2005a).

Ecosystem services valuation thus has become a crucial tool to tackle information failure, with the aim to influence policy makers and managers at all spatial scales, in their decision for wisely placing natural resources under various management options. Ecosystem service valuation has gained major recognition since Millennium Ecosystem Assessment (2005). Now The Economics of Ecosystems and Biodiversity initiative by United Nations Environment Programme and European Commission, and the set-up of the Inter-Governmental Platform on Biodiversity and Ecosystem Services testify the importance of ecosystems, by placing monetary value on the ecosystems (Ninan and Inoue, 2013).

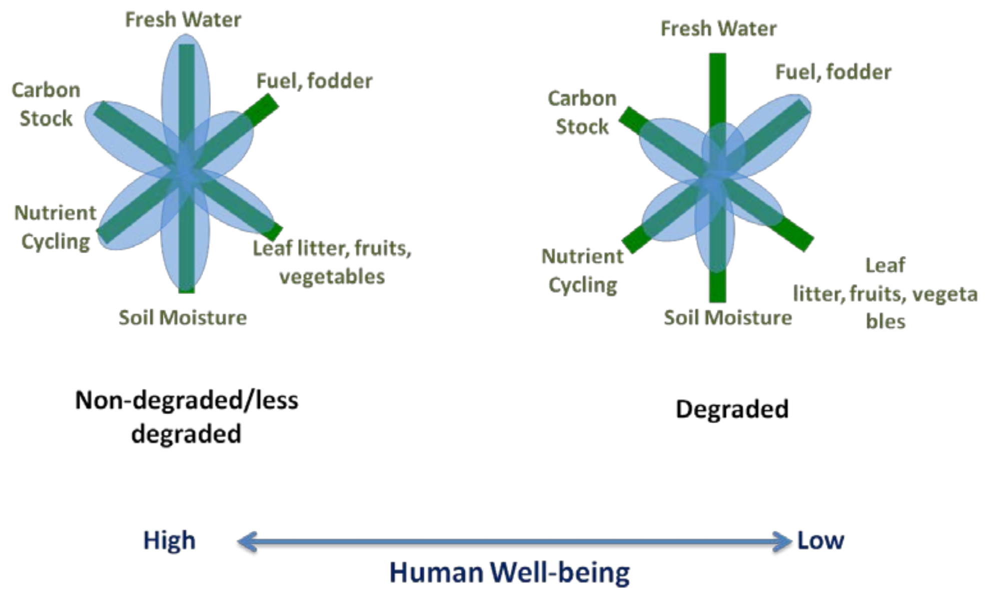


Figure 9.1. Schematic representation of amount of services provided by degraded and non/less degraded landscapes

9.1. Failure towards valuation and conservation of ecosystem services provided by NDBR

9.1.1. Market failure: is it the case with NDBR?

The markets for goods and services are present for provisioning and cultural services but the values assigned to them are not actual value and have not been revised recently (Table 9.1). Due to absence of market for these services from the NDBR, these do not receive due importance in policy decisions (Costanza et al. 1997; Costanza et al. 1998; Bernard et al. 2009; TEEB 2008, 2009, 2010). Existing markets fail to conserve ecosystem services because they lack mechanisms to compensate resource users and thus do not send signals that encourage participants to use and manage natural resources sustainably (Whitten and Shelton 2005; Arifin and Hudoyo 1998) (Table 9.1).

9.1.2. Information failure – is it the case with NDBR?

The state and national government recognizes NDBR as a biodiversity rich area with unique cultural and natural heritage, which are interlinked and complex. This has lead to the designation of the area as UNESCO's world heritage site. Also, the services (especially regulating services) obtained from this region and their linkages with human welfare are being recognized by national and international level legislative measures, such as National Mission on Himalayan Ecosystem (2009), Green India Mission, Green Bonus and the Japan International Cooperation Agency. Also, at local level people are highly aware of the direct services (fuel wood and fodder) provided by the NDBR ecosystem. But majority of the tourists visiting the pilgrimage sites in the NDBR were not aware of the protection status and objectives of protection for the region. One third of the visitors did not know how the conservation status of the area will improve the condition of natural ecosystems.

9.1.3. Intervention failures

Policies for ecosystem services valuation are influenced by different sectors as implemented through different government agencies, which often work in isolation. Often the objectives of these sectoral developmental plans are in contradiction to the forest conservation objectives. The National Biodiversity Action Plan 2008 and National Mission for Sustaining Himalayan Ecosystems 2009, provide measures for reducing the environmental impacts of production and use of ecosystem goods and services. These legislative measures emphasize the need for incorporating the costs of depletion of natural resources into the decisions of economic actors to reverse the tendency to treat these resources as "free goods" and to pass the costs of degradation, thus integrating environmental concerns in economic and social development.

9.1.4. Drivers of degradation of ecosystem services

The changes in ecosystems have led to substantial net gains in human well-being and economic development, but these gains have been traded off against increasing degradation of many ecosystem services. Population growth, economic activity, cultural factors, technological development and revolutionized social-political-cultural dynamics (especially change of most of the rural to urban lifestyle) are the most important factors that have contributed to direct ecosystem degradation reducing the provision of ecosystem services (MEA, 2005b; Bullock et al., 2011). Discrepancy in the economic condition of people and communities and socio-political setup of the area affects the environment and changes the flow of ecosystem services at the local and regional level (Chazdon, 2008). Land use classes change (from natural ecosystem to human modified land use classes), expansion of agricultural land, industrial use of natural resources (McNeely, 2010), introduction of alien species (Pimentel et al., 2000; Vilà et al., 2009), rapid growth in human population, industrializations and urbanization (UNEP, 2006) has reduced ability of natural ecosystems reducing to provide ecosystem services continuously (Peters and Lovejoy, 1992; Schneider and Root, 2002).

In the NDBR the main drivers of change were found to be developmental activities including hydroelectric project, road construction, change from locally sufficient economy to market based economy. The developmental programs have not only put extra pressure on the local biological diversity and loss of agricultural and natural ecosystems affecting the provision of services provided by these land use classes. New development projects have provided new livelihood opportunity to the local people and have empowered them to avail the services of different sectors which have changed the societal setup of the area and lead to the social discrepancy.

9.2. Recommendations for reducing the vulnerability of local communities

9.2.1. Market Based Instruments

Presently the market for services provided by NDBR are nascent as demand on existing services, the opportunity costs of conserving services and unclear property rights, add to the complexities of understanding of the value of ecosystem resources and results in over use of the common property resources (Gunningham and Young 1997; Collins and Whitten 2007; Bromley 1990; de Groot et al. 2009). However, yet we have given estimate of the ecosystem service value of NDBR, which can be used for measuring trade-offs between society and the nature when natural resources can enhance human welfare in a sustainable manner. Regulation and clarification of property rights (ownership and use rights) is considered crucial while dealing with the issue of market failure arising due to notation of 'free goods' and 'easy access'. Market based instruments (MBI), which aim at behavioral change by changing prices in existing markets can be applied in case of NDBR. MBI can be price based or quantity based market instruments, such as environmental taxes, charges, fees and penalties that would internalize negative externalities, payment for ecosystem services and rewards for conservation friendly behavior to address positive externalities. Other MBI aims at making existing markets work better through information and transaction costs (Collins and Whitten, 2007). Some of the MIB, such as taxes, tolls, fees, permits, administrative charges can be levied.

9.2.2. Information measures

Though at the scale of governance, the officials in the policy making, scientific community are well informed of the services provided by the NDBR ecosystem, but at grass root level the visitors (non-locals) did not know the significance of protecting the region as National Park and Biosphere reserve. It is important to target this sector at grass root level, as demand of expanding the tourists' related infrastructure from this sector could become one of the main reasons for degradation of this ecosystem and thereby reducing the capacity of this ecosystem to provide the services. Through the use of suasive instruments, such as education, extension, outreach, research, and monitoring people should be informed about the links between ecosystem goods and services to climate change and human welfare.

9.2.3. Governance structure for maximizing benefits to local people

Nature based tourism in and around PAs has potential to augment equitable livelihood opportunities for forest dependent communities, thereby eliciting local participation in biodiversity conservation around PAs (Wunder, 2000; Karanth and Nepal, 2011; Nepal and Spiteri 2011). Tourism can create local constituency for conservation by compensating local communities for the cost incurred by them (Sekhar, 2003; Sebele, 2010). Tourism also helps in diversification of livelihoods by creating alternatives for local communities, reducing pressures on the natural resources (Neto, 2003). In case of NDBR, prominent pilgrimage site in the proximity of the PA has negatively affected the ecosystem leading to commercialization, where outsiders accrue the monetary benefits of tourism, as they have resources to make preliminary investments. Because of the large number of tourists; 10-12, 00,000 tourists within a four month period, there is a concomitant increase in the number of tourism staff (mostly outsiders) which also has an adverse impact on the habitat. However, tourism has also help reduce dependence of local communities on forest resources by providing alternative livelihoods but the involvement of local communities in tourism is indirect and limited to insignificant monetary gains. The local communities have little control on the management of tourism and the monetary flow from therein. In case of religious tourism in Badrinath and Hemkunt, the non-locals *viz*., Hemkunt Sahib Trust, the tour operators, the infrastructure owners control the monetary flow. The locals are involved in petty activities with little monetary gains. Local and other institutions i.e. forest department, NGOs, religious trust work nearly independent of each other. Also linkages between tourists and the local communities are minimal, resulting in reduced opportunities for the local community to derive monetary gains. Regulated and controlled tourism in core areas has helped in generating income for the local community, yet the benefits here are skewed in favour of the village elite, because mechanisms to ensure equity are absent. However, the benefits of mass tourism from the religious sites accrue mainly to the outsiders and have negative impacts on social relationships.

The efficacy of vertically integrated governance structure has been advocated to be the ideal model for public participation (Pierre and Peters, 2000), and only recently studies have started focusing on hierarchical governance in tourism. A layered and complex institutional arrangement, created with the participation of multiple agencies working in close coordination is able to channel the benefits of tourism to local people. Such institutions are capable of adapting and responding to the challenges of a globalized economy, but the government institutions need to evolve more effective and stricter mechanisms to deal with unforeseen challenges (UNDP, 2010) (Table 9.1).

Table 9.1. Ecosystem services provided by NDBR landscape and their markets

Services and values		Market existing	Market Possible	Level of difficulties in establishing market	Spatial scale of	
					Benefits	**Market**
Provisioning	Fresh water	Present	Yes	Easy	Regional, National (water for domestic and agricultural use, hydroelectric production)	Regional, National
	Biomass	Present	Yes	Easy	Local	Local
Cultural	Recreation	Present	Yes	Easy	Regional, National	Regional, National, International

9.3. Specific recommendations

On the basis of the results of the present study following specific recommendations are made:

1. Forest resources have significant contribution to the local economy of the NDBR landscape. This is almost comparable to the contribution of the agricultural output. Policy and management sector have to recognize this.
2. Most of the ecosystem services generated from the forested ecosystem of the NDBR, due to their off-site nature, do not benefit the local communities. To capture ecosystem services such as freshwater, site specific strategies for instance storing and distribution channel should be developed to channelize the functional output of the streams to the villages which are not able to use the services due to terrain and distance from the water resources. Micro-hydel projects can be developed as they help and support local communities more than bigger hydro-electric projects.
3. Almost 100% of the households surveyed were found to be dependent on the forests; this is impacting the quality of forest and also hampering their ability to provide other ecosystem services. Direct dependence on natural resources can be reduced through providing alternative non-forest based livelihoods such as nature and culture based tourism and ensuring equity in benefits.
4. The social and economic vulnerabilities were found to result from lack of better education. Educational facilities, especially vocational training, should be provided to diversify livelihoods.
5. Tourism is clumped at few valleys and pockets in the areas hence, providing niche based jobs such as tourist trekking guide and porters, benefiting only small number of residents. The benefits can be shared by introducing and developing tourist attractions like farm tourism, cultural tourism, homestays.
6. Onsite tourism related leakages occurring due to economic capitalization should be channelized to local communities based business sectors e.g. homestays, market for local handicrafts.

7. Local varieties of crops should be promoted and subsidized (MBIs) for its popularity in nature-based tourism. This will help in maintaining the agro-biological diversity and food security particularly for women and children.
8. Traditional crops production will help in reducing exploitation of natural resources for cash crop based agriculture.
9. Most of the cases of crop depredation reported by respondents were for cash crops, promotion of local varieties can help to reduce the loss caused by such conflict cases.
10. Payment for ecosystem services strategies like, Grain for Green Programme (also known as Grain for Tree policy), REDD+, can be adopted and developed to ecological protection and poverty alleviation of the dependent community.
11. Institutions should be identified to develop integrated plan to ensure the conservation of natural resources and continuous flow of ecosystem services, and for the equitable benefit sharing from conservation of natural resources among different stakeholders.

9.4. Conclusions

Notwithstanding the limitations cited earlier, findings of this study establish that the ecosystem service contribute significantly to the human well-being in the region. Governments and societies faced with the development versus conservation dilemma need to factor in such benefits while taking decisions that impact on natural resources and ecosystems. Realization about these significant intangible benefits will help in more informed decisions and policies that will help conserve forest ecosystems and the services they provide as well as promote human well-being and sustainable development. Most conservation plans focus on biodiversity and ignore the importance of ecosystem services (Singh, 2002). Using biodiversity approach may neglect areas that are degradation prone and crucial for human welfare. Thus, valuation of ecosystems and the assessment of the distribution of costs and benefits of conservation are essential for sustaining ecosystem services. There are few studies dealing with ecosystem service valuation in mountain regions leading to a lack of information of opportunity costs of putting land under different uses viz. conservation, agriculture, development, tourism.

The informatory, regulatory and market instruments do not function in isolation. For sustainable environmental governance, they need to have positive synergistic interactions. To manage or regulate a resources use, it is important to have information about the resources' quantity, quality and their economic worth. Resource uses create markets and vice-versa, which are regulated by pricing and incentive mechanisms. Natural resources are further impacted by developments in the other sectors. Hence, presence of all three instruments is important for policy or legislative measures to achieve sustainability in managing natural ecosystems. A policy portfolio approach combining several measures promises to prove the best choice for biodiversity protection (Ring and Schroter-Schlaak, 2011). Sustainability of the ecosystem resources across states of the Indian Himalayan region calls for proactive management that blends anticipation, adaptation and preparation for future environmental challenges such as escalating population, climate change, shrinking natural resource base and natural disasters. An adaptive and integrated policy approach, both at national and local levels, that is able to address ecological and economical well-being of the communities inhabiting the IHKH and develops their stakes in conservation of these vulnerable and fragile ecosystems is called for.

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APPENDICES

Objective of survey: To assess the status of human well-being of local people in Nanda Devi Biosphere Reserve.

Date: Village: Distance from forest:

Condition of forest:

1. Name of the respondent-
2. Age-
3. Religion-
4. Caste-
5. Qualification-
6. Occupation-
7. Family structure- Nuclear/ Joint

Name	Age (yrs)	Sex	Relation with respondent	Education	Employment status	Income

Hypothesis I- There is no difference in the education level of people living close to and away from forests.

Reason for not attending the school-

a. No school facility is available in village and nearby area
b. Engaged in other work
c. Lack of interest
d. Poverty
e. Other

Hypothesis II- There is no difference in the economic status of people living close to and away from forests.

Type of house-

Land owned by person-

If any land in another village (purchased/ ancestral)-

How much you earn in a month?

Source of income	Yes/ No	Amount		
		Month	Season	Year
Agriculture				
Floriculture				
Horticulture				
Bee keeping				
Dairy				
Other livestock				
Govt. employment				
Pvt. Employment				
Business				
Labourer				
Handicrafts				
Others				

Livestock:

Type	No.	Out put		Sale price		Months fodder available (kg)			
		Type	Qty.	Amt.	Unit	Own	Purchased	Cost	Forest
Cow desi									
Cow hybrid									
Buffalo desi									
Buffalo hybrid									
Goat									
Sheep									
Mules									
Poultry									
Ox									
Calf/ calves									

1. Reasons for cattle rearing-

   a. Dairy b. Meat c. Wool d. Dung e. Ploughing

2. Are you able to save a part of your income?
   - If yes, how much?
3. Do you have any debt? Y/N
   - If yes, how much and from where you have taken this-

   a. Money lender b. Bank c. Local Govt.

4. What has been mortgaged?
5. Why did you need that money?
6. Where do you spend major part of your income?
7. Do you have property in other village?

   If yes, do you earn money from that property?

Hypothesis III- There is no difference in the dependence of the people living closer to forest and those living away from forests.

1. Extraction from forests

Product	Y/N	Quantity extracted	Quantity used	Quantity sold	Income
Fuel wood					
Fodder					
Grazing					
Thatching					
Fruits					
Vegetables					

Medicinal plants					
Others					

Income from forest products:

Product	Seasons	Nearest market	Mode of selling	Market rate	Demand very high/ high

Hypothesis IV- There is no difference in the status of health of the people living near the forests and the people living away from the forests.

1. Have you/ your family member been to doctor for treatment within (1) last one week, (2) last 15 days, (3) last one month, (4) last two months, (5) last three months

Name	Age (yrs)	Visitation rate					Disease	Treatment	Expenditure
		1	2	3	4	5			

Medicinal plant extracted	Part of plant used	Season of extraction	Against which disease	Form in which consumed

2. Method of treatment home or local vaidh or doctor treatment. Why?
3. Have your children vaccinated? Y/N
   If no, why-
   If yes, against which diseases-
   a. DPT b. TT c. BCG d. OPV

4. Is there a recent birth in the family? Y/N

   If yes then who helped in the delivery of the baby? Local midwife/ Trained nurse/ Doctor/ At home

5. If any case f child mortality- Y/N Age- Sex: Male/ Female.
   Reason- Mal nutrition/ Lack of vaccination/ Lack of antenatal care/ Lack of medical help
6. If any case of maternal mortality- Y/N Age-
   Reasons- Mal nutrition/ Lack of antenatal care/ Lack of medical help/ Any other

7. Is there any death in the family during last one year? Y/N

Sex	Age (yrs)	Reason	
		Known	Unknown
Male/ Female		a. Old age b. Ailment c. Lack of treatment d. Suicide e. Accident	

8. Do you know about AIDS/HIV? Y/N
9. Case of mental illness-

Hypothesis V- There is no difference between the living standards of people living close to and away from forests.

1. Source of drinking water: stream/ river/ tap/ natural source/ hand pump
2. Do you think you are getting pure drinking water? Y/N, If not, why
   a. Natural resource is contaminated
   b. Water borne diseases are common in the area
3. Is your house electrified? Yes/ No
   If no then what alternative you have to illuminate your house?
4. Do you have toilets or defecate in open
   If toilets, then a. common toilets b. separate
5. Have you adopted the following fuel resources?

Recourse	Yes	No	Preferred	Reason for preference
LPG				
Kerosene				
Dung				
Wood				
Biogas				
Solar cooker				

In case of LPG-

How many LPG connections in a family?	
How many days can one cylinder be used?	
Nearest place from where you buy cylinder?	
Do you buy cylinders in black? Yes/ No	
Is process of buying cylinders is difficult/ easy?	

In case of kerosene-

How many lts. Of kerosene consumed in a month?	
From where do you buy?	
Do you buy in black or from community shop?	
Is process of buying it is difficult/ easy?	

Facility/ house infrastructure-

Telephone	

Television	
Radio	
Bi-cycle	
Motorcycle	
Car for self	
Vehicle for rent	
others	

6. Does any doctor or health worker (nurse/ ANM/doctor) visit the village? Y/N
   If yes, how frequently- (weekly/ monthly)

Hypothesis VI- There is no difference in harvest from field in village close to and away from forests.

Crop	Area sown	Seed type	Fertilizer type	Fertilizer quantity/ ha	Yield (kg)	Market price /kg	Earning	Quantity sold (kg)

Hypothesis VII- There is no difference in the livelihood options of people living close to and away from forests.

1. If crop failed what will you do-
   - Cattle rearing
   - Medicinal plant extraction
   - Selling of other firewood
   - Selling of other NTFPs
   - Daily labour
   - Pvt. Job

Hypothesis VIII- The clearing of the forest will not affect the general wellbeing of the local people.

1. What will you do if the forest near you degrades totally?

Effect of degradation	1	2	3	4
Economy				
Mental status				
Health				
General wellbeing				

Environmental wellness-

1. Is the condition of the forest near your village has changed in last-
a. One year b. 1-5 years c. 5-10 years d. 10 years and above

2. Do you feel quality of air which you breathe has degraded in last-
a. One year b. 1-5 years c. 5-10 years d. 10 years and above

3. Reason-

   Effect of this change on your life-

4. Is there any increase in noise pollution in last-

a. One year b. 1-5 years c. 5-10 years d. 10 years and above

If yes, in what way it has affected your life-

Workplace wellness

1. Are you adequately paid for the work you are doing?
2. Would you like to change your current job and workplace?
3. Have you changed your occupation in recent period of time? Y/N
   If yes, why-
   a. Loss of agriculture land b. Crop failure c. Insufficient return

   d. Increased job opportunities e. Because of Govt. aided schemes

4. Do you face discrimination based on sex, caste, religion at your workplace?

Political wellness

1. Are you happy with the working of the present village panchayat?
2. Would you like to change the elected person?
3. What benefit are you getting from panchayat?
4. Do you think that eco-development committee, women development committee of your village are doing their job?
5. Is your opinion taken into account when committee meeting held in village?
6. Do you think women participation or their views are considered in policy making?
7. Do you feel free to vote for any person or you feel pressurized at the time of election?

Social wellness

1. Do you face discriminated because of your caste religion gender?
2. Is there any case of divorce in the family?
3. Any case of physical and mental harassment against women?
4. Is there adequate representation of women in self help groups?
5. Do you feel secure at your place? Y/ N

If no, why-

   a. Environmental hazards as landslide
   b. Insecurity for continuing livelihood
   c. Probability of crop failed
   d. Lack of prospects for future generation

6. Are you happy with the upbringing of your children?

If no, why

If you have choice what would you have differently?

7. Is any person in family is involved in any kind of legal case, police case?

8. How your living condition can be improved?

   a. By technical and vocational education
   b. Provide improved livelihood options
   c. Access to basic facilities like PHC, clean drinking water

Hypothesis IX- There is no difference in the perception of the people living closer to forests and those living away regarding the conservation benefits of forests (ecosystem services).

1. What are the direct and indirect benefits you obtain from the forests?

Direct benefits	Rank			
	1	2	3	4
Fuel				
Fodder				
Manure				
Material for construction				
Material for bedding in cowshed				
Medicinal plants				
Tourism				

Indirect benefits	Rank			
	1	2	3	4
Water retention				
Nutrient retention				
Air purification				
Prevention of landslide				
Genetic value				
Aesthetic value				
Spiritual & religious				
Biodiversity value				

2. Is it important to conserve the forest? Y/N
   If yes, why and how
   a. It provides resources
   b. It supports livelihoods
   c. It provides water
   d. It provides shelter to animals
   e. Aesthetic value
3. What should be done to improve forest near your village?
4. Is it important to conserve the wild animals? Y/N

If yes, why	If no, why
a. Aesthetic beauty b. Recreational value c. Right to live	a. Kill people b. Kill livestock c. Damage crop d. No benefit for society

5. What do you think about the forest near your village?

Forest should be cut and land should be used for agriculture	Yes/ No
Animals should be removed and forest should remain	
Present condition of forest is good and beneficiary so it shouldn't change	
More plantation should be done	

6. Do you think forest near your agricultural land contribute in agriculture? Y/N

If yes, how-

Areas near the forest give more yield	Yes/ No
Fertilizers required in less quantity near forest	
Water table is high near forest	
Regulates rainfall	

Cultural and religious values of the forest close to village-

1. How many temples are there?
2. Are there any god/ goddess linked to the forest?
3. Do people from different parts of country come here to pay homage?
   If yes,
   a. Do they hire local people as tourist guides?
   b. How much do you charge for this?
4. Any historical epic associated with the god/ goddess?
5. Any religious fair associated with the deity?
   Y/N, if yes
   a. In which month of year?
   b. Any case of animal sacrifice? Y/N
      If yes, which animal?
6. How much money is collected annually?
7. The presence of renowned temple plays any role in your economical condition?
8. Do you have trust in a name of temple?
9. What do you do with the money collected?

Change in forest condition				Change in species of plant in the forest
Degraded		Improved		
High	Less	High	Less	

Change in sp. Of wild animals	Change in no. of wild animals	Change in pattern and intensity of human wildlife conflict		
		Crop	Livestock	Human

Distance traveled for forest resources		Time spend		Risk		Change in plant sp. Brought from forest	
Earlier	Now	Earlier	Now	Earlier	Now	Earlier	Now

AN INTEGRATED APPROACH TO REDUCE THE VULNERABILITY OF LOCAL COMMUNITIES TO ENVIRONMENTAL DEGRADATION IN WESTERN HIMALAYAS

Objective: To estimate the recreational value of the Nanda Devi Biosphere Reserve and tourism potentials.

TOURIST PROFILE

Date:		Place:	
Name:	Age:	Income per month:	Education:
Occupation:	Sex:	State/ Country:	Distance of NDBR from hometown:

1. Which of the following group would you place yourself in?
a. Local resident
b. Foreign tourist
c. Tourist on independent holiday
d. Tourist on inclusive/ package tour
e. Visiting friends/ relatives
f. Business
g. Official tour
h. Other

MOTIVATION FOR VISIT

2. What are the main reasons for your visit to the site?

Reason for visit	Present	Past	I	II	III	IV	V	VI	VII	VIII	IX	X
Religious												
Aesthetic beauty												
Recreation												
Trekking												
Educational trip												
Expedition												
Skiing												
Recuperation												
Official tour												
Just passing through												
Others												

3. GROUP COMPOSITION

Adults	Children	Total

4. COST OF TRAVEL

Mode of travel	Air-Road	Air-Train-Road	Train-Road	At the site	Road				Money spent	
				Local travel	Personal vehicle	Hire (shared/ not)	Public transport	Govt. vehicle	Total	Per head
Travel cost										
Who paid for your travel					Self	Govt.	Company	Partly by company/ Govt.		

5. TIME SPENT

To reach the place	Hours
At the place	Hours

6. COST OF STAY

Place of stay	Hotel/ Lodge	Guest House	Home Stay	With friends/ relatives	Money spent	
Joshimath					Total	Per head
Auli						
Badrinath						
Pandukeswar						
Ghangaria						
Others						
TOTAL						

7. HOW MUCH YOU HAVE SPENT

Money spent on food	(Rs.)
Hiring guides	
Porters	
Ponies	
Handicrafts	
Others	

8. TO DERIVE THE CHANGE IN THE TRAVELLING COSTS

Q. Whether the cost of travel has increased since your last visit? Yes/ No;

If yes, earlier price- Now-

9. EVALUATING PROMOTIONAL MATERIAL

Q. Which of the following has influenced your decision to visit the site?

a) A previous visit with advice from friends/ relatives
b) Advice from a tourist information centre with brochure
c) Tourist guidebook
d) Newspaper/ magazine advertisement
e) Internet
f) TV programme

10. ATTRACTION AND ACTIVITIES

(A) ATTRACTION

Attractions of site	For present visit			If already visited			
	Not visiting (reasons)	Already visited	Intend to visit	Spent	Money spent		
					On travelling	On stay	On others (specify)
Badrinath							
Hemkund							
Kalpeswar							
VOF							
NDNP							
Auli							
Tapovan							
Others							

(B) ACTIVITIES

Participated in activities	Professional	Amateur	Level of satisfaction
Trekking			
Bird watching/ Nature walk			
Mountaineering			
Rock climbing			
Expedition			
Others			

**Rate the above on the scale of: - Excellent, Very good, Good, Average, Poor.*

11. Have you noticed any change in the place after your visit? Yes/ No; if yes, what-

Change	0	<25%	25-50%	50-75%	75-100%
Cleanliness increased/ deteriorated					
No. of trees increased/ decreased					
No. of shops increased/ decreased					

Basic facilities are better now					
No. of tourist increased/ decreased					
No. of building increased/ decreased					
Change in climate					
Change in snowfall					
Any other (specify)					

12. LEVEL OF SATISFACTION

Attraction	Culture	Scenic beauty	Biodiversity	Adventurous games	Others (specify)
Badrinath					
Hemkund					
Kalpeswar					
VOF					
NDNP					
Auli					
Tapovan					
Others (specify)					

* *Rate the above on the scale of: - Excellent, Very good, Good, Average, Poor.*

1. If you rated poor, please explain-
2. Would you like to visit the site in the future?

   a. Very likely
   b. Likely
   c. Unlikely
   d. Don't know

3. If you have answered unlikely, please explain-

RECOMMENDATIONS FOR IMPROVEMENT

1. Are there any specific ways to make the visit to this site more enjoyable?\

2. What would you say was the most enjoyable part of your visit to?......................................

3. What have you enjoyed least?...

4. Would you recommend this site to someone? Yes/ No
   If no, please explain:

AWARENESS OF WORLD HERITAGE SITE/ PROTECTED AREAS

5. Do you know this place is a World Heritage Site/ Protected Area/ Biosphere Reserve?

6. Do you know which part of the Biosphere Reserve is protected as National Parks?

7. What do you understand by World Heritage Site/ Protected Area or Biosphere Reserve?

8. Do you think it is justified declaring this place a World Heritage Site, Protected Area or Biosphere Reserve?

PUBLICATIONS

LIST OF PUBLICATIONS

Peer reviewed paper:

1. Badola R., Hussain S.A., **Dobriyal P.** and Barthwal S. (2015, in press). Assessing the efficiency of policies in the Indian-Himalayan region to sustain and promote ecosystem services. International Journal of Biodiversity Science, Ecosystem Services & Management. DOI:10.1080/21513732.2015.1030694.

2. **Dobriyal, P.**, Qureshi, A., Badola, R., and Hussain, S. A. (2012). A review of the methods available for estimating soil moisture and its implications for water resource management. Journal of Hydrology, 458, 110-117.

3. Qureshi, A., **Pariva**, Badola, R. and Hussain, S.A. (2012). A review of protocols used for assessment of carbon stock in forested landscapes. Environmental Science and Policy 16: 81-89.

Book Chapters:

1. Badola R., Hussain S.A., **Dobriyal P.** and Barthwal S. (2015). An introduction to ecosystem services. In: Ecosystem Services and its Mainstreaming in Development Planning Process, Editors: Manju Sundriyal and V.K. Dhaundiyal, 2015. Uttarakhand Science Education and Research Centre (USERC), & Bishen Singh Mahendra Pal Singh, Dehradun, India. 1-16 pp.

2. Badola R., Hussain S.A., **Dobriyal P.** and Barthwal S. (2015). Methodological framework to assess the services provided by mountain ecosystems. In: Ecosystem Services and its Mainstreaming in Development Planning Process, Editors: Manju Sundriyal and V.K. Dhaundiyal, 2015. Uttarakhand Science Education and Research Centre (USERC), & Bishen Singh Mahendra Pal Singh, Dehradun, India. 68-91 pp.

Popular article

1. **Dobriyal, P.,** Qureshi A. and Rastogi, A. (2012). The Hills are Alive with the Sound of Hydropower Projects “Forest of Ideas” project initiated by Young Asian Reporters (YAR) & United Nations Environment Programme (UNEP).

2. **Dobriyal, P.** (2011). Warming or Warning? Asia Pacific Mountain Courier, 12(1): 9.

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Assessing the effectiveness of policies in sustaining and promoting ecosystem services in the Indian Himalayas

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Abstract

We examined existing policy instruments of the Indian forest, wildlife, and environment sectors for the period 1927–2008 to (a) assess their strengths and weaknesses in addressing information, market and policy failures in ecosystem service provision in the Indian Himalayan region and (b) determine if they were informatory or regulatory in nature and whether they encouraged the use of market-based instruments. Our analysis revealed that Indian policy measures can be categorized into four eras: Production (1927–1972), Protection (1972–1988), Community Participation (1988–2006) and Climate Change and Globalization (2006 onwards). The policies of the earlier two eras were largely regulatory in nature. From 1988 onwards, community participation in biodiversity conservation has made the policies more informatory and market-based. The recognition that Himalayas are a distinct ecosystem, crucial for their services but vulnerable to climate change impacts, has come about only with the National Mission on Sustaining Himalayan Ecosystem. Given the multiple stakeholders in Indian Himalayas and the off-site nature of ecosystem services, a complementarity of instruments and their ability to address the consequences of local decisions on downstream ecosystem services are essential. A participatory and sectorally coordinated mixed governance approach is needed to sustain ecosystem services in the region.

Keywords: Indian Himalayas; ecosystem services; climate change; policy instruments; mixed governance approach

1. Introduction

The concept of ecosystem services has become an important model for linking the functioning of ecosystems with human well-being (Fisher et al. 2009). But even as demands for ecosystem services are growing, human actions are diminishing the capability of ecosystems to meet these demands. Sound natural resource management strategies can often reverse ecosystem degradation and enhance the contributions of ecosystems to human well-being (MEA 2005). In recent years a large and rapidly growing body of research has been seeking to identify, characterize and value ecosystem goods and services (Bagstad et al. 2013) and strategize ways to ensure their continuous provision.

A study conducted by UNEP-WCMC indicated that there is a high degree of coverage of ecosystem services in policy instruments but this is still inadequate because the concept of ecosystem services evolved recently and there are constraints to defining, assessing, and regulating impacts on ecosystem services (CBD & UNEP-WCMC 2012). The understanding of the complementarities and inter-linkages of ecosystem services is limited (Pagiola et al. 2004). Consequently, they have largely been ignored in both domestic and international markets and land use law and policy decisions (Barbier 2007; TEEB 2010). Till recently, international and national legislative measures were not designed to safeguard ecosystem services. Hence, the negative impacts of development policies often resulted in repercussions for the availability and provision of ecosystem services.

Current ecosystem-based approaches have suggested that policies and measures be adopted that take into account the role of ecosystem services in reducing societal and ecological vulnerability through multi-sectoral and multi-level approaches (Andrade et al. 2011). Economists, environmentalists, and lobbyists have proposed various types of policy mix (Figure 1), arguing that ‘single-instrument’ or ‘single-strategy’ approaches are misguided and when used individually fail to address complex causes of ecosystem service degradation (e.g. Gunningham & Sinclair 1999; Ring & Schroter-Schlaak 2011).

The policy mix approach works towards building and working with the strengths of individual instruments, even as it compensates for their weaknesses through additional or complementary instruments. Gunningham & Young (1997) classified the policy instruments as being (a) motivational that shift individual and community preference functions and (b) those that inform people about relationships between resource management practice and the environment.

INSERT FIGURE 1 HERE

The literature dealing with policy issues on ecosystem services (Goulder & Parry 2008; de Groot et al. 2010; Ring & Schroter-Schlaak 2011) addresses policy instruments as following:

a. Regulatory, which aim to regulate the use of natural resources through protection and planning. They include provision of permits, zoning or planning, and control of environmentally degrading activities. Regulatory approaches can promote efficiency, but they inhibit innovation and impose unnecessary costs.
b. Market-based (MBIs), which aim to introduce behavioral change by changing prices in existing markets rather than through explicit directives and by specifying the revised rights and obligations. MBIs can be price based or quantity based (such as environmental taxes, charges, fees, and penalties that will internalize negative externalities), payment for ecosystem services (PES), and rewards for conservation-friendly behaviour. Taxes, subsidies, tradable permits, and auctions of property rights are a few MBIs that economists have long recommended for efficient environmental policy making (Seccombe-Hett 2000; Badola et al. 2014).
c. Informative and motivational, such as education, extension, research, and monitoring, which aim to inform communities about the relation between human activities and their impact on the environment.

International debates on strategies to sustain ecosystem services have emphasized the need to revisit natural resource policies and legislative measures to ensure that they contain regulatory mechanisms and backups in the form of MBIs and motivational approaches. This need is more pronounced for the Himalayas, which are (a) important for the lives and livelihood security of a large number of people, (b) critical for sustaining provisioning, regulatory, and supportive functions of other ecosystems, and (c) fragile.

The Indian Himalayas are one of the richest and most complex regions in the world from geological, biological, and cultural points of view. They cover approximately 5,91,000 km^2 or 18% of India’s land surface. Located at the junction of the Palearctic, Afro-Tropical and Indo-Malayan realms, they are widely considered to be one of the global hotspots of biodiversity and account for 50% of India’s forests and 40% of the species endemic to the Indian sub-continent (Semwal et al. 1999). The Himalayas are the water tower of the Indian sub-continent. Major rivers of the region have their origin here (Government of India 2010). The Himalayas provide vital ecosystem services for the ecological and economic security of the people living downstream. They are a repository of geological and agricultural assets and harvested wild goods, besides being a center of cultural, social, and religious identity to a large number of people (Saxena et al. 2001; Birch et al. 2014). However, the Himalayas are also one of the most degradation-prone and fragile mountain ranges in the world. They are more vulnerable due to geological reasons, the stress caused by the increasing human population, exploitation of natural resources, and effects of climate change, which have multifaceted repercussions on human well-being (Liu & Chen 2000; Dyurgerov & Meier 2005). The temperature increase is predicted to be more noticeable in the Himalayan region (INCCA 2010; Singh et al. 2011) with resultant impacts such as glacial melts, sediment mobilization, draught, landslides and flash floods (Dale et al. 2001; Wulf et al. 2012). These impacts have resulted in reduced productivity of natural and human modified ecosystems, loss of tourism revenue, infrastructure and food and water security for the communities living in the region (WHO 2012;

Badola et al. 2014; Smith 2014) Notwithstanding all this, the Himalayas have remained at the periphery of policy space (http://himlayaforum. org). The failure to recognize the economic value of the Himalayan ecosystem services and to address the issues of sustainability using policy tools has been cited as the primary cause of the continued degradation of this vulnerable ecosystem (Singh 2002; Blaikie & Muldavin 2004). There is increasing concern that this apathy will lead to a rapid decline in the provisioning, regulatory, supporting, and cultural services of this region and adversely impact the provision of ecosystem services downstream. Numerous scientific and political forums have underpinned the uniqueness, environmental challenges and political legacies of the Himalayan region and the need to address the extremely diverse environmental threats faced by the region in policy making (Blaikie & Muldavin 2004; Gautam et al. 2013).

The objectives of this review are to (a) analyze the existing policy instruments of the forest, wildlife, and environment sector for their strengths and weaknesses in addressing the challenges of ecosystem service management in the Himalayas and (b) identify the policy gaps or failure of the policies as informatory, market-based and regulatory instruments for promoting sustainable management of ecosystem services in the region.

2. Approach and methods of analysis

In India the natural resource sector is largely governed by the policies of the forest, wildlife, and environment sector; however, the policies of other sectors, such as the rural development, agriculture, tribal affairs, and defense also impact it. We restricted this review only to the acts and policies of the forest, wildlife, and environment sector of the Government of India that have a bearing on the Himalayan region (Table 1).

INSERT TABLE 1 HERE

The analysis covered a period of about 90 years, from the enactment of the Indian Forest Act 1927 (IFA) (which forms the basis of subsequent forest acts and policies) to the promulgation of the National Action Plan on Climate Change (NAPCC), 2008. The NAPCC is the first policy document in India that deals with the Himalayas as a separate and crucial ecosystem. Based on the key national policy milestones we divided the period from 1927 to 2008 into four eras (Figure 2):

a. *Production Era (1927–1972)*: During this period, forest management was closely linked with commercial interests since the 'need for realization of maximum annual revenue from forests' was considered vital and the relevance of forests in meeting the needs of development and foreign trade during the colonial and post colonial period was given prominence in managing forests.
b. *Protection Era (1972–1988)*: This was the period when the degradation of forests was realized and highlighted by conservationists in India and measures were taken to provide legal protection to the flora and fauna in their natural habitat.
c. *Community Participation Era (1988–2006)*: The National Forest Policy (NFP), 1988 was a total turnaround in the government's stand on local people and forests. It was the initiation of community participation in forest and wildlife management. The policies and acts formed during this era recognized and legalized the links between human welfare and natural ecosystems.
d. *Climate Change and Globalization Era (2006 onwards)*: It was only with the promulgation of the National Environment Policy, 2006 (NEP) that the impacts of climate change were addressed. A further step in this direction was the promulgation of the NAPCC.

For this study the term 'policy' is defined as a system of law, regulatory measure, or course of action concerning conservation of natural resources and the environment. The term 'policy instrument' refers to a set of guidelines adopted by the state to implement and achieve the desired effect of a particular policy, while the term 'governance' is used for the formal and informal institutions used to manage natural resources and environment. Original policy documents were examined to understand the nature of the instruments used for managing natural resources and addressing information, market, and policy failures in ecosystem service provision in the Himalayas and to evaluate if the policies are (i) informatory or (ii) regulatory in nature and whether they (iii) encourage the use of MBIs. Additionally, the published literature and government records were also consulted to substantiate the aforesaid material.

Each document was further assessed on the basis of the following parameters: whether the policies (a) recognize the Himalayas as a complex and inter-linked system, (b) recognize the Himalayas as a provider of ecosystem goods and services, (c) recognize the linkages between the goods and services provided and their vulnerability to climate change, (d) have provisions for suasive instruments, such as dissemination of information, training and extension, education, and research, (e) contain regulatory measures such as permits, administrative charges, formulation of management plans, and setting of standards needed for protecting the ecosystem and its components, (f) encourage the use of MBIs, such as consistent pricing, value chain analysis, subsidies, and quality checks, and (g) clarify property rights through public provisions, specifying ownership and use rights. The indicators '*a–d'* indicate that a document is informatory; '*e'* indicates a regulatory document; and '*f–g'* indicate that a policy is market based.

3. Results

3. 1. Changing dimensions of policies and legislative measures impacting ecosystem services

The present environmental legislative framework of India broadly comes under the purview of the Environment Protection Act, 1986 (EPA). The law related to management of forests and wildlife is contained in the IFA, Forest Conservation Act, 1980 (FCA) and Wildlife (Protection) Act, 1972 (WPA). The forest policy of the country has been shaped by its colonial and post-colonial circumstances (Badola 1995). The directives of colonial forest policy were governed by considerations of imperialism and commercialism, *i.e.* meeting the need for wood for railways and for the two world wars and, assuring a steady revenue for the state. For example, the IFA, specifically denied people any rights over forest produce 'simply because they were domiciled there' (Table S1). Independence made little difference to the position of people in relation to forests. The NFP, 1952 retained the concept of 'reserved forests', now justified in the name of 'national need', and placed such forests under the exclusive control of the forest department (Arora 1994). The NFP, 1952 asserted the 'need for realization of maximum annual revenue from forests', and the relevance of forests in meeting the needs of defence, river valley projects, industry, and communication were emphasized. Although these and subsequent policy statements mention the need for maintaining the ecological integrity of forests, the approach of the state continued to reflect a lack of recognition of ecosystem services, focusing only on exploitable forest products. Villagers lost their sense of 'belongingness' to the forest and came to feel that any self-denial they might exercise in using the forest would simply end up in the forest being appropriated by the government. While traditional institutions continued to exist, their roles as mechanisms for regulating resource use among their members became more or less redundant. Thus common property resources under communal control now became open access resources and were consequently liable to be used in an exhaustive manner (Gadgil & Iyer 1989). This was a classic case of market and policy failures.

With the enactment of the WPA and the launch of Project Tiger the same year, there was a steady increase in the area under national parks and sanctuaries with an implicit focus on maintaining the natural systems. However, the approach to forest and wildlife conservation focused on patrolling by guards and imposition of penalties to discourage encroachment and illegal activities. Commonly, the people living in and around forest areas were the relatively poor inhabitants of agricultural villages. Even if they had other sources of income, which were most often seasonal, given their limited purchasing power, they depended totally on the surrounding forest for their fuel, fodder, timber, and, sometimes, food requirements. The result was a number of protests and social conflicts over forest resource use. This and the failure of the state to control degradation of forests through its traditional policing approaches were important factors in reorienting natural resource management policy towards people's participation (Figure 2). The subsequent amendment to the WPA in 2002, 2006 & 2013 addressed these issues and created space for incorporating human livelihood and development concerns in wildlife conservation (Table S1).

INSERT FIGURE 2 HERE

In the NFP, 1988, for the first time it was emphasized that the forests were not to be commercially exploited but were to contribute to conservation of soil and the environment and meet the subsistence needs of local people. However, this approach was largely driven by the tenets of involving local communities in forest management and meeting their needs rather than securing the provision of ecosystem services. Yet it did open the way for correcting the market and policy failures related to ecosystem services, albeit indirectly. The recent policy, the NAPCC, has recognized the fact that climate change may 'alter the distribution and quality of India's natural resources and adversely affect the livelihood of its people'. Among its guiding principles is 'engineering new and innovative forms of market, regulatory and voluntary mechanisms to promote sustainable development' (Government of India 2008). Each of India's 35 states and union territories has been asked to prepare a state-level action plan as an extension of the NAPCC contextualized within local governance constraints (INCCA 2010; Smith 2014). Acknowledging the challenge due to climate change and the commitment of the government to address these, the union Ministry of Environment and Forests was renamed as Ministry of Environment, Forests and Climate Change. The Ministry on October 14, 2009 launched the Indian Network for Climate Change Assessment (INCCA). The INCCA was conceptualized as a network-based scientific programme designed to assess the drivers and implications of climate change through scientific research, and develop decision support systems and capacity for management of climate change related risks and opportunities.

Through the National Mission for Sustaining the Himalayan Ecosystem (NMSHE), the NAPCC recognizes the loss of ecosystem services of the region and its vulnerability to climate change and aims to conserve biodiversity, forest cover, and other ecological values of the Himalayas. A detailed analysis of the key features, strengths, and weaknesses of the policies impacting the Himalayan region has been provided in Table S1.

3. 2. Inter-sectoral legislative measures

The efforts of the forest department and the rural department to achieve inter-sectoral cooperation for managing natural resources, particularly in hill areas, resulted in the implementation of the Integrated Watershed Development Program (IWDP), which aimed at economic improvement of the local communities and protection of watersheds. The Guidelines for Watershed Development, 2000 covered the various watershed development schemes of the Ministry of Agriculture and the Ministry of Environment and Forests & Climate Change. The common guidelines thus propagated the holistic area-oriented Integrated Watershed Development (IWD) involving comprehensive treatment plans including soil and moisture conservation, water harvesting structures, horticulture and pasture development, and upgrading of existing common property resources. The IWD recognizes the multiple functionality of the watersheds, involves local people in the decision making process, ensures equitable access to resources, and promotes multi-layered and multi-stakeholder involvement; yet it does not address the uncertainties due to climate change and does not account for settling of rights in places where protected areas were created. The implementation of recent policies such as the NEP, National Biodiversity Action Plan (NBAP) and the NAPCC hinges on substantial inter-sectoral coordination.

3. 3. Efficacy of policy instruments in ecosystem service management

The Indian environmental and forest policy has been modified from time to time to adapt it to changing political–economic conditions. It has substantially contributed towards minimizing environmental degradation and maintaining the ecological integrity of natural systems. While the policies of the Production Era were largely focused on marketable goods such as timber and non timber forest products (NTFPs) provided by natural ecosystems, those of the Protection Era were largely regulatory and focused on a ‘hands off’ approach as far as natural ecosystems were concerned (Figure 2). In the policies promulgated during these two periods, informatory and market instruments remained in the backseat. In the IFA, policy implementation was in the form of levying duty on timber and forest produce. A clear mention of ecosystem services and well-defined rules for protecting and enhancing them came only with the NEP. All subsequent action plans and programs of the Indian Government have identified maintaining the sustainability of ecosystem goods and services as being their primary agenda. However, the need for a concerted policy focus on the Himalayas due to their ecological characteristics, human interface, and vulnerability to climate change, was addressed only by the NAPCC.

3. 4. Policy as informatory instruments

The NFP 1952 was the pioneer law that recognized the Himalayas as set of complex and interlinked ecosystems. It also recognized the importance of forests for continued provision of water and for human well-being. However, till 1988, the laws acknowledged only timber and NTFPs (goods) and their contribution to human well-being. The NFP, 1988 recognized the provision of both goods and services by forests. Except for the NEP and the NAPCC, the policies have remained silent on the linkages between the ecological health of the Himalayas, climate change, and human well-being.

It is clear that none of the policies recognized the multifunctional aspects of the Himalayas and the challenges of the impacts of climate change on them or related opportunities. The NAPCC has provisions for sustaining the Himalayan region through conservation of biodiversity and restoration of the forest cover and other ecological values. The NBAP drew attention towards valuation of ecosystem services provided by natural ecosystems and suggested the use of valuations in national accounting and decision making processes (Table S2).

3. 5. Policy as market instruments

MBIs have been used in Indian forest sector laws since 1927, when the IFA made provisions for levying duty on forest produce in transit. The WPA provides a comprehensive list of wild plants and animals that cannot be traded. The NFP, 1988, Biological Diversity Act, 2002 (BDA), NEP, NBAP, and NMSHE provide measures for reducing the environmental impacts on and unsustainable use of ecosystem goods and services. These legislative measures emphasize the need for incorporating the costs of depletion of natural resources in the decisions of economic actors to reverse the tendency to treat these resources as ‘free goods’ and to pass the costs of degradation to other sections of society or to future generations thus integrating environmental concerns in economic and social development.

The NFP, 1988, BDA, NEP, and NBAP are legislative and guiding measures for ensuring equitable incentive sharing. The NFP, 1988 encourages substitution of wood and efficient utilization of forest produce, including non-wood forest products, to meet national needs. It is now increasingly recognized that efficiency in the production and use of goods and services can be improved by having a proper mountain-specific value chain analysis of a mountain ecosystem's goods and services, such as medicinal and aromatic plants and livestock products (Hoermann et al. 2010; Badola et al. 2011). The NEP and NBAP aim to ensure efficient use of environmental resources by incorporating economically feasible and socially acceptable incentives such as value addition and direct markets. The NBAP provides examples of approaches incorporating value chain analysis and value addition in attaining sustainable development and economic uplift of local communities (Table S2).

3. 6. Policy as regulatory instruments

The IFA and the WPA advocated limited and restricted use of forest and natural resources to ensure the protection of natural resources. The policies emerging from the forestry sector have laid particular emphasis on maintaining the integrity of ecosystems by containing any destructive activity, such as grazing, within limits. The National Forest Policies of 1952 and 1988 provide for maintaining tree cover on the hill and non-hill regions of the country through afforestation plans. The FCA has a provision of imposing penalties for contravention of its provisions through imprisonment. The EPA lays down emission standards. The 'polluter pays' principle emerges in the EPA, wherein a person responsible for a discharge of an environmental pollutant exceeding the prescribed limits is bound to pay for the remedial measures incurred during the abatement of the pollutant. The BDA ensures regulated access to biological resources by levying charges and mandating permissions for accessing or collecting biological resources for commercial purposes. The NEP provides for regulatory reforms: revisiting the policy and legislative framework to follow a holistic and integrated approach to the management of the environment and natural resources; inclusion of environmental considerations in sectoral policymaking; and strengthening of relevant linkages among various agencies at the central, state, and local self-government levels charged with the implementation of environmental policies. It recommends the implementation of multi-stakeholder partnerships involving the forest department, land-owning agencies, local communities, and investors, with obligations and entitlements clearly defined for each partner (Table S2).

3. 7. Regulation of property rights

Previous legislative measures, such as the Indian Forest Policies of 1894 and 1952 and the IFA governed as they were by colonial and commercial interests, failed to address equitable access to the Himalayan resources since these measures brought land resources under government rule and ownership, alienating local communities. The National Commission on Agriculture, 1976, recommended that a social forestry program be promoted to meet the needs of user groups and provided for differential institutional arrangements for different stakeholder groups outside the limits of reserved and protected forests. These recommendations are reflected in the forest policies framed in1988 and afterwards.

Regulation and clarification of property rights (ownership and use rights) are considered crucial when dealing with the issue of market failure arising due to the notions of 'free goods' and 'easy access'. Nonetheless property rights, particularly the usage rights of local communities, have remained ambiguous in almost all the policies although the FCA and NEP provide for legal recognition of traditional entitlements of forest-dependent communities. The FCA prohibits interference with the rights of local communities, such as *Nistar* rights (land set apart to meet the requirements of fuel, fodder, timber, and other necessities) (Ramanathan 2002) or concessional use rights provided under the IFA. The BDA and NEP provide for securing the intellectual property rights of conservers of biological resources and local communities, respectively (Table S2).

The Forest Rights Act, 2006 (FRA) of the Ministry of Tribal Affairs seeks to clarify the rights of forest-dwelling communities. Contradictions and a lack of coherence between the objectives of the policies of the Ministry of Environment and Forests and the Ministry of Tribal Affairs have led to more confusion. The National Forest Commission, 2003 is of the opinion that recognition of the FRA will be harmful to the interests of forests and the ecological security of the country- it would bad in law and would be in open conflict with the rulings of the Supreme Court in 2000. Legislation therefore needs to be framed to provide forest-dwelling communities a right to a share of forest produce on an ecologically sustainable basis.

4. Discussion and conclusions

The NFP, 1952 was a pioneer in recognizing the link between forests, denudation of the Himalayas, and their contributions to human well-being. Therefore, it advocated maintaining 66% of the Himalayas under tree cover. Yet the need to place a market value on goods and services provided by natural ecosystems received attention through the NEP and NBAP only when these became buzzwords. The NEP echoed the need to include natural resource accounting in economic decisions, and the NBAP called for valuation of biodiversity as an integral part of pre-appraisal of projects. But most conservation plans focus on biodiversity and ignore the importance of ecosystem services (Singh 2002). Using the biodiversity approach may neglect areas that are degradation prone and are crucial for human welfare. However, to adapt and mitigate environmental degradation and climate change impact, policies based on prevailing scientific information are needed (Hertin et al. 2007; Eriksson et al. 2009).

The lack of understanding regarding the role of the Himalayas in providing ecosystem services and their contribution to human well-being has created an information gap about the opportunity costs of putting land to different uses, *viz.* conservation, agriculture, development, and tourism. To manage or regulate ecosystem services, it is important to have information about their quantity, quality, and economic worth (PCAST 2011). Resource uses create markets, and vice versa, and pricing and incentive mechanisms regulate these processes (TEEB 2010). Although putting a price on ecosystem services may not be enough to ensure their sustainability, this step may modify 'everyday behaviour and decisions toward a future in which nature is no longer seen as a luxury we cannot afford, but as something essential for sustaining and improving human well-being everywhere' (Daily et al. 2009).

Our analysis reveals that the Indian legislative measures and policy have so far been regulatory in nature. It was more prominent in the policies of the Production and Protection eras, which aimed at controlling the forest and forest produce to derive the maximum revenue and conserving them through a conventional 'isolationist approach' (Pretty & Pimbert 1995). The policies of the Community Participation era had informatory and market instruments to some extent. It is only in the recent era of Climate Change and Globalization that all the three instruments are being addressed, albeit the focus remains regulatory. Property rights, particularly usage rights of local communities, have remained ambiguous in almost all the policies, although the NEP provides for legal recognition of traditional entitlements of forest-dependent communities. None of the earlier policies addressed the issue of differential institutional arrangements to manage different ecosystems or the issues of climate change. For sustainable environmental governance, the informatory, regulatory, and market instruments need to have positive synergistic interactions. Because of the cross-cutting nature of ecosystem services, they are not confined to a single subject or a single administrative agency, department, or ministry; their management and sustainability require national commitments and a policy portfolio approach combining several measures (Gunningham & Young 1997; Dernbach & Mintz 2011; Ring & Schroter-Schlaak 2011**)**. In the context of the Himalayas, the above is reflected in the NAPCC through the NMSHE that proposes to network knowledge institutions to develop a coherent database on scientific and social dimensions of conserving the Himalayas; detect and decouple natural and anthropogenic causes of environmental change; assess the consequences of climate change and study traditional systems for community's adaptation to it, develop sustainable tourism and resource development; raise awareness among stakeholders in the region; assist states in the Indian Himalayan region with informed actions; and develop regional cooperation with neighboring countries (Government of India 2010; Smith 2014). However the success of implementation of NMSHE remains to be seen.

To achieve the goals of biodiversity conservation and ecosystem service provision, policies need combinations of instruments that protect natural ecosystems through direct regulation (or command-and-control), economic (or price-based) instruments that provide positive incentives to promote the compatibility of use with biodiversity conservation, and information provision (or moral suasion). Given the multiple uses and stakeholders in the Indian Himalayas and the off-site nature of the ecosystem services, a complementarity of instruments and an ability to address the consequences of local decisions on distant ecosystem services are essential (Seppelt et al. 2011; Balthazar et al. 2015). Acts, such as the IFA and WPA that are regulatory in nature are important for securing a safe minimum standard for biodiversity conservation and ecosystem service provision. However, given the antagonism generated due to their regulatory nature and to address the opportunity costs of ecosystem service provision and to provide information that may lead to motivation and self-regulation, effective implementation of policies (NFP, 1988; NEP; NBAP; BDA; NMSHE) that have market-based and informatory instruments becomes important. Policy mixes are even more relevant in sustained provision of ecosystem services because multiple sector policies come into play, be it in a synergistic way or through adverse effects (Ring & Schroter-Schlaak 2011; Ring et al. 2011; Andrés et al. 2012).

The integration of conservation into decision making processes will be aided by, among others, moving from confrontation to participatory efforts seeking a wide range of benefits and thereby developing a broader vision for conservation (e.g. Theobald et al. 2005; Manning et al. 2006; Goldman et al. 2007; Pejchar et al. 2007). This vision should be able to provide space for community-based self-organized systems for biodiversity conservation to co-exist along with state-imposed policies and take lessons from other countries (e.g. Ostrom et al. 1999).

The emerging policy framework for the Himalayas needs to address the ecological issues and human well-being in the face of growing anthropogenic pressures and climate change impacts, and develop the stakes of local communities in the conservation and maintenance of ecosystem services by promoting an enabling governance environment in the region.

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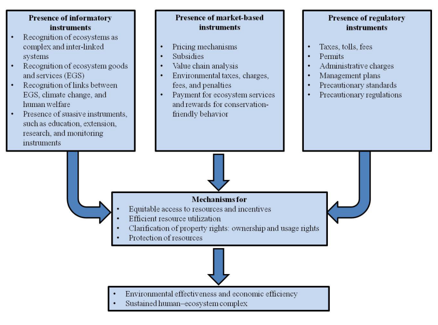
Table 1. List of environmental acts and policies of India examined for this analysis

Acts and policies	Year of enactment	Abbreviation
The Indian Forest Act	1927	IFA
The National Forest Policy	1952	NFP, 1952
Forest (Conservation) Act	1980	FCA
National Forest Policy	1988	NFP, 1988
Wildlife (Protection) Act	1972	WPA
Biological Diversity Act	2002	BDA
Environment Protection Act	1986	EPA
National Environment Policy	2006	NEP
National Biodiversity Action Plan	2008	NBAP
National Action Plan on Climate Change	**2008**	NAPCC


Presence of informatory instruments
Recognition of ecosystems as complex and inter-linked systems
Recognition of ecosystem goods and services (EGS)
Recognition of links between EGS, climate change, and human welfare
Presence of suasive instruments, such as education, extension, research, and monitoring instruments
Presence of market-based instruments
Pricing mechanisms
Subsidies
Value chain analysis
Environmental taxes, charges, fees, and penalties
Payment for ecosystem services and rewards for conservation-friendly behavior
Presence of regulatory instruments
Taxes, tolls, fees
Permits
Administrative charges
Management plans
Precautionary standards
Precautionary regulations
Mechanisms for
Equitable access to resources and incentives
Efficient resource utilization
Clarification of property rights: ownership and usage rights
Protection of resources
Environmental effectiveness and economic efficiency
Sustained human–ecosystem complex

Regulatory	**National Forest Policy, 1952** Maintaining 66% of the Himalayas under tree cover **Indian Forest Act, 1927** Creation of reserve, village, and protected forests; imposing duties and penalties on forest produce	**Environment Protection Act 1986** Lays down procedures and standards for emissions and provision for eco-sensitive zones **Forest (Conservation) Act, 1980** Provision of penalty for contravention of the provisions of the act **Wildlife (Protection) Act, 1972** Provides protection to flora and fauna	**The Biological Diversity Act, 2002** Makes obtaining permission and paying fee for accessing biological resource compulsory **National Forest Policy, 1988** Recommends maintaining two-thirds of hill areas under forest cover	**National Action Plan on Climate Change, 2008** Aims at tax reforms, strengthening existing environmental regulations and introducing new ones **National Biodiversity Action Plan, 2008** Aims at strengthening and integrating existing conservation plans **National Environment Policy, 2006** Provides for regulatory reforms and monitoring of compliance
Market based	**Indian Forest Act, 1927** Levying of duties on timber and forest produce in transit		**Biological Diversity Act, 2002** Payment of fair and equitable benefits to the conservers of biological resources **National Forest Policy, 1988** Recommends sharing of incentives arising from community participation with local communities	**National Action Plan on Climate Change, 2008** Aims at reforming markets, pricing mechanism **National Biodiversity Action Plan, 2008** Calls for assigning market value to goods and services and inclusion of natural resource accounting in economic planning **National Environment Policy, 2006** Calls for eco-labelling, value chain analysis, and enhance market access
Informatory	**National Forest Policy, 1952** Recognizes the importance of forests in maintaining physical condition	**Environment Protection Act, 1986** Recognizes links between components of ecosystems	**Biological Diversity Act, 2002** Provides for research, training, and public education **National Forest Policy, 1988** Envisages need for forest education, extension, research, and monitoring	**National Action Plan on Climate Change, 2008** Calls for promoting environmental awareness, research, and monitoring **National Biodiversity Action Plan, 2008** Calls for promoting and strengthening ongoing education, training, and extension activities **National Environment Policy, 2006** Calls for developing publicly accessible environmental information
	Production Era	**Protection Era**	**Community Participation Era**	**Climate Change and Globalization Era**

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Review Paper

A review of the methods available for estimating soil moisture and its implications for water resource management

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SUMMARY

The maintenance of elevated soil moisture is an important ecosystem service of the natural ecosystems. Understanding the patterns of soil moisture distribution is useful to a wide range of agencies concerned with the weather and climate, soil conservation, agricultural production and landscape management. However, the great heterogeneity in the spatial and temporal distribution of soil moisture and the lack of standard methods to estimate this property limit its quantification and use in research. This literature based review aims to (i) compile the available knowledge on the methods used to estimate soil moisture at the landscape level, (ii) compare and evaluate the available methods on the basis of common parameters such as resource efficiency, accuracy of results and spatial coverage and (iii) identify the method that will be most useful for forested landscapes in developing countries. On the basis of the strengths and weaknesses of each of the methods reviewed we conclude that the direct method (gravimetric method) is accurate and inexpensive but is destructive, slow and time consuming and does not allow replications thereby having limited spatial coverage. The suitability of indirect methods depends on the cost, accuracy, response time, effort involved in installation, management and durability of the equipment. Our review concludes that measurements of soil moisture using the Time Domain Reflectometry (TDR) and Ground Penetrating Radar (GPR) methods are instantaneously obtained and accurate. GPR may be used over larger areas (up to 500 × 500 m a day) but is not cost-effective and difficult to use in forested landscapes in comparison to TDR. This review will be helpful to researchers, foresters, natural resource managers and agricultural scientists in selecting the appropriate method for estimation of soil moisture keeping in view the time and resources available to them and to generate information for efficient allocation of water resources and maintenance of soil moisture regime.

Contents

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1. Introduction

Soil moisture is the content of water in the soil, held in the spaces between soil particles (Ali, 2010). It represents a small fraction (0.15%) of the globally available freshwater (Dingman, 1994) but is an influential store of water in the hydrologic cycle and is of fundamental importance to many hydrological, biological and biogeochemical processes. Soil moisture modulates interactions between the land surface and atmosphere, thereby influencing the climate and weather (Delworth and Manabe, 1993; Jung et al., 2010; Mittelbach et al., 2012) and is important in determining the rainfall-runoff response of catchments, especially where saturation excess runoff processes are important (Wei, 1995). The maintenance of elevated soil moisture is an important ecosystem service of the natural ecosystems; a failure in its management may lead to desertification (MEA, 2005a). The availability of moisture in soil is essential for nutrient cycling, a pre-requisite for primary production. Soil moisture affects the land evapotranspiration which is a central process in the climate system and a nexus of the water, energy and carbon cycles (Wan et al., 2007; Garten et al., 2009; Holsten et al., 2009; Jung et al., 2010; Falloon et al., 2011). Maintenance of such related ecosystem services enhances the productivity of natural ecosystems (Betts, 1999) and helps to sustain biodiversity (Pielke et al., 2002; Rhymer et al., 2010). Soil moisture retention is also an important determinant of water availability in agroecosystems (Power, 2010).

The chemical and physical properties of a soil, such as alkalinity, acidity, field capacity, wilting point, soil water potential and soil matric potential (Table 1) determine the quality and productivity of the soil (Burk and Dalgliesh, 2008; SAI, 2010). Soil moisture is the main source of natural water for agriculture and natural vegetation and influences a variety of processes related to plant growth and (Rodriguez-Iturbe, 2000) agricultural production, as well as a range of soil processes (White, 1997). Changes in the hydrological regime resulting from climate alterations, especially with regard to water availability and quality, are affecting society more than any other change (Schroter et al., 2005; Fraiture et al., 2008; Madani, 2010) with 1.2 billion people worldwide already living in areas of acute water shortage (Mayers et al., 2009). Human migrations due to desertification, land degradation and climate change may affect between 50 million and 1 billion people by 2050 and displace more than half the expected human population of the world by 2030 (IPCC, 2007; UNWWDR, 2009). Therefore, the conditions and accessibility of the soil moisture will decide the fate of water allocation for various human needs, including domestic, agricultural and industrial uses (MEA, 2005b).

According to the United Nation Convention to Combat Desertification (UNCCD), understanding long term negative effects of improper management on soil ecosystems causing reduced structural stability of the ecosystems, availability of important nutrients and the water holding capacity of the soil is needed to prevent desertification (Prince et al., 2007; Sivakumar, 2007). Soil moisture information is valuable to a wide range of agencies concerned with the weather and climate, runoff potential and flood control, soil erosion and slope failure, reservoir management, geotechnical engineering and water quality (NASA, 1999). Knowledge of the spatio-temporal variability and the patterns of soil moisture distribution at watershed level is helpful in estimating the rates of soil erosion and release of sediments in rivers, which are important for sharing limited resources during crises (Gleick, 1998; Borga et al., 2007). Information gaps exist with regard to determining those situations in which agriculture, plantations and natural forests enhance the water yielding capacities of ecosystems (FAO, 2007; Thompson et al., 2009). The need for accurate measurement of soil moisture at spatio-temporal scales for hydrologic, climatic, agricultural and domestic applications over time has led to the development of different methods of determination of soil moisture content (Minet et al., 2011, 2012). However, the large heterogeneity in the spatial and temporal distribution of soil moisture at the landscape level and the lack of standard methods to estimate this property limit its quantification and use in research (Engman and Chauhan, 1995; Western et al., 2002; Mittelbach et al.,

Table 1
The properties of soil that are influenced by soil moisture content and vice versa.

Soil property	Definition	References
Field capacity	Field capacity is the amount of water a soil can hold against gravity, i.e. volume of water retained after drainage due to gravity from a thoroughly saturated soil	Burk and Dalgliesh, 2008; Kabat and Beekma, 1994; Duryea and Dougherty, 1991
Permanent wilting point	The permanent wilting point is the soil moisture content at which plants that have wilted during the day will not regain turgor at night in a saturated atmosphere	Werner, 2002; Kabat and Beekma, 1994; Duryea and Dougherty, 1991
Available water	The amount of water held by a soil between field capacity and wilting point is defined as the amount of water available for plants	International Atomic Energy Agency, 2008; Kabat and Beekma, 1994
Soil water potential	The soil water potential, also called the soil tension, is the energy status and describes how tightly the water is held in the soil	Ali, 2010; Huang et al., 2010; Werner, 2002
Soil's porosity	A soil's porosity and pore size distribution characterize its pore space, that portion of the soil's volume that is not occupied by or isolated by solid material	Nimmo, 2004; Robock et al., 2000
Soil matric potential	Soil matric potential is the portion of the total water potential due to the attractive forces between water and soil solids as represented through adsorption and capillarity. It is always negative in nature and is also called the soil moisture tension	Ali, 2010; Huang et al., 2010
Soil alkalinity	Soil alkalinity is associated with the presence of sodium carbonate (Na_2CO_3) in the soil, either as a result of natural mineralization of soil particles or brought in by irrigation and/or floodwater	Merry et al., 2002
Soil acidity	Soil becomes acidic due to oxidation of the pyritic minerals in it. Un-drained soils containing pyrites need not be acid, and they are called potential acid sulfate soils	Merry et al., 2002

2012). Numerous methods are available for estimating soil moisture in different landscapes (Tables S1, S2); however, consolidated information on their advantages and limitations is lacking. This review aims to (i) compile the available knowledge on methods for soil moisture measurement at the landscape level, (ii) compare and evaluate the available methods on the basis of various common parameters, namely resource efficiency, accuracy of results and spatial coverage, and (iii) identify the method that will be most useful for forested landscapes in developing countries. Regular and periodic soil moisture estimation will help identify priority areas for conservation where there are ‘trade-offs’ or ‘win–win’ association between ecosystem services and to establish payments for watershed services (Jackson et al., 2005; Carpenter et al., 2006; Fisher et al., 2009). This review will be helpful to researchers, foresters, natural resource managers and agricultural scientists in selecting the appropriate method for estimation of soil moisture keeping in view the time and resources available to them in order to enhance the productivity of the land and manage watersheds to help coordinate relief efforts at times of droughts or inclement conditions due to climate change and to redirect policy implementation (Mayers et al., 2009).

2. Methods

Scientific databases such as SciVerse Scopus, ScienceDirect, JSTOR, and Google Scholar were searched using the keywords methods of soil moisture estimation, UNCCD, payment for ecosystem services, gravimetric methods, use of neutron probe, time domain reflectometry, tensiometers, remote sensing for soil moisture estimation, capacitive sensor, gypsum blocks for soil moisture, pressure plate apparatus and ground penetrating radar to obtain an overview of the different methods used to measure soil moisture. Peer reviewed journals such as Journal of Hydrology, Hydrological Processes, Remote Sensing of Environment, Water Resource Management, Ecological Economics, Water Resource Research, Environmental Science and Policy and Science were consulted. Terms such as methods of soil moisture estimation, UNCCD, payment for ecosystem services, gravimetric methods, use of neutron probe, time domain reflectometry, tensiometers, remote sensing for soil moisture estimation, capacitive sensor, gypsum blocks for soil moisture, pressure plate apparatus, and ground penetrating radar were sought in the keywords and abstracts of published scientific papers while browsing.

The available methods were evaluated and a matrix was developed following Qureshi et al. (2012) to compare these on the bases of cost effectiveness, accuracy, spatial scale, response time and the measured parameter (Baker, 1990; Mittelbach et al., 2012; Muñoz-Carpena, 2012) (Table 2). For this matrix, *cost effectiveness* is defined as the comparative cost involved in the purchase, operation and maintenance of the apparatus used for a particular method; *accuracy* refers to the degree to which results are free from instrumental errors (error < ±0.01 $ft^3\ ft^{-3}$; Muñoz-Carpena, 2012); *spatial scale* is the geographic area covered (point readings *vs* larger areas); *response time* refers to the time taken to generate one reading of soil moisture content ; and *measured parameter* refers to the surrogate parameters measured to estimate the soil moisture content.

3. Review of methods used for estimation of soil moisture

Soil moisture measurements are difficult to carry out on a consistent and spatially comprehensive basis (Bindlish et al., 2006). Non-destructive methods that can be used to directly estimate moisture content and give precise results with higher accuracy and resolution are required to enhance our understanding of water movement in soil and to determine the water content in it (Nissen et al., 1998; International Atomic Energy Agency, 2008). The available methods can be classified into two categories: (i) direct methods and (ii) indirect methods (Table 2). In direct methods, the soil moisture is determined using the difference between the weights of a soil sample before and after it is dried; in indirect methods, measurements are made through calibrations against other measurable variables that vary with soil moisture content (Evett and Parkin, 2005; Muñoz-Carpena, 2012). The only direct method is the gravimetric method or thermostat–weight technique; all others fall in the category of indirect methods. Except for remote sensing, all the methods used for soil moisture estimation are ground based. The various available methods are discussed along with their advantages and their limitations in the following (Table S2).

3.1. Ground based techniques

Ground based techniques are techniques of soil moisture estimation in which the instrument is in direct contact with soil particles. Such techniques provide more precise data. The instruments can be accurately calibrated, give depth wise measurements of soil moisture and can be logged at any time scale, but only point measurements are taken and this makes spatial interpretation difficult (Western et al., 2002). Different ground based techniques are discussed below.

3.1.1. Gravimetric method or thermostat–weight technique (oven drying and weighing)

This method is widely used for determining soil moisture content (Schmugge et al., 1980). It involves oven drying a soil sample of known volume at 105 °C for 24 h. The water content is calculated by subtracting the oven dry weight from the initial field soil weight (Lunt et al., 2005). The moisture content can be expressed in terms of percent water by volume or inches of water per foot

Table 2
Comparison of different methods used for estimation of soil moisture based on the identified criteria.

Methods		Criteria				Measured parameter
		Cost effectiveness	Accuracy	Spatial scale	Response time	
Direct methods	Gravimetric method	Economical	High	Limited	24 h	Mass water content
	Neutron probe	Expensive	High	Limited	1–2 min	Volumetric soil moisture content
	Time domain reflectometry	Economical	High	Limited	Instantaneous (~28 s)	Volumetric soil moisture content
	Capacitance and FDR	Expensive	Low	Limited	Instantaneous	Volumetric soil moisture content
	Tensiometer	Economical	High	Limited	2–3 h	Soil water potential
Indirect methods	Gamma ray attenuation	Expensive	Low	Limited	Instantaneous (~60 s)	Volumetric moisture content
	Remote sensing	Expensive	Low	Large	Instantaneous	Soil surface moisture
	Capacitance sensor method	Expensive	High	Limited	Instantaneous	Volumetric soil moisture content
	Gypsum block method	Economical	Low	Limited	2–3 h	Soil moisture tension
	Pressure plate method	Expensive	Low	Limited	Soil dependent	Soil water potential
	Ground penetrating radar	Expensive	High	Large	Instantaneous	Volumetric moisture content

of soil. This technique is cost effective, easy and accurate, but it is labor and time intensive, destructive and difficult to use with rocky soils (Stafford, 1988). The use of the gravimetric method is intricate with heterogeneous soil profiles (Schmugge et al., 1980).

3.1.2. Neutron probe technology

The equipment used in obtaining soil moisture content using neutron probe technology consists of a probe and an electron counting scaler connected by an electronic cable. High energy, fast moving neutrons are released into the soil by a radioactive source. The neutrons are slowed down by collisions with the nuclei of hydrogen atoms present in the molecules of water in the soil (Chanasyk and Naeth, 1996). Neutron probes are of two types: *depth probes*, which can be lowered to the soil depth at which the moisture content is to be measured and *surface probes* which can be used to measure the moisture content in the uppermost layer of soil (Schmugge et al., 1980). Neutron probes yield accurate results (Muñoz-Carpena, 2012) and are non-destructive. They may be used irrespective of the state of the water. The output from the neutron probe can be directly related to the soil moisture content (Chanasyk and Naeth, 1996). The measurement is related to the physico-chemical properties of the soil (Keys, 1989). The instrument requires a trained operator due to the use of the radioactive source and is potentially hazardous to health and the environment (Tarantino et al., 2008). The equipment is expensive and requires extensive soil specific calibrations, which limits its use. The depth resolution is inadequate, making soil moisture measurements difficult (Baker, 1990).

3.1.3. Time domain reflectometry

In Time Domain Reflectometry (TDR) the propagation velocity (v) of an electromagnetic energy pulse in the soil is determined. To determine v in soil, very short electrical pulses are sent through a metallic 2 or 3-rod probe. From the travel time t and the length l of the probe, which has been travelled along twice, the propagation velocity $v = 2l/t$ is calculated (Worsching et al., 2006). The velocity of the pulse changes with the change in soil moisture content due to the relatively large dielectric value of water (Malicki et al., 1992; Muñoz-Carpena, 2012). The pulse velocity in the probe is measured and correlated to the soil moisture. A lower velocity indicates a wetter soil. TDR has been used for measuring volumetric soil water content by several workers (Amente et al., 2000; Yu and Drnevich, 2004). TDR is a non-destructive and relatively less labor intensive technique; the instrument used is portable, easy to install and safe to operate. This technique allows reliable measurements of volumetric water content to be made within a short time (Benson and Bosscher, 1999). No soil specific calibrations are required (Topp and Davis, 1985; Zazueta and Xin, 1994; Ferrara and Flore, 2003). This technique gives accurate results within an error limit of ±1% and allows continuous measurements to be obtained over the full soil moisture range (Anisko et al., 1994; Chandler et al., 2004), along with measurements of the electrical conductivity of the soil (Robinson et al., 2003; Thomsen et al., 2007). However, the probe length influences the accuracy of moisture measurement (Richardson et al., 1992). TDR probes are environment sensitive. Thus the measurements could be erroneous due to gaps between the soil and probe (Zegelin et al., 1989; Ferre et al., 1998; Sakaki et al., 1998). It has limited applicability in highly saline soils (Ferrara and Flore, 2003).

3.1.4. Capacitance and frequency domain reflectometry

Frequency Domain Reflectometry (FDR) is similar to TDR, but FDR provides an estimate of the soil moisture content on the basis of a variation in the frequency of a signal due to the dielectric properties of the soil (Robock et al., 2000). The electrical capacitance of a capacitor that uses the soil as a dielectric depends on the soil moisture content. When the capacitor is coupled to an oscillator, forming an electrical circuit, changes in the frequency of the circuit indicate changes in the soil moisture content. The oscillator frequency is restricted within a certain range to determine the resonant frequency. This gives a measure of the water content of the soil (Muñoz-Carpena et al., 2004). This technique gives accurate results (±0.01 $ft^3\ ft^{-3}$) but requires soil specific calibration. The ambiguity in measurement of the automatic travel time of the instrument, restricted sphere of influence (about 1.6 in.), sensitivity to air gaps, soil salinity, temperature, bulk density and clay content limit the use of this method (Evett, 2003; Erlingsson et al., 2009).

3.1.5. Use of tensiometers

A tensiometer measures the capillary or moisture potential on the basis of the suction force exerted on water by soil (Schmugge et al., 1980). The instrument consists of an airtight water filled hollow tube with a permeable ceramic cup attached to the tube. The instrument is inserted into the soil, and a vacuum gauge is attached to the upper end. The porous ceramic cup is connected to the manometer, which can be buried at the soil depth where the moisture content is to be measured. The system is filled with water and sealed. Changes in the capillary tension in the soil are accompanied by a movement of water through the soil pores until the capillary tension inside the ceramic cup is equal to the tension outside it. The manometer measures the capillary tension. The water flow is determined by the change in volume required to produce the new reading of the manometer (Wallhan, 1939). This technique is non-destructive and cost effective. It is capable of determining the moisture distribution under both saturated and unsaturated conditions. Long term use is possible if the equipment is maintained properly (Zazueta and Xin, 1994). It can provide continuous measurements of soil moisture without causing disturbance to the soil (Wallhan, 1939). No complex electronics is involved, and the use of ethylene glycol water solution allows tensiometers to be used in cold regions. But tensiometers have been found to be unsuitable for measurements in dry soils (Mckim et al., 1976; Schmugge et al., 1980). The high maintenance requirements limit the use of this method in research (Dukes et al., 2010).

3.1.6. Gamma ray attenuation

This is a radioactive method capable of determining the moisture content in the upper soil layers (up to 1–2 cm). There is an assumption that the diffusion and gamma rays absorption are correlated with the density of the matter in its path, gravity being constant irrespective of the moisture content in the soil. The gamma transmission gives a measure of the change in wet density, which can give a direct estimate of the soil moisture content (Zazueta and Xin, 1994). The instrument comprises a source that emits gamma rays encircled by a collimator, detector and scaler (Schmugge et al., 1980). Gamma ray attenuation is a non-destructive technique capable of giving depth-wise soil moisture content readings and is unaffected by the state of moisture in the soil. It can be used with frozen soil (Goit et al., 1976). Using this method, any temporal change in the soil can be easily monitored (Schmugge et al., 1980). The high cost and difficulty of use limit the applicability of this technique in the field. In highly stratified soils, large variations in the bulk density and moisture content have been noticed while using this technique (Pires et al., 2005).

3.1.7. Use of capacitive sensors (probes)

The capacitance probe method is a non-destructive method in which the soil moisture content is determined by measuring the capacitance between soil implanted electrodes. The probe is subjected to excitation at a frequency to measure the dielectric constant. When the soil moisture is present as free water, the dielectric constant is directly related to the moisture content (Zazueta and Xin, 1994). With calibrations, a capacitance probe can provide the absolute value of the soil moisture at any depth as well as the moisture profile (Schmugge et al., 1980; Zazueta and Xin, 1994). Capacitance based sensors do not require maintenance after installation (Muñoz-Carpena et al., 2005; Dukes et al., 2010). The results are soil and temperature specific, requiring soil specific calibrations. Sensors are expensive and their long term sustainability is questionable (Zazueta and Xin, 1994; Pardossi et al., 2009).

3.1.8. Gypsum block measurement

A gypsum block is an electrochemical cell with a saturated solution of calcium sulfate serving as an electrolyte, placed at root zone depths. To determine the resistance between the electrodes, a small AC voltage is applied using a bridge circuit. Since the readings can be affected by the electrical conductivity of the soil, gypsum blocks are used as buffers against changing soil salinity. The blocks absorb moisture from the soil, and the electrodes in the blocks are used to measure the electrical conductance, which increases with the moisture in the blocks. These measured values are used to estimate the soil matric potential (Table 2) and soil moisture content (Werner, 2002). The technique is simple and inexpensive, with minimal maintenance requirements. The large sampling volume (up to 8 cm radius) is an advantage in field studies. The biggest limitation of this technique is the dissolution and degradation of the gypsum block (International Atomic Energy Agency, 2008) and need for recalibration with time (Bulut and Leong, 2008). The gypsum block is affected by salt and temperature, resulting in errors (> $\pm 0.01\ ft^3\ ft^{-3}$) in moisture estimation (Erlingsson et al., 2009). This method is unsuitable for sandy soils, where water drainage is fast (Zazueta and Xin, 1994).

3.1.9. Pressure plate method

The pressure plate method is generally used to estimate the field capacity, permanent wilting point and moisture content at different pressures. The apparatus consists of air tight metallic chamber with porous ceramic pressure plate (Madsen et al., 1986). The pressure plate and soil samples are saturated and are placed in the metallic chamber. The required pressure is applied through a compressor and the water from the soil sample, which is held at less than the pressure, trickles out of the outlet till equilibrium against applied pressure is achieved. The soil samples are oven dried for determining the moisture content (Rao et al., 2010). The apparatus is susceptible to errors at low water potentials (Bittelli and Flury, 2009). The method gives overestimates (Madsen et al., 1986).

3.1.10. Ground penetrating radar method

Ground Penetrating Radar (GPR) measurements are based on the transmission and reflection of an electromagnetic wave in the soil (Chanzy et al., 1996). The transmitter antenna of the radar systems generates radio-waves propagating in a broad beam (Reynolds, 1997). The receiver detects variations in the electrical properties of the sub-surface by detecting the part of the transmitted signal that is reflected (Du and Rummel, 1994). A number of radar antennas are moved over the ground surface simultaneously when assessing moisture content (Reynolds, 1997). GPR is a fast and non-destructive technique with high resolution that can penetrate beyond the surface layer and is capable of covering large areas (up to 500×500 m a day; Huisman et al., 2001) with differential hydrological conditions in a short time (Lunt et al., 2005). Soil volume estimations are relatively quick. This method bridges the gap between point measurements and remote sensing. The performance of GPR varies across soil types (Doolittle and Collins, 1995). Many soil types, due to their high electrical conductivity, are radar opaque and dissipate radar energy, thus restricting its use (Doolittle and Collins, 1995). Steep and rocky slopes limit its use due to the large sizes of the antennas. The use of GPR in forests is difficult because trees behave as reflectors generating erroneous data (Schrott and Sass, 2008).

3.2. Remote sensing

Remote sensing based methods include the use of satellites, radar (microwaves) and active and passive sensors (Puma et al., 2005). They provide an alternative tool for obtaining quick estimates of soil properties (Mattikalli et al., 1998) (Table S3). All parts of the electromagnetic spectrum can be used for sensing soil moisture remotely, but only the microwave region is most suitable for quantitative measurements (Engman and Gurney, 1991; Mattikalli et al., 1998) because the primary physical properties affecting the measurement are dependent on the soil moisture. Remote sensing of soil moisture is dependent on the electromagnetic energy either reflected or emitted from the soil surface (Schmugge et al., 1980). The radiation intensity varies with the soil moisture, which affects the soil dielectric properties and temperature. Remote sensing is most suitable for larger areas that need to be covered on a repetitive basis uniformly, but it is complex and costly. The uncertainty in the relationship between the brightness, temperature and soil moisture limits the accuracy (Wang and Qu, 2009). Estimation of soil water content in dense vegetation is difficult (Njoku and Entekhabi, 1996; Ulaby et al., 1996). The measurements obtained are averages, and there is inconsistency across pixels. The underlying heterogeneity observed at the land surface is therefore not detected (Famigliette et al., 1999; Weihermuller et al., 2007).

4. Discussion

Attempts have been made by several workers to review soil moisture measuring techniques (Lunt et al., 2005; Robinson et al., 2008; Vereecken et al., 2008; Erlingsson et al., 2009; Pan et al., 2010) (Table S1). However, the earlier reviews do not compare the methods based on the inputs required, spatial coverage and accuracy of results obtained. They do not conclude which methods are the best for soil moisture estimation in different landscape types. The choice of a method for soil moisture estimation depends on the application and the resource availability. While choosing a method one should consider characteristics such as the accuracy of the results, replicability, calibration requirements, spatial resolution, cost and ease in using the methods (Baker, 1990).

On the basis of the strengths and weaknesses of each of the methods reviewed we conclude that the direct method (gravimetric method) is accurate and inexpensive but is destructive, slow and time consuming and does not allow replications in the same location, thereby having limited spatial coverage. The suitability of each indirect method depends on several issues such as the cost, accuracy, response time, effort involved in installation, management and durability of the equipment (Muñoz-Carpena, 2012). The remote sensing method can be used to estimate soil moisture over a larger area, but the results are less accurate and need ground-truthing. It only gives information about the surface moisture content and cannot be used where there is thick vegetation. Remote sensing is expensive and at an intermediate stage of development in local scale monitoring (Ozdogan et al., 2010). Indirect methods such as Capacitance and Frequency Domain Reflectometry, Gamma Ray Attenuation and the Pressure Plate method yield less accurate results. They have limited spatial application and are expensive. However, all the indirect methods give instantaneous results, except the Pressure Plate method, which requires time according to the soil type. The use of gypsum blocks is economical, but the blocks are susceptible to dissolution after some time and have a low accuracy and spatial coverage. Tensiometer methods are economical and yield accurate estimates, but they are time consuming and have limited spatial applicability. The neutron probe and capacitance sensor methods give accurate results and require less time but are expensive and have limited spatial applicability. The applicability of the neutron probe and gamma ray methods is further limited due to the use of radioactive sources (Table S2).

TDR is an economical method. It yields accurate and instantaneous results, but it is appropriate only for smaller areas. The TDR technique uses a wide variety of probe configurations. Thus it does not need any soil specific calibration (Muñoz-Carpena, 2012). This technique can be used on steep and rocky slopes and in densely forested landscapes (Gray and Spies, 1994; Chen et al., 2009). Measurements made using TDR are relatively insensitive to the variations in mineral composition, temperature, and salinity in a wide range of soils (Topp and Davis, 1985; Roth et al., 1992). The TDR instrument is portable and therefore can be carried easily in the field (Table S2).

The GPR is non-destructive, accurate, easy, gives instantaneous results and can cover larger areas, but is expensive and sensitive to unwanted signals (noise) caused by various geological factors. The data do not need to be subject to complicated calculations and can often be interpreted in the field without any data processing (Do, 2003). The GPR data collected from closely spaced (less than 1 m) lines can be used to generate three dimensional views of radar data, greatly improving the ability to interpret subsurface conditions (USACE, 1995). However, GPR cannot be used on steep and rocky slopes and in forested landscapes. TDR can be used to obtain accurate results in these ecosystems (Pumpanen and Ilvesniemi, 2005) (Table S2). Thus our review concludes that both the TDR and GPR techniques are efficient at soil moisture estimation. The use of TDR is preferred over GPR in forested landscapes due to the portability of the instrument used in the former technique. Due to the accuracy of TDR measurements the results are used as reference points in several studies (e.g. Plauborg et al., 2005; Bogena et al., 2007; Mittelbach et al., 2011).

5. Conclusions

Soil moisture plays a decisive role in ecosystem level processes (e.g. Reynolds and Cunningham, 1981; Rhymer et al., 2010). In the recent years the pressure on water resource managers and policy makers is increasing for devising means to maintain soil moisture regime for maximizing productivity of natural and agricultural ecosystems. The development of policies related to maintain soil moisture system, hydrological research and water resource management require evidence based information on the spatio-temporal distribution of soil moisture in different land use/land cover types (Moran et al., 2004; Penna et al., 2009; Alexander et al., 2010; Sommer et al., 2011). The approach to measure soil moisture in different land use classes is expected to improve land-unit mapping, regional management planning, afforestation activities, agricultural planning (Adams and Evans, 1989; Merry et al., 2002) and contribute to understanding the reciprocal influence of land surface processes on the weather and climate change.

The applicability of the methods reviewed here is dependent on the landscape types and availability of resources, hence no single method can be used for all the situations. The present review can potentially be used to select the methods to measure the soil moisture in simulation and validation studies at regional and global scales. It will be of use to generate information for decision making for efficient allocation and distribution of soil moisture in different land use types, considering the variety of soil moisture research directions, practical applications and emerging trends as an ecosystem service. Although the review has examined a number of literature sources, it seems to be practically impossible to include all the publications on the topic. Besides, it is possible that some methods are only briefly referred. These gaps could be filled by subsequent contributions and there is a scope for further discussion about the current status of available knowledge on methods to estimate soil moisture and its relationship with other ecosystem services.

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Appendix A. Supplementary material

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Review

A review of protocols used for assessment of carbon stock in forested landscapes

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ABSTRACT

The Subsidiary Body for Scientific and Technical Advice of the UNFCCC is focused on methodological issues that include reference levels of CO_2 emissions from deforestations and forest degradations under Reduced Emissions from Deforestation and Forest Degradation (REDD). Quantification of forest carbon stock is a challenging task involving high degrees of uncertainty and discrepancies because of methods used. It is important that the REDD stakeholders be able to compare the REDD designs options, using standardized data. In this paper, we provide a review of the various methods used for estimation of above and below-ground biomass for carbon stock and soil organic carbon to help decide what would best suit different landscapes and regions so as to set standardized reference levels. Our review suggests that the 'forest yield method', 'biomass expansion factor' and 'Walkley–Black' methods are simple, time and cost effective and yield accurate results as the 'forest yield method' covers all strata of forest vegetation, 'biomass expansion factor' method can be directly applied to volume data and the 'Walkley–Black' method is rapid and requires minimal equipment. However, the effectiveness and feasibility of different methods may vary depending upon landscape and forest types.

1. Introduction

Around the world, policy makers are increasingly recognizing ecosystems as natural capital assets that supply life-support services. The condition and management of ecosystem services is a dominant factor influencing the prospects for reducing poverty. The challenge is to turn this recognition into incentives and institutions that will guide wise investments in natural capital on a large scale. Advances are required on three key fronts: the science of ecosystem functions and service mapping; the design of appropriate policy, and governance systems; and the art of implementing these in diverse biophysical and social contexts (Daily and Matson, 2008).

Changes in global and regional climates have been attributed to greenhouse gas emissions (GHGs) and forests provide large mitigation opportunities to stabilize GHG concentration (2–4 Gt C year^{-1}) in the atmosphere along with benefits such as biodiversity conservation and protection of ecosystem services and goods (Scholes and Noble, 2001; Lu et al., 2010). Deforestation contributes 12–17% of global GHG emissions (van der Werf et al., 2009). Thus, growing and maintaining forests is considered to be a cost effective option for mitigating global climate change (Zhang and Xu, 2003).

The Kyoto Protocol sets a collective global target of reducing GHG emissions by about 5% of 1990 levels by the first commitment period of 2008–2012 (UN, 1998). But efforts to curb deforestation and degradation have not yet been

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incorporated in the binding agreements to reduce GHG emissions such as the Kyoto Protocol or UN Framework Convention on Climate Change (UNFCCC, 2006). With increasing pressure on world's remaining forests, policy makers are now exploring means to incorporate prevention of forest carbon losses as a global climate agreement, and considering the inclusion of REDD in the UNFCCC post-Kyoto climate agreements (Murray et al., 2009). During the UN Climate Conference in Cancun (2010), it was recognized that nations should take urgent actions to cut down global GHG emissions, to hold the increase in global average temperature below 2 °C above pre-industrial levels. The carbon dynamics in terrestrial ecosystem is an integral component of global carbon budget and offers a potential measure to mitigate global warming and climate change (DeFries et al., 2000). Different forest types store different amount of carbon and changes in forest cover can be monitored to understand potentiality of forests as carbon sink (Dixon et al., 1994). Carbon stock monitoring approach is directly linked with biomass dynamics (Goetz et al., 2009). However, accurate information on forest biomass and its distribution is lacking (Djomo et al., 2011).

Forest carbon budget is of special interest as it is a large active carbon pool and offers a set of mitigation options (Heath et al., 1996). To understand carbon pool changes in forests, quantification of the biomass is a prerequisite. In the last few years, quantification of forest biomass and its carbon fixation has emerged as an important field of research (Usuga et al., 2010). Theoretical and empirical research has examined the technical aspects and limitations of various carbon stock assessment methods. However, consolidated information regarding the methods available for biomass estimation in different carbon pools in an ecosystem is lacking. The major carbon pools in a forest ecosystem are the living trees and the understory vegetation, litter and soil organic matter (Fig. 1).

Destructive and non-destructive methods are used to estimate forest biomass. Destructive sampling methods involve harvesting, drying and weighing. Dry biomass is converted to carbon content using a conversion factor (carbon content = 50% of biomass; Westlake, 1966). Though accurate, destructive methods are not preferred as they are expensive and cause damage to forest health (Nordh and Verwijst, 2004). Non-destructive methods are better, but no method can directly measure forest carbon stocks across landscapes (Gibbs et al., 2007). Consequently, efforts have gone into developing tools and models that can extrapolate destructive harvest data points to larger scales based on proxies measured in the field or obtained using remote-sensing instruments (Saatchi et al., 2007).

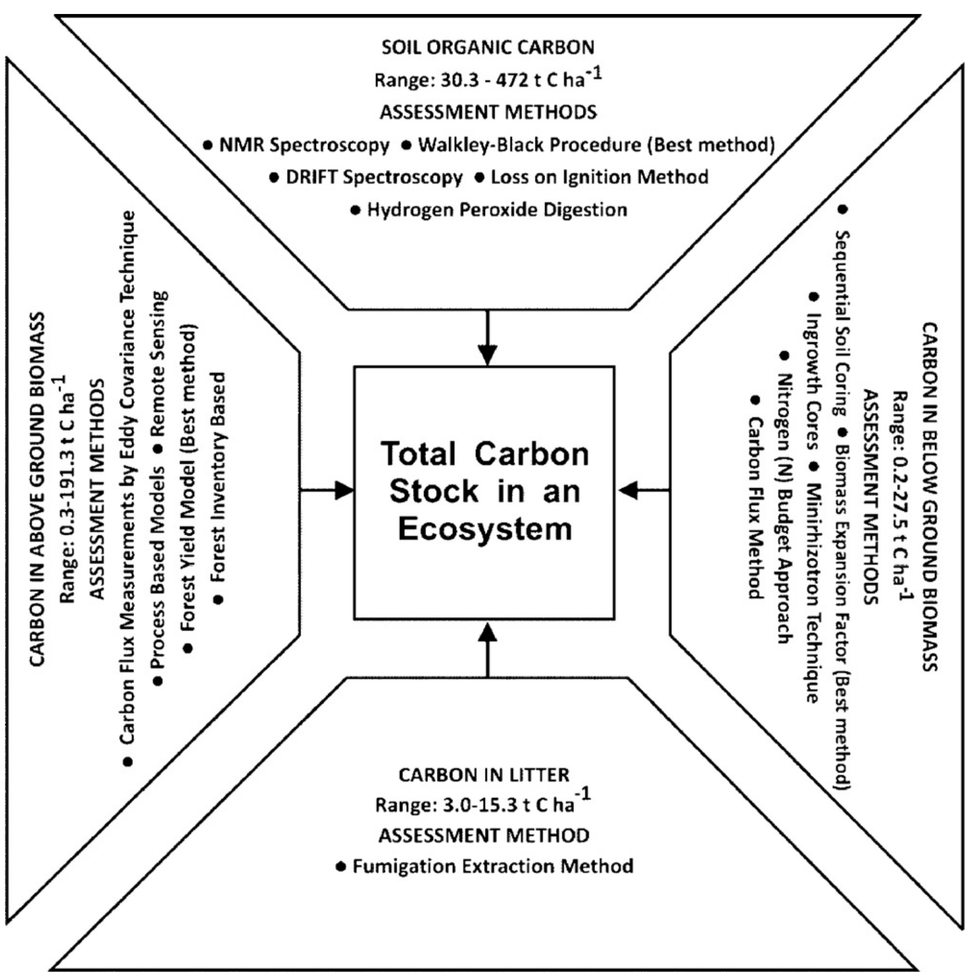

Fig. 1 – Representation of carbon pools in forested landscapes showing range of carbon stocks based on existing studies (supplementary online data).

This review aims to (a) compile and synthesize the current knowledge of available methods for carbon contents estimation in different pools in a forested ecosystem and (b) compare methods on the basis of operational ease, resource efficiency, accuracy, spatial scale, and strata coverage to help researchers and foresters particularly in developing countries, to choose the best, based on a discussion of their strengths and weaknesses. This analysis is intended for researchers, foresters and policy makers dealing with carbon stock estimation and its implications for local, national and global processes such as in REDD and REDD+.

2. Methods of review

Online scientific database such as 'ScienceDirect', 'JSTOR', 'Wiley Online Library', 'Google Scholar' were searched using the terms '*methods of carbon estimation*', '*REDD*', '*carbon stock*', '*carbon stock methods*', '*above ground biomass estimation*', '*below ground biomass estimation*' and '*soil organic carbon*' to obtain an overview of the various carbon protocols. When searched using '*above ground biomass estimation*', Google Scholar generated 217 results, '*below ground biomass estimation*' provided 13 results, '*soil organic carbon estimation*' yielded 24 results and '*carbon stock studies*' produced 7 results. Peer-reviewed journals such as '*Forest Ecology and Management*', '*Journal of Remote Sensing*', '*Global Change Biology*', '*Plant and Soil*', '*Science*' and '*Environmental Science and Policy*' were individually browsed using the IP addresses of their online database. While browsing, keywords and abstracts of research papers were scrutinized for terms such as '*methods of biomass estimation*', '*above ground biomass estimation*', '*below ground biomass estimation*', '*carbon stock*', 'REDD' and 'REDD+.'

A brief description of the methods adopted for forest carbon estimation and their advantages and limitations are summarized in Tables S1–S3 of supplementary online data. On the basis of a comparison of all the methods in terms of operational ease, cost effectiveness, accuracy, spatial scale and time efficiency, a matrix was prepared for each carbon pool (Tables 1–3). For this review, operational ease is defined as how easily data in the field can be collected without technical complications; cost effectiveness refers to the relative cost incurred in the use of a particular method; accuracy is defined as the degree to which results are error free; time efficiency is the time taken to gather and analyze data; spatial scale refers to the geographic area covered; and strata coverage refers to the application of a method to different vegetation strata in a forested ecosystem.

3. Comparison of methods of biomass estimation

3.1. *Above ground biomass (AGB) as carbon pool*

AGB consists of all biomass of living vegetation, above the soil (woody and herbaceous). Carbon stored in the AGB is directly impacted by deforestation and degradation. AGB is expressed as tones of biomass or t C ha^{-1} (IPCC, 2006) and is given highest importance in carbon inventory and in mitigation projects under the Kyoto Protocol (Ravindranath and Ostwald, 2008). Below Ground Biomass (BGB) and soil organic carbon accumulation is directly linked to the AGB dynamics. A comparative account of advantages and disadvantages of different methods of AGB estimation have been summarized in Table S1.

3.1.1. *Process based or physiological based model*

This model is based on the vital physiological processes contributing to the carbon balance of stand leaf photosynthetic efficiency, respiration, leaf area distribution, litter fall and mortality losses (Landsberg, 2003). Numerous models for forest growth have been developed (e.g. BIOMASS and FOREST-BGC), driven by simplified descriptions of physiological processes, providing insight into the underlying vital plant process and good estimates of growth and biomass productivity at various scales (Korol et al., 1996; Landsberg, 2003). However, since these are based on the fundamental causes of productivity, it is difficult to demonstrate accurate stand development (Monserud, 2003). Knowledge of important biological process and environmental data are required. Need for massive amount of environmental data and complex calculations limit their ability to scale up to the region or globe (Ståhl et al., 2004).

3.1.2. *Remote sensing based models*

Forest carbon stocks can be estimated using remote sensing instruments mounted on satellites or airborne platforms, but refinements are needed before routine assessments can be made at national or regional scales (DeFries et al., 2007). This method can neither measure forest carbon stocks directly nor understory and BGB; thus requires additional ground based data (Drake et al., 2003). Remote sensing can be used in association with process based models for carbon cycle monitoring (Cihlar et al., 2002). Some models developed in recent years are the Boreal Ecosystem Productivity Simulator for short term (Liu et al., 1997) and the Integrated Terrestrial Ecosystem Carbon model for long term monitoring (Chen et al., 2003). Remote sensing system relying on optical data is limited by cloud cover, but newer technologies, such as radar systems and LiDAR, can penetrate clouds and provide data day and night (Asner, 2001). The benefit of a satellite based approach is its potential to provide 'wall-to-wall' observation of carbon stock proxies and estimation over large areas using uniform method in a short time. However, errors arise due to mismatches between the field plots and satellite pixels (Ståhl et al., 2004).

3.1.3. *Carbon flux measurements using eddy covariance technique*

The exchange rate of carbon dioxide (CO_2) across the interface between the atmosphere and plant canopy is measured by the covariance between the fluctuation in vertical wind velocity and CO_2 ratio (Baldocchi, 2003). The vertical velocity of eddies must be known together with their CO_2 concentration. Fast sensors are needed as eddies move with high velocities giving site-specific estimates. The advantages are high resolution data over time and direct measurement of net changes in ecosystem productivity. This method is applicable for flat terrain and only when the environmental conditions are steady. Violation of these assumptions can cause errors in data interpretation. This method is complex and there are difficulties in estimating night-time fluxes (Baldocchi, 2003).

3.1.4. *Forest yield model*

This model is based on the stand density and tree growth and thus is tree and stand-specific (Gustavsen et al., 1998). Allometric equations are developed based on extensive measurements of foliage, branches, roots and stems of the felled trees (Ash and Helman, 1990) and provide detailed prediction of tree and stand dynamics covering entire vegetation strata. This method is referred to as 'empirical' since it cannot be linked to the underlying causes of productivity such as carbon and nutrient cycles and moisture regime. Although, it is cost effective but it is insensitive to environmental change, tedious and time consuming (Monserud, 2003).

3.1.5. *Forest inventory based approach*

Forest volume inventory data are a valuable source for biomass estimation, widely collected and available throughout the world, applicable to different species and site conditions (Schroeder et al., 1997). Forest inventories data are abundant, collected from sub-national to national levels using a planned sampling designed for population of interest. The approach is based on the use of existing measured volume estimates volume over bark per hectare converted to biomass density ($t\,ha^{-1}$) (Brown et al., 1989). It uses the National Forest Inventory (NFI) or other sampling network covering a wide range of conditions across a country or region. The output of the inventories is converted into biomass and carbon stock estimates (Phillips et al., 1998). The relationship between biomass and stand volume enables estimation of forest tree biomass at the national level from NFI data (Fang et al., 1998).

Among the different methods of AGB estimation forest yield method is accurate and effective in strata coverage, but is less time efficient. Eddy covariance and process based biomass estimation methods involve technical complications, whereas forest inventory and remote sensing methods are neither cost effective nor strata coverage efficient (Table 1).

3.2. *BGB as carbon pool*

BGB is biomass in living roots of trees excluding fine roots < 2 mm diameter (IPCC, 2006). It is an important component in carbon and nutrient cycling in forests, consisting of 20–26% of the total biomass (Cairns et al., 1997). Root production contributes to about half of the carbon being cycled annually in many forests and 33% of the global annual primary production (Jackson et al., 1997); however, estimation of root biomass is difficult and time consuming and the methods are not standardized (Cairns et al., 1997). There are direct and indirect methods for BGB estimation. A comparison of advantages and disadvantages of different methods of BGB estimation is summarized in Table S2.

3.2.1. *Sequential soil coring*

This is a common approach used for determining root production, mortality and net primary productivity (Vogt and Persson, 1991), suitable for measuring standing biomass and root production (Majdi et al., 2005). It requires repeated collection of soil samples of fixed volume using a soil corer, from which roots are extracted by washing over sieves, separated into living or dead, diameter classes and plant species and quantified in terms of dry weight or length. The difference in biomass produced between maximum and minimum fine roots, during a sampling year is measured (Vogt et al., 1998). To analyze the data, compartmental flow model or decision matrix method can be used (Persson, 1978) or all positive differences in root biomass between each sequence of sample dates can be summed. Error arises in separating roots into the living and dead categories, and the results are overestimated due to sampling errors (Sala et al., 1988).

3.2.2. *Ingrowth cores*

This method gives rapid and less laborious estimates of fine root production (Flower-Ellis and Persson, 1980). It involves removing roots from a fixed volume of soil and monitoring the re-growth of roots (O'Neill, 1994). Cores are removed from the soil and roots are either sieved or handpicked. The root-free soil is placed back in the soil, in a mesh bag. After a period of time, the mesh bag is removed from the soil and roots are again separated. This second sample of root biomass is an estimate of the amount of root biomass produced during the interval (Jordan and Escalante, 1980). This method can be used to estimate the relative growth and to study the effect of experimental manipulations on roots (Majdi et al., 2005), in agricultural as well as forest ecosystems, where root growth is rapid.

3.2.3. *Minirhizotrons*

It is a visual, non-destructive technique of monitoring roots over a period of time, where glass tubes fitted with miniature cameras are inserted into the ground to capture photographic images of fine-root growth at different depths (Hendrick and

Table 1 – Comparison of different methods for above ground biomass estimation for carbon stock measurement using identified criteria.

Methods	Operational ease	Cost effectiveness	Accuracy	Spatial scale	Time efficiency	Strata coverage
Process based	Complex	Expensive	Low	Limited	Efficient	Understory included
Remote sensing	Simple	Expensive	Low	Large area	Efficient	Understory excluded
Eddy covariance	Complex	Expensive	Low	Large area	Efficient	Understory included
Forest yield	Simple	Economical	High	Large area	Time consuming	Understory included
Forest inventory	Simple	Economical	Low	Large area	Efficient	Understory excluded

Pregitzer, 1992). The roots can be monitored through different seasons and phenological cycles. The installation of cameras requires high capital input but root parameters such as the spread depth, length, density and lateral roots can also be studied. The images obtained are difficult to analyze in the absence of appropriate algorithms (Vogt et al., 1996).

3.2.4. *Nitrogen (N) budget approach*

The nitrogen budget approach estimates the total mass of N allocated to fine roots as the difference between annual N uptake of vegetation and the annual allocation of this N to non-fine-root pools (Hendricks et al., 2006). Information is needed on the N inputs into ecosystem, N storage in plant tissue and N mineralization in the soil (Aber et al., 1985). This approach assumes that root production is driven by mineral soil N and can be determined from this single index. A few assumptions need to be satisfied for this approach to work *viz.* (a) there is no N re-translocation from roots, (b) there are steady-state conditions and (c) mineralizable N is totally taken up by plants. Some of the assumptions are not valid for all ecosystems due to differences in response of plant roots to low and high N levels (Vogt et al., 1990). Further, N does appear to be re-translocated from fine roots of some cold temperate conifers (Meier et al., 1985) other than pines (Nambiar, 1987). Steady-state conditions generally do not exist as microbes are effective competitors with plants for nutrients, and thus all mineralizable N in the soil is not taken up by plants (Ballard, 1979).

3.2.5. *Biomass expansion factor (BEF)*

The BEF is the ratio of total oven-dry AGB of trees with a minimum DBH (diameter at breast height) of 10 cm or more, to the oven-dry biomass of the inventoried volume (Brown, 1997). BEF and root-to-shoot ratios (*R*) are commonly used in converting standing volumes of timber into total carbon stocks. These factors are species and site-specific depending upon size and age that affects the biomass allocation strategies of tress (Levy et al., 2004). Thus they may not accurately reflect the true biomass of trees. BEF values are related to the corresponding biomass of the inventoried volume on the basis of generic equations (Brown and Lugo, 1992). In most cases, sample trees, should be destructively harvested to test their validity. BEF from inventories in tropical Asia, America and Africa range from 1.1 to 2.5. The advantage of using site specific BEF based on large number of trees and diameter classes is high accuracy and precise results (Brown, 1997).

3.2.6. *Carbon flux method*

This approach estimates BGB by using extensive databases existing around the world for soil respiration or CO_2 efflux from the soil (Vogt et al., 1998). The difference between the CO_2 efflux and aboveground litter-fall inputs provides estimates of total carbon allocation to roots (Raich and Nadelhoffer, 1989). The advantage is that belowground carbon is estimated by measuring aboveground parameters which are relatively easy to monitor. However, it gives only a rough estimate of the upper limit of the actual root production (Vogt et al., 1998).

The biomass expansion factor method is based on non-destructive sampling and is more accurate. Minirhizotron and carbon flux methods are less accurate and cost effective. The ingrowth core, sequential coring and nitrogen budget methods are time consuming and complicated and therefore least suitable for field data collection (Table 2).

3.3. *Carbon in litter*

Litter refers to the slow decomposing dead organic debris supplied by litter fall and dead plant parts. Litter accounts for 6–8% of plant biomass (Whittaker and Likens, 1973). Jenkinson and Powlson (1976) developed a fumigation–incubation procedure to estimate soil microbial carbon in which microbial carbon is made susceptible to mineralization following exposure to chloroform vapors, releasing CO_2. The amount of CO_2 produced following fumigation is proportional to the amount of microbial biomass originally present. Biomass mineralization is not 100% because decomposition is incomplete, and only a part is respired as CO_2. This method was modified into a fumigation–extraction technique (Sparling and West, 1988). Microbial model estimates do not provide direct measurements of the pool sizes and potential turnover rates of soil labile organic carbon (Jenkinson et al., 1987).

3.4. *Soil organic carbon (SOC)*

SOC is a mixture of dead plant residue in various stages of decomposition. Forest soil harbors *ca* 20% of world's carbon stock (DeGryze et al., 2004) representing short to long term carbon storage medium. Three techniques used for determining soil organic carbon are qualitative, semi-quantitative and quantitative techniques. A comparative account of advantages and disadvantages of different methods of SOC estimation is summarized in Table S3.

Table 2 – Comparison of different methods for below ground biomass estimation for carbon stock measurement using identified criteria.

Methods	Operational ease	Cost effectiveness	Accuracy	Spatial scale	Time efficiency	Sampling technique
Sequential coring	Simple	Expensive	Low	Limited	Time consuming	Destructive
Ingrowth cores	Simple	Economical	Low	Limited	Efficient	Destructive
Minirhizotron	Simple	Expensive	High	Limited	Efficient	Non-destructive
Nitrogen budget	Complex	Economical	Low	Limited	Efficient	Destructive
Biomass expansion	Simple	Economical	High	Limited	Efficient	Non-destructive
Carbon flux	Simple	Economical	Low	Limited	Efficient	Non-destructive

Table 3 – Comparison of different methods for soil organic carbon estimation using identified criteria.

Methods	Operational ease	Cost effectiveness	Accuracy	Time efficiency	Infrastructure requirements
NMR spectroscopy	Simple	Expensive	High	Time consuming	High
DRIFT spectroscopy	Simple	Expensive	Low	Efficient	High
Loss on ignition method	Simple	Economical	Low	Efficient	Low
Hydrogen peroxide digestion	Simple	Economical	Low	Efficient	Low
Walkley–Black procedure	Simple	Economical	High	Efficient	Low

3.4.1. *Nuclear magnetic resonance (NMR) spectroscopy*

NMR spectroscopy is a valuable tool for characterizing soil organic matter and soil humification process. It works on the principle of measuring characteristic energy absorbed and re-emitted by atomic nuclei placed in a static magnetic field and subjected to an oscillatory magnetic field of a known radio-frequency. This method is expensive and time-consuming but does not require extraction of organic matter (Schumacher, 2002).

3.4.2. *Diffuse reflectance infrared fourier transform (DRIFT) spectroscopy*

In DRIFT spectroscopy, carbon compounds are identified by assigning main infrared absorption bands to the bonds being stretched or deformed at those particular frequencies. This technique provides a rapid and inexpensive means of differentiating and identification of both inorganic and organic carbon forms (Nguyen et al., 1991) but requires an association with the dry combustion technique (Schumacher, 2002).

3.4.3. *Loss on ignition (LOI) method*

LOI method involves the heating and destruction of all organic matter in the soil. A soil sample of known weight is placed in a ceramic crucible and heated to 350–440 °C overnight (ASTM, 2000). The sample is cooled and weighed. The organic matter content is calculated as the difference between the initial and final sample weights divided by the initial sample weight.

3.4.4. *Hydrogen peroxide (H_2O_2) digestion*

A soil sample of known weight is digested with concentrated H_2O_2, dried at 105 °C, cooled and weighed. The organic matter content is determined as the difference between the initial and final sample weights divided by the initial sample weight. The major limitation is incomplete oxidation of organic matter and varied oxidation across soil types (Robinson, 1927).

Both the methods determine the soil organic matter. To convert the organic matter to total organic carbon content, conversion factors ranging from 1.724 to 2.5 have been used based on the assumption that the organic carbon (OC) content of organic matter is 58% (g organic matter/1.724 = g OC) (Nelson and Sommers, 1996).

3.4.5. *Destructive technique*

The Walkley and Black procedure is widely used because of its simplicity and minimal equipment requirements (Nelson and Sommers, 1996). Potassium dichromate and concentrated sulfuric acid are added to 0.5–1.0 g of a soil sample to digest it. The solution is swirled and allowed to cool prior to adding water to stop the reaction (Walkley and Black, 1934). However, the technique leads to incomplete oxidation of OC and is not suitable for elemental carbon forms. Therefore, in the absence of a site-specific correction factor, a correction factor of 1.33 is commonly used (Schumacher, 2002).

3.4.6. *Non-destructive technique*

This technique for SOC estimation was developed by Wielopolski et al. (2000) and is based on the detection of 4.44 MeV gamma rays produced when carbon atoms are bombarded with 14 MeV neutrons. The gamma rays are detected and quantified and the intensity is converted to carbon content (percentage). This technique can be performed *in situ*. However, it is in preliminary stages of development and requires a radioactive neutron generator to be used in the field for analysis (Schumacher, 2002).

A comparison of the above SOC estimation methods revealed that the Walkley–Black method is more accurate whereas the LOI and hydrogen peroxide digestion methods are less accurate. The spectroscopic methods (NMR, DRIFT) are least accurate, least cost and time effective and require much infrastructure (Table 3).

3.5. *Conclusions*

Developing countries are required to produce robust estimates of forest carbon stocks for successful implementation of climate change mitigation policies related to REDD (Saatchi et al., 2011). Many studies have estimated carbon stock in different forest ecosystems using different methods (Table S4 and S5 of supplementary online data). Controversy does exist in literature regarding the best method to use for AGB, BGB and SOC estimation in a forested ecosystem (Vogt et al., 1998).

Estimating national emissions of CO_2 on a regular basis requires information on changes in biomass. Although, destructive methods of biomass estimation are more accurate and give estimates for all the strata of forest, these cannot be used over large areas and protected areas as they involve harvesting of trees, and are expensive and time consuming. The non-destructive and indirect methods of biomass estimation are appropriate as they are easy and cover larger areas in less time.

For estimating the AGB, the process based, forest yield and carbon flux methods provide information on the all strata of forest but are site-specific and difficult to estimate whereas remote sensing methods can be used at large scales but cannot estimate BGB and understory biomass. Forest yield method combined with remotely sensed data should preferably be used for biomass assessment (Foody et al., 2003). The field measurement can be used either to develop a predictive model for biomass or to validate the outcome from remotely sensed data. Once the predictive model is developed and validated, it can be used to assess biomass on wider scales that are not covered by ground data (Brown et al., 1989).

In the case of BGB, the use of the sequential soil coring method for big trees is challenging. Minirhizotrons method is expensive and unsuitable for stony substratum. The N budget approach is limited to systems where N availability limits plant growth and the BEF method is site-specific and not representative of the target population. The carbon flux method gives rough estimate of root production. Therefore, we suggest estimating BGB using the biomass expansion factor with the AGB volume data obtained using the forest yield method. Spectroscopy is a non-destructive means of assessing the SOC, but it is expensive. Semi-quantitative methods are easy to use but give an overestimation of organic content. The Walkley–Black method is favored due to its simplicity, rapidity and minimal equipment requirements.

The methods recommended as an outcome of this review are familiar to most researchers and are time tested and can be applied to existing NFIs and incorporated into future forest inventories. More than 160 countries are required to report their national GHG inventories. However, at national level, the approaches can differ significantly (Lim et al., 1999). Even in the implementation of REDD and REDD+, differing methodological design for carbon estimation have established varying ''reference levels'' for countries, which in turn lead to differing incentives for countries to participate in a REDD program. The Subsidiary Body for Scientific and Technical Advice (SBSTA) of the UNFCC is focusing on methodological issues that include reference levels of emissions from deforestations and degradations under REDD. The reference levels are the benchmarks against which future emission reductions can be measured and potentially rewarded. The designs of these reference levels will determine the effectiveness, efficiency and equity of the REDD mechanism (Stern, 2006; Angelsen, 2008; Parker et al., 2008). However, as a result of the differences in their designs, these options will likely vary in terms of their impact on the overall reductions in emissions from deforestations (effectiveness), reduction per dollar spent (efficiency) and distribution of REDD revenues across the countries and region (equity) (Busch et al., 2009). It is important that the REDD stakeholders be able to quantitatively compare the likely impacts across REDD designs options, using standardized data. A review of the methods used to determine the carbon stocked in forests is therefore important for deciding which of the method would best suit different landscapes and regions so as to set standardized reference levels for countries as well as for estimating the changes in carbon stocks as a result of measures taken to avoid deforestation or as reforestation activities.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.envsci.2011.11.001.

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ECOSYSTEM SERVICES AND HUMAN WELLBEING

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The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the earth's life-support system. Over recent years, much progress has been made towards getting a better understanding of the role of the natural environment in contributing to our economic performance as a country and as individuals. Environmental assets provide benefits that enhance economic performance, offer new opportunities for investment and employment, and improve living standards and quality of life. In forested areas of developing countries, there are communities which are dependent on the forest for a range of goods and services. Forests contribute to the economy through employment, forest products and energy sources - and investments in the forest sector. Provisioning services of the forest are more valued than other services locally as they help the people to meet the daily needs while regulating, supporting and cultural services have a broader market and more users. Changes in availability of these ecosystem services affect human well-being through impacts on security (food, environmental and economic), the basic material for a good life, health, and social and cultural relations. Ecosystem degradation tends to harm rural populations more directly than urban populations and has its most direct and severe impact on economically vulnerable communities. The changes to ecosystems have led to substantial net gains in human well-being and economic development, but these gains have been traded off against increasing degradation of many ecosystem services. Human well-being can be enhanced through sustainable human interaction with environment and its products with the support of appropriate management instruments, institutions and improved technology. Understanding of ecosystem services is crucial to meet the goals of overall human wellbeing and biodiversity conservation.

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INTRODUCTION

Ecosystem functions are the conditions and processes through which natural ecosystems and their constituent species sustain and fulfill human life (Daily *et al.*, 1997). Ecological services are those ecosystem functions that are perceived to support human welfare (Ehrlich & Ehrlich 1992; Barbier, 1994; Costanza *et al.*, 1997a; de Groot *et al.*, 2002). These services include provisioning, regulating, and cultural services that directly affect people and supporting services needed for production and maintenance of other services (de Groot *et al.*, 2002; MEA, 2003) (Fig. 1). These services are both direct and indirect in nature, some easily recognized and others more subtle (MEA, 2003).

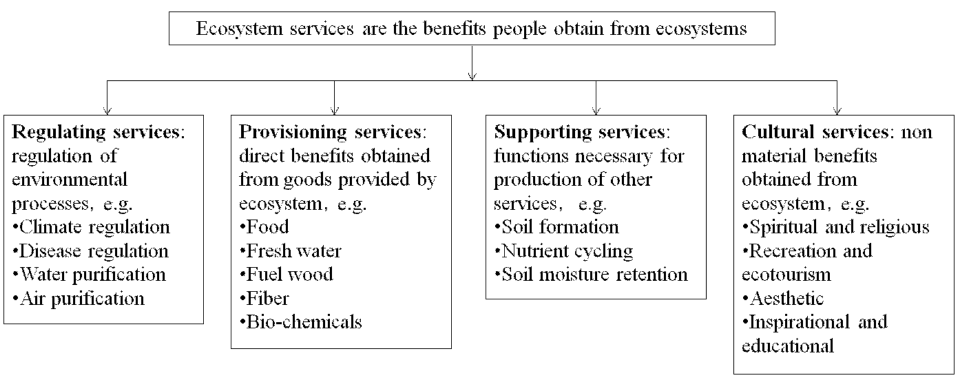

Fig. 1: Different types of services provided by natural ecosystems (source: MEA, 2003)

The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the earth's life-support system (de Groot, 1992; 1994; Barbier, 1994; Costanza *et al.*, 1997b). They consist of flows of materials, energy and information from natural capital stocks which combine with manufactures and human capital services to produce human welfare (Costanza *et al.*, 1998). Ecosystem services include preservation of the composition of the atmosphere, amelioration and stability of climate, flood control and drinking water supply, waste assimilation, recycling of nutrients, generation of soils, pollination of crops, provision of food and maintenance of species and genetic diversity. Besides they have recreational, aesthetic and amenity values (Ehrlich & Ehrlich, 1992). Biodiversity at genetic, species, population and ecosystem levels contribute in maintaining these functions and services. The ecosystem functions and biodiversity values are dependent on each other, i.e. as an ecosystem degrades it loses biodiversity value and ability to optimally perform ecological functions and vice versa. Many of the functions are provided by all natural ecosystems regardless of their management status, i.e. these functions can be attributed to both protected and unprotected areas provided these are in their natural state. This is especially true for the regulation and habitat functions. The other functions are more specifically related to human needs and activities and thus to the management objectives. The first two function groups are essential to the maintenance of natural processes and components and are therefore conditional to the maintenance of the availability of the other two.

LINKING ECOSYSTEM SERVICES AND HUMAN WELLBEING

Changes in availability of ecosystem services affect human well-being through impacts on security, the basic material for a good life, health, and social and cultural relations (MEA, 2005a). Over recent years, much progress has been made towards getting a better understanding of the role of the natural environment in contributing to our economic performance as a country and as individuals. Environmental assets provide benefits that enhance economic performance, offer new opportunities for investment and employment, and improve living standards and quality of life. Enhancing or diminishing the condition of environmental assets increases or reduces the stream of benefits communities can derive from them in the future. Humans utterly depend on Earth System resources and services for economic and cultural well-being (White & Pettit, 2004; Cummins, 2005). The ecological, economic, personal and social security of the local communities has a direct and strong link with the ability of the natural ecosystems to provide services (MEA, 2003).

In territorial ecosystems, forests provide most of the services especially regulatory (e.g. carbon sequestration and regulation of water regimes) and provisioning services (e.g. provision of freshwater, fodder and food) (Deal *et al.*, 2010; Smith *et al.*, 2011). Forests provide diverse economic and social benefits to human societies. These include contributions to the economy through employment, forest products and energy sources - and investments in the forest sector (Sharma *et al.*, 2012). In forested areas of developing countries, there are communities which are dependent on the forest for a range of goods and services. These communities generally lack alternatives to their existing way of life which make them vulnerable to degradation of quality and quantity of ecosystem services (Peluso, 1993; Peluso *et al.*, 1994) (Figure 2). This also create a challenge for the society to sustain natural resources while promoting economic growth and achieving Millennium Development Goals (Jordan *et al.*, 2010). The role of forest resources in development, poverty alleviation and improving food security in developing countries have been accepted and confirmed by committee on world food security at sessions in 1996 and 2002, UN's millennium assembly in 2000 and Global Sustainable Development conference in 2002 (Faham *et al.*, 2008). Not only economic but the social organization of the communities also influenced and dependent on the availability and accessibility of forest resources for the daily requirements e.g. food, fodder, forest product to support the agriculture etc. Despite the contribution of forested landscapes towards local, regional and global economy their social value is significantly undervalued by the society. Social and economical benefits from ecosystem services are often ignored in economic decisions as the genuine net benefits are still indistinct.

Ecosystem degradation tends to harm rural populations more directly than urban populations and has its most direct and severe impact on poor people. The wealthy control access to a greater share of ecosystem services, consume those services at a higher per capita rate, and are buffered from

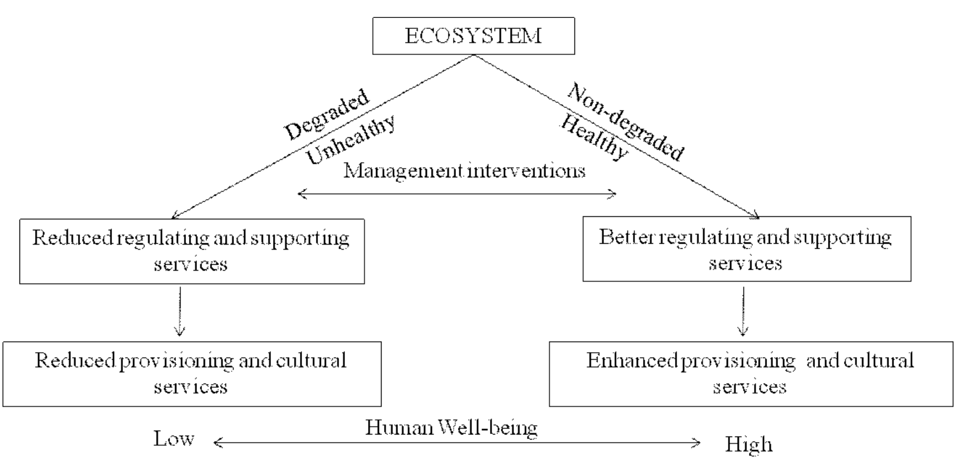

Fig. 2: Flow of ecosystem services and human wellbeing

changes in their availability (often at a substantial cost) through their ability to purchase scarce ecosystem services or substitutes (MEA, 2005a). High degree of dependence of people on forest resources and their ecological and economical services, and availability of these resources define the social and economical structure of community (Figure 2).

In developing countries like India, the use of forests by rural communities is entrenched in the history and is part of their culture, social and economical paradigm (McSweeney, 2004; Paumgarten & Shackleton, 2011) and local populations are dependent on nature for meeting their daily subsistence needs (Chandola, 2012). Most of the rural communities in India still survive on marginal non-sophisticated agriculture and livestock production which are basically dependent on forest products.

DIRECT BENEFITS: PROVISIONING SERVICES

Provisioning services, or the supply of goods of direct benefit to people, and often with a clear monetary value, such as timber, medicinal plants, fuelwood, fodder and food. Human societies are highly dependence on the supply of provisioning services (food security, environmental and ecological security and sustainability) provided by natural ecosystems of their vicinity.

The concept of dependency stems from a rural sociological perspective on communities and their interaction with risky resources, primarily in a North American context (e.g., Machlis & Force, 1988; Machlis *et al.*, 1990; Freudenburg, 1992). The direct contribution of natural resources depends on the availability, accessibility and economic and physical condition of the user. The dependence on resources for direct benefits relates to communities and individuals whose social order, livelihood and stability are a direct function of their resource production and localized economy (Machlis *et al.*, 1990). The World Bank (2002) highlights that more than one billion people depend on forests for their livelihoods to varying degrees. The direct benefits to communities vary with time, place and economical and social conditions (Adhikari *et al.*, 2004). The rural communities are dependent directly on forests for almost all the basic necessities of life. Provisioning services of the forest are more valued than other services locally (Power, 2010) as they help the people to meet the daily needs. Contribution of forests in household economy of communities who live in or close to the forests has been increasingly recognized (Byron & Arnold, 1997). For millions of forest forms such a dominant part of their physical, material, economic and spiritual lives that its importance is not most appropriately described and assessed in terms of the individual products or services that the forest provides. Especially in the developing countries, forests are the main source of fuel, timber and fodder. Diminution of forest will degrade the living standards of the local communities as well as ecosystem stability of the landscape (Singh & Sundriyal, 2009). Traditionally the fuel wood has been the only source of energy to the rural mountain communities. Livestock and agriculture has always been completely dependent on the forest products. Local communities who live in the close vicinity of forests will face both direct (depletion of ecosystem goods) and indirect (climate change) impact of degradation of forest resources. These natural resources form the base for the sustainability of both wildlife and human society. The same resources are used by the populations and in this process and interaction takes place. Constriction of resources and growth in any population forms a condition of conflict among them.

INDIRECT BENEFITS: REGULATING, SUPPORTING AND CULTURAL SERVICES

Regulating services are the functions of ecosystems which are often of great value but generally not given a monetary value in conventional markets. They include regulation of climate through the storing of carbon and control of local rainfall, the removal of pollutants by filtering the air and water, and protection from disasters such as landslides and coastal storms. Cultural services not providing direct material benefits, but contributing to wider needs and desires of society, and therefore to people's willingness to pay for conservation. They include the spiritual value attached to particular ecosystems such as sacred groves, and the aesthetic beauty of landscapes or coastal formations that attract tourists. Supporting services, not of direct benefit to people but essential to the functioning of ecosystems and therefore indirectly responsible for all other services, e.g. formation of soils and the processes of plant growth (MEA, 2005b; CBD, 2010).

The human activities on earth have expanded to such an extent that all ecosystems are modified and degraded (Boulding, 1966; Daly & Cobb, 1989; Vitousek *et al*., 1997). This forced the managers to focus on indirect values and services of forested landscapes. As these benefits do not generally attract a price, they are often referred to as non-market benefits (NMBs): they include open access recreation, public amenity and landscape benefits, biodiversity, and carbon sequestration, as well as a number of other environmental and educational benefits. These NMBs can be described as 'public goods' - they can be enjoyed by everybody, and the fact that one person benefits from them does not usually affect the enjoyment of anyone else. The open-access nature of such public goods means that it is difficult to charge people who want to enjoy them, and therefore such goods are not provided by market mechanisms which tend to be driven by profit. For the same reason these public good benefits are not reflected in the national income accounts. Nevertheless, the public-good aspects of forest management make a significant contribution to the overall welfare of. If the NMBs of forests are incorrectly valued, or if NMBs are not fully incorporated into decision making on resource allocation, or into management decisions on the structure of individual forests, then an optimally efficient allocation of resources will not be achieved, and societal welfare will not be maximized. Some examples of NMBs and their linkages with societal benefits and policy are discussed below:

Humans are changing the natural rate of exchange of carbon between the atmosphere and the terrestrial biosphere through land use, land-use change, and forestry activities. Consequently, it is important to examine how carbon flows between different pools and carbon stock changes in response to afforestation, reforestation, and deforestation and other land-use activities (IPCC, 2007). Human activities currently emit greenhouse gases (GHG) equivalent to over 50 billion tonnes of $CO_2 yr^{-1}$. Approximately 30% come from land use and land use change. Sustainable land management projects have the potential to not only reduce GHG emissions, by reducing emissions from biomass burning, biomass decomposition and the decomposition of soil organic matter, but also to sequester carbon through practices that increase biomass production and promote the buildup of soil organic matter. Most changes in land use affect the amount of carbon held in vegetation and soil, thereby, either releasing carbon dioxide to, or removing it from, the atmosphere. Recently, there has been a growing interest in understanding the carbon stocks of each ecosystem worldwide. With the growing global interest and policy negotiations on carbon sequestration, knowing the size of these carbon stocks and the factors that impact them is becoming economically to countries (Walker & Desanker, 2004). The Subsidiary Body for Scientific and Technical Advice of the UNFCCC is focused on methodological issues that include reference levels of CO_2 emissions from deforestations and forest degradations under Reduced Emissions from Deforestation and Forest Degradation (REDD).

Recreation is one of the numerous services provided by ecosystems. The value that users attach to nature recreation can be substantial although it is not reflected by market prices and is provided as quasi- public goods (Zandersen & Tol, 2009). Tourism has emerged as an instrument for employment generation, poverty alleviation and sustainable human development. Globally, an estimated 842 million people were international tourists in 2006. The number of international tourists is expected to double again by 2020 (Manfredo, 2008). Recreation benefits constitute a substantial part of the total economic value of forests in modern societies, and are an increasingly important determinant in multi-functional forest management.

However, over exploitation and increased social costs of natural resources is an important issue on the global agenda. Environmental valuation methods have been widely applied to value these benefits and losses to support sustainable management of natural resources (Barbier *et al.*, 1997; Gürlük & Rehber, 2008). On a practical level, taking these values into account can make a significant difference in the management, conservation and planning options for nature recreation. On a research level, gaining knowledge on the range of values attributed to ecosystems, dependent on population characteristics, quality and quantity of the natural resource as well as specification of demand models is essential when assessing general trends and impacts on the use of forests for recreation. The recognition of economical benefits of recreation has provided a sound economic rationale globally and has been identified a tool for biological conservation (Ahmed *et al.*, 2007). The benefits of nature-based tourism to biodiversity conservation are often presumed but rarely quantified (Naidoo & Adamowicz, 2003).

DRIVERS OF DEGRADATION OF ECOSYSTEM SERVICES

The changes to ecosystems have led to substantial net gains in human well-being and economic development, but these gains have been traded off against increasing degradation of many ecosystem services (McNeely, 2010). Population growth, economic activity, cultural factors, technological development and revolutionized social-political-cultural dynamics (especially change of most of the rural to urban lifestyle) are the most important factors that have contributed to direct ecosystem degradation reducing the provision of ecosystem services (MEA, 2005b; Chazdon, 2008; Halpern *et al*., 2008; Butchart *et al*., 2010; CBD, 2010; McNeely, 2010; Bullock *et al*., 2011). Discrepancy in the economic condition of people and communities and socio-political setup of the area affects the environment and changes the flow of ecosystem services at the local and regional level (Chazdon, 2008). Landuse classes change (from natural ecosystem to human modified landuse classes), expansion of agricultural land, industrial use of natural resources (McNeely, 2010), introduction of alien species (Pimentel *et al*., 2000; Vilà *et al*., 2009), rapid growth in human population, industrializations and urbanization (UNEP, 2006) has reduced ability of natural ecosystems reducing to provide ecosystem services continuously (Peters & Lovejoy, 1992; Schneider & Root, 2002).

Information failures

The provisioning services provided by the ecosystems have been central to economic and financial decisions and transactions whereas the services, which cannot be translated into direct trade-able goods have largely been ignored by the policy planers, till recently. To understand the actual value of services provided by natural ecosystems and to assess their linkages with human wellbeing, it is important to have information about the quantity, quality and economic worth of ecosystem services.

Market failures

Existing markets fail to conserve ecosystem services because they lack mechanisms to compensate resource users and thus do not send signals that encourage participants to use and manage natural resources sustainably (Arifin & Hudoyo, 1998; Whitten & Shelton, 2005).

Intervention failures

Policies for ecosystem services valuation are influenced by different sectors as implemented through different government agencies, which often work in isolation. Often the objectives of these sectoral developmental plans are in contradiction to the forest conservation objectives. The National Biodiversity Action Plan 2008 and National Mission for Sustaining Himalayan Ecosystems 2009, provide measures for reducing the environmental impacts of production and use of ecosystem goods and services. These legislative measures emphasize the need for incorporating the costs of depletion of natural resources into the decisions of economic actors to reverse the tendency to treat these resources as "free goods" and to pass the costs of degradation, thus integrating environmental concerns in economic and social development.

RESULT OF DEGRADATION OF IMPORTANT ECOSYSTEM SERVICES: A FUNCTION OF ECOSYSTEM

There is a strong link between the state of the environment and food production, apart from the natural environment being the entire platform upon which all life is based. For crops, the state of the environment directly influences soil nutrient availability, water (ground and surface water for irrigation), climate and weather (rainfall and growth season), availability of insects for pollination, and not the least, the abundance and effects of certain pests, such as pathogens, insects and weeds, which have major impact on crops worldwide, particularly in Africa (Sanchez, 2002). Without these services, there would be no production, Ecosystem services enhance agro-ecosystem resilience and sustain agricultural productivity. Thus, promoting the healthy functioning of ecosystems ensures the sustainability of agriculture as it intensifies to meet the growing demands for food production. Environmental degradation and loss of ecosystem services will directly affect pests (weeds, insects and pathogens), soil erosion and nutrient depletion, growing conditions through climate and weather, as well as available water for irrigation through impacts on rainfall and ground and surface water. These are factors that individually could account for over 50% in loss of the yield in a given "bad" year. The interactions among these variables, compounded by management systems and society, are highly complex. A changing climate will affect evapotranspiration, rainfall, river flow, resilience to grazing, insects, pathogens and risk of invasions, to mention a few. In the following section we attempt to provide for each variable, rough estimates of how much environmental degradation and loss of some ecosystem services could contribute to reducing yields by 2050. This is based on peer reviewed studies, models and expert judgment, and with the understanding that conditions and estimates vary considerably and relationships are highly complex. In developing nations and especially in rural areas human societies and wildlife share and compete for the same natural resource. This leads to the degradation in quality and quantity of the resources resulting in conflict between both the populations (Mishra, 1997).

CONCLUSIONS

Human well-being can be enhanced through sustainable human interaction with environment and its products with the support of appropriate management instruments, institutions and improved technology. Creation of these through participation and transparency may contribute to people's freedoms and choices and to increased economic, social, and ecological security. For poor people, the greatest gains in well-being will occur through more equitable and secure access to ecosystem services. In the long run, the rich can contribute greatly to human well-being by reducing their substantial impacts on ecosystems and by facilitating greater access to ecosystem services by the poor. The quantification of environmental income may serve as an input into conservation policy, and particularly establishment of protected areas, by determining the potential loss to rural dwellers of reduced access to environmental resources. Economic valuation of biodiversity is important since it provides a useful vehicle to highlight and quantify the range of benefits delivered by biodiversity. Importantly, placing monetary values on biodiversity and its ecosystem services will bring biodiversity into a common currency for use in decision-making, allowing its benefits to be directly compared with other development trajectories. The academician and policy planners should put a positively thinking in this direction as ecosystem services are directly linked to wellbeing of the people.

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METHODOLOGICAL FRAMEWORK TO ASSESS THE SERVICES PROVIDED BY MOUNTAIN ECOSYSTEMS

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The economic value of direct products from natural ecosystems proves more important in decision making for their management while the indirect and non use values or ecosystem services as they are referred to, are often ignored in the decision making process. As ecosystem services are neither fully captured by the markets nor adequately valued in monetary terms, they do not receive due importance in policy decisions. To address these issues managers and users should be aware of the quantity, quality and sustainability of these services. Economic valuation is important to maintain the long term flows of ecosystem services and allow the spatial distribution of benefits and costs to be compared to the distribution of biodiversity, allowing us to locate areas of value for both biodiversity and people. Economic valuation is an attempt to assign quantitative values to the goods and services provided by natural resources where market prices are not available, and thus help to inform decisions regarding resource allocation. Although numerous methods have been developed to assess and evaluate the ecosystem services and their economic value, consolidated information is lacking.

The methods available for valuing ecosystem services can be categorized in three classes, the revealed preference where the consumers reveal their preference for certain goods or commodities through their price or price of related goods. The cost based approaches focus on costs that would be imposed if natural areas were converted from their natural state to an alternative use. Stated preference or survey based approaches are the ones where the consumer is made to state his or her preference for a certain level of environmental goods/services through well designed studies.

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For the present paper we have reviewed and analysed the existing literature about different methods. The analysis was done using the criteria of cost effectiveness, accuracy, spatial scale, operational ease, impact on surrounding environment and time efficiency, to select the best methods used to place an economic value of services of mountain ecosystem in developing country scenario. Criteria were selected keeping in mind the condition of economically developing countries with limited access to resources, unskilled manpower and fragile and accessibility in the mountain region. For the present paper we are only describing some of the approaches that have placed economic values on ecosystem services based on an ecological understanding in the Nanda Devi Biosphere Reserve, Western Himalayas, for the research project entitled 'An integrated approach to reduce the vulnerability of local people to local people to environmental degradation in western Himalaya' conducted by Wildlife Institute of India. Economic valuation of a particular ecosystem service will effectively contribute to its better use and conservation only if it rests on robust scientific data.

Keywords: Economic valuation, quantitative values, vulnerability, Carbon stock, Questionnaire

INTRODUCTION

The contribution of ecological services to human life outline the life support systems that have a major significance among the scientific communities and general masses and precious legacy which belongs to both the present and future generations (Kumar, 2008) and within which all economic development takes place. However the high dependence on natural systems and their products leads to degradation and loss of the benefits and services which is occurring not only at local, but also regional and global level. The economic value of direct products from natural ecosystems proves more important in decision making for their management as these usually accrue locally and the indirect and non use values are often ignored in the decision making process. As ecosystem services are neither fully captured by the markets nor adequately valued in monetary terms, they do not receive due importance in policy decisions (Costanza *et al.*, 1997a; Costanza *et al.*, 1998; Bernard *et al.*, 2009; TEEB, 2008, 2009, 2010). To address these issues managers and users should be aware of the quantity, quality and sustainability of the available services. To ensure their sustainability and develop rational natural resource use policies, valuation of ecosystem services provided by natural ecosystems has become an essential analytical tool. Economic valuation is an attempt to assign quantitative values to the goods and services provided by natural resources where market prices are not available, and thus help to inform decisions regarding resource allocation (Costanza *et al.*, 1989; Barbier *et al.*, 1997; Daily, 1997).

In recent years, the focus of forest management and conservation has significantly shifted from the highly technical commercial forestry to a more people- oriented social forestry orientation (Harrison *et al.*, 2002). In past most of the social and economic research has overlooked links between human well-being and natural resources and thus has undervalued the social, economic and environmental contribution of ecosystem services (Hirvilammi *et al.*, 2013). However, now there is a growing interest about the sustainability of forests and ability of dependent communities to sustain themselves through fluctuating political and environmental conditions (Zobolo & Mkabela, 2006; Jury *et al.*, 2007). This requires the capacity to maintain the long term flows of ecosystem services for human well-being. There is a need to understand the flow of these services and their availability for future use. Efforts to assess the monetary value of ecosystem services play multiple roles in managing the links between human and natural systems (Howarth & Farber, 2002). The process of identifying and quantifying ecosystem services is increasingly recognized as a valuable tool for the efficient allocation of environmental recourses (Heal *et al.*, 2001). At macro-level ecological evaluation will contribute to the construction of indicators of human welfare and sustainability (Daly & Cobb, 1989). It would allow the spatial distribution of benefits and costs to be compared to the distribution of biodiversity, allowing us to locate areas of value for both biodiversity and people (''win-win'' areas for conservation), and also allowing us to identify areas of conflict or tradeoff, where net economic benefits of ecosystem conservation are low but biodiversity values are high (and vice versa). Second, a spatial cost-benefit analysis would highlight which areas have the greatest benefits per unit cost, thus allowing the most efficient targeting of efforts towards conservation. Third, the quantification and assessment of the ecosystem services would help identify suppliers and consumers of ecosystem services, allowing the identification of efficient and equitable payment mechanisms to fund conservation projects as a specific area of practice (Naidoo *et al.*, 2006).

THE VALUATION FRAMEWORK

Ecosystem valuation has taken a visible step forward through the work of Daily (1997) and Costanza *et al.,* (1997b). Economic benefits to communities are usually measured in monetary terms (Paul, 2012) and include: direct income from employment and indirect income from the goods and services from forests (FAO, 2005). The forestry income also contributes significantly to the national economy, energy supplies and international trade (Shackleton *et al.*, 2007). The social contribution and benefits of forests are difficult to quantify and vary among communities, depending on economic and cultural conditions. For example, an economically well-off community may give more value to recreational and regulating services while a marginal forest dependent community gives more value to the provisioning services as their daily requirements are met from the forest resources (Power, 2010). In marginal communities people share same resources which structure the societal setup. Given the difficulties social functions and benefits measurements are often measured in terms of inputs rather than outputs (e.g. the area or proportion of forests used to provide various social functions). Numerous methods are available for the estimation and economic valuation of the services provided by the nature (Table 1).

Table 1: Overview of methods for estimating ecosystem services

Benefit	Description	Commonly used valuation approaches
Direct use values	Goods and service consumed directly, recreation, tourism, natural resource harvesting	Change in productivity, cost-based approaches, hedonic prices, travel cost, contingent valuation
Indirect Use values	Ecological processes	Surrogate market price
	Watershed protection, climate stabilization, carbon sequestration, option value, protection from storms and cyclones, prevention of soil erosion, soil moisture, soil nutrients, pollination	Change in productivity, cost-based approaches, contingent valuation
Non use values	Existence, option and bequest value	Contingent valuation, Hedonic prices

The methods available for valuing ecosystem services can also be understood according to a classification of the methodological approach themselves (Figure 1). Broadly there are three approaches, the reveled preference where the consumer reveals his preference for certain goods or commodities through their price or price of related goods (surrogates). The cost based approaches focus on costs that would be imposed if natural areas were converted from their natural state to an alternative use. Stated preference or survey based approaches are the ones where the consumer is made to state his or her preference for a certain level of environmental goods/services through well designed studies. They are often useful in measuring the services where markets are not well developed e.g. for measuring non use values.

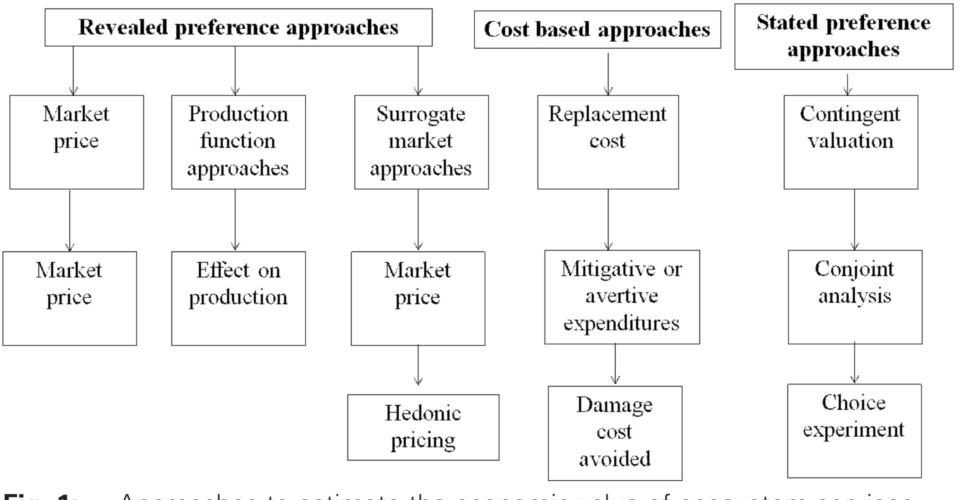

Fig. 1: Approaches to estimate the economic value of ecosystem services

To estimate the economic value of the ecosystem services for which a commercial market is already exists market price method is used (Hussain & Badola, 2010), e.g. for provision of biomass. For the economic valuation of services which support production of other services productivity method is used (Bann, 1997), e.g. for soil nutrient retention. Market price method and productivity method are different types of market based techniques and known as adjusted market prices (Wackernagel *et al.*, 2002; Fisher *et al.*, 2011). Hedonic Pricing Method is used for the valuation of ecosystem services which directly affect the market of other services (Garrod & Willis, 1992; Sander & Haight, 2012), e.g. property prices being affected due to environmental parameters. Replacement cost method estimates economic values of ecosystem services based on cost incurred due to degradation and loss of a particular service (Fisher *et al.*, 2011), e.g. carbon stock and soil nutrients. Travel cost method is used to evaluate the economic value of places and areas which provide recreational and cultural services (Clawson, 1959; Badola *et al.*, 2010). The contingent valuation method (CVM) is a flexible nonmarket valuation method used to evaluate all types of services and also widely used in cost–benefit analysis and environmental impact assessment. CVM is used to estimate both use and non-use values (Cummings *et al.*, 1986). The conjoint and choice experiment methods are similar to CVM and evaluate ecosystem services on the basis of willingness to pay and attitude of users (Carson *et al.*, 1996). Although numerous methods have been developed to assess and evaluate the ecosystem services consolidated information is lacking.

THE ECOLOGY-ECONOMIC LINKAGE

The ecological understanding of ecosystem services is quite limited. Previous work maps the supply and demand for services, assesses threats to them, and estimates economic values, but does not measure the underlying role of biodiversity in providing services. In contrast, experimental studies of biodiversity–function examine communities whose structures often differ markedly from those providing services in real landscapes. While each of these approaches have provided many valuable insights, a bridge is needed between these two approaches: one that will provide fundamental, ecological understanding of ecosystem services to assist in devising the best management and policy tools for their conservation and sustainable use (Kremen, 2005). Given forecasts of global declines in basic services (MEA, 2005), it is critical to develop and implement this research agenda on the ecology of ecosystem services, and to integrate it within existing or future inter-disciplinary studies of ecosystem services (e.g. Biggs *et al.*, 2004). The following section describes some of the approaches that have placed economic values on ecosystem services based on an ecological understanding in the Nanda Devi Biosphere Reserve, Western Himalayas, for the research project entitled 'An integrated approach to reduce the vulnerability of local people to local people to environmental degradation in western Himalaya' conducted by Wildlife Institute of India (Figure 2).

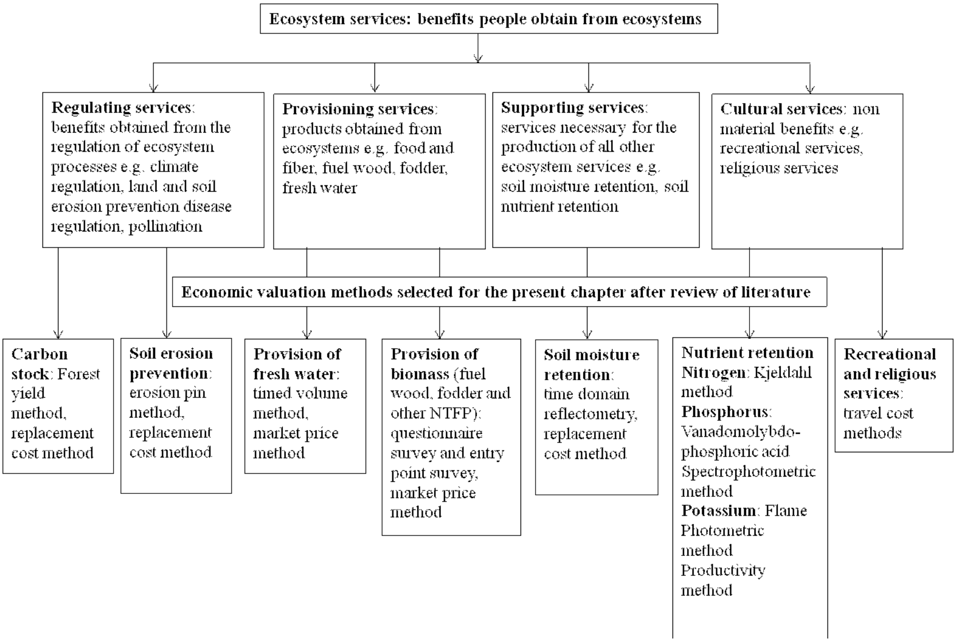

Fig. 2: Assessment and evaluation methods used for different ecosystem services described in present paper

METHODS USED FOR ESTIMATION AND QUANTIFICATION OF DIFFERENT ECOSYSTEM SERVICES

Two types of methods exist for the assessment and quantification of the ecological services destructive and non-destructive. In destructive methods the sample from field is collected and then analyzed in laboratories using various techniques.

I. REGULATING SERVICES

1. Carbon stock

There are two methods of carbon stock estimation: Destructive (e.g. sequential coring method, the Walkley and Black method) and Non Destructive (e.g. forest yield method, biomass expansion factor method and spectroscopy) methods. A destructive method involves a harvest method, employing cutting, drying and weighing of plant is a straight forward procedure to apply but it's destructive and time consuming (Nordh & Verwijst, 2004). Whereas nondestructive methods are generally used for the biomass estimation and there are many models through which biomass estimation can be done.

Carbon stock: forest yield method

This model is based on the stand density and tree growth and thus is tree and stand-specific (Gustavsen *et al.*, 1998). Allometric equations are developed based on extensive measurements of foliage, branches, roots and stems of the felled trees (Ash & Helman, 1990) and provide detailed prediction of tree and stand dynamics covering entire vegetation strata. This method is referred to as 'empirical' since it cannot be linked to the underlying causes of productivity such as carbon and nutrient cycles and moisture regime. Although, it is cost effective but it is insensitive to environmental change, tedious and time consuming (Monserud, 2003). To assess the carbon stock in the different vegetation classes of NDBR plot method was used. The area was divided into grids and transects were laid. While in field, forest type was noted for each grid and the same was used as field data points for the LULC map on ARCGIS platform. Besides noting the forest type, altitude and GPS locations were also recorded. On the each side of transect at the interval of 100m circular plot of 10m radius was laid. Data on parameters as species, tree height and GBH were collected.

For trees, the growing stock density (GSVD) is estimated using volume tables or volume equations based on the Forest Research Institute (FRI) and Forest Survey of India (FSI) publications for the respective species (Chaturvedi, 1973; Sharma & Jain, 1977). The estimated GSVD (m^3/ha) is then converted into above ground biomass density (AGBD) of tree components, which is calculated by multiplying GSVD of the tree species by appropriate biomass expansion factors (BEF) (Brown *et al.*, 1999). The below ground biomass density, BGBD can be estimated using the regression equation of Cairns *et al.,* (1997). AGBD and BGBD are added to get the total biomass density (TBD). The total C density (TCD) is computed using formula following IPCC (2000) (TCD = TBD $\times$ 0.5). Walkley - Black acid digestion method (Walkley & Black, 1934; Nelson *et al.*, 1996) is carried out for determination of organic carbon in soil. Besides, soil sample from each plot was taken for measuring the bulk density. Carbon thus obtained in various pools is summed up to get the carbon stock present under various land use, land cover types.

Organic carbon: Walkley - Black acid digestion method

The Walkley and Black procedure is widely used because of its simplicity and minimal equipment requirements (Nelson *et al.*, 1996). Potassium dichromate and concentrated sulfuric acid are added to 0.5–1.0 g of a soil sample to digest it. The solution is swirled and allowed to cool prior to adding water to stop the reaction (Walkley & Black, 1934). However, the technique leads to incomplete oxidation of organic carbon and is not suitable for elemental carbon forms. Therefore, in the absence of a site-specific correction factor, a correction factor of 1.33 is commonly used (Schumacher, 2002).

The benefit of reducing carbon from the environment can be estimated using replacement cost methods (Bann, 1997; Dixon & Sherman, 1991). The replacement cost method uses the cost of replacing an ecosystem or its services as an estimate of the value of the ecosystem or its services. This method assigns a value to the environmental service by estimating the cost of replacing the environmental benefit with alternatives (Dixon & Sherman, 1991). It focuses on the costs of providing manmade substitutes for ecosystem services and regards the value of an ecosystem service as the price of the cheapest alternative (Woodward & Wui, 2001; Hussain & Badola, 2008). A monetary value required of off-setting the additional carbon stored in the natural ecosystem as compared to other human modified land uses such as pasture or cropland was calculated. The excess was the value of the carbon storage service provided by natural ecosystems.

2. Protection from landslides and soil erosion: erosion pin method

For estimation of soil erosion two types of methods are available, (i) methods for smaller areas and with limited resource requirement and manual execution e.g. erosion pin method, catchment pit method, (ii) method with large area coverage and with the use of GIS technique, e.g. universal soil loss equation and revised universal soil loss equation methods.

The erosion pin method is a widely-used method consists of driving a pin into the soil so that the top of the pin gives a datum from which changes in the soil surface level can be measured. Alternatively called pegs, spikes, stakes or rods, the pins can be of wood, iron or any material which will not rot or decay and is readily and cheaply available. Off-cut lengths of round iron bars for reinforced concrete can usually be picked up at little or no cost from construction sites (Lawrence, 2004; Hsieh *et al.*, 2009). This method is cheap and simple, many measurements can be made and so the results can be reliable and representative - which means they are believable and usable - more so than a single precise measurement at a site which may not be representative and need little maintenance. The time interval between measurements may be flexible, e.g. the pins can be measured after few days, a month or after a season or year.

For valuing the erosion prevention function of the forested landscapes, the preventive expenditure method was used. This procedure examines actual expenditures made to alleviate an environmental problem. It is based on the idea that a person/community would make expenditure only if they felt that the reduction in damage is at least equal to the amount spent.

II. PROVISIONING SERVICES

1. Estimation of biomass extracted from natural ecosystems

For the assessment of the contribution of forests to needs for fuel wood and fodder and other NTFPs questionnaire-based interviews, participant observation method, entry point method and light detection and ranging method (Wessels *et al.*, 2013) are available. For the cultural services contingent valuation method and travel cost method (with individual and zonal approach) are available (Figure 3).

Interview based questionnaire method

Questionnaire based survey to assess the socio economic conditions of local people and their dependence on forest ecosystems are widely used (Hussain & Badola, 2010; Badola *et al.*, 2012). The questionnaires need to have a proper mix of open ended and close ended questions (Holmern *et al.*, 2007). Closed-ended questions were used to get quick information and because of simplicity of analysis of the data while open-ended questions were used to get the unique responses and exploratory data about the subject (Gurung *et al.*, 2008). Personal interview were conducted to overcome the poor response rates of a normal questionnaire survey (Austin & Cunningham, 1981). Personal interviews provide opportunity to evaluate the validity of the respondent's answers by observing non-verbal indicators.

Entry point monitoring

To validate the data about biomass extraction, obtained from questionnaire, entry point method is used (Dhaundiyal, 1997). All the traditional entry points to forests should be identified and monitored (Ganesan, 1993) as villagers use these fixed points to access the forest resources (Soussan *et al.*, 1991). Weight of head loads of all the people carrying fuelwood, fodder, thatching material, grasses and leaf litter should be recorded using a spring balance. The repetitive monitoring should be done i.e. monthly, seasonally.

2. Provision of fresh water: Timed volume or Volumetric stream flow method

For the estimation of freshwater in natural streams and rivers methods can be divided into three categories on the basis of the peer reviewed literature (Herschy, 2009): *viz.* (i) direct measurement methods, (ii) velocity-area methods, (iii) formed constriction or constricted flow methods (Martin, 2006). Timed volume or Volumetric stream flow method is a direct measurement method and is used for the streams where the entire flow converses into a single descend (Hauer & Lamberti, 2007). The time required to fill a container of a known volume is recorded, and later used to calculate the average flow rate (Gunn, 1974; Lawson, 1995). For reliable and accurate results, container must be of a large size and the flow rate measured at least five times while more than three replicates for the stream width and depth should be recorded (Ely, 1994; Pfeffer & Wagenet, 2007). Cross-section area can be calculated using average depth and width (USEPA, 1997). The flow rate is the fraction of average stream cross-section area and average time taken to fill the container. This method is accurate, both cost and time effective, non-polluting, and requires limited resources and technical knowledge (Friederich & Smart, 1982). Human error may occur in measuring velocity, stage height and cross-sectional area. To minimize such errors, a high number of trials are required (Weight & Sonderegger, 2001).

For the economic evaluation of the provisioning services provided by forests, local markets of the area were surveyed and prices of ecological commodities being sold were recorded. For fresh water the rates charged by municipal water supply was used. These values were used to calculate the economic contribution of natural ecosystems to the households for provisioning services.

III. SUPPORTING SERVICE

1. Soil nutrient retention

For estimation of soil nutrients under different forest types, samples are collected from the sample plots under various land use land cover classes using the plots laid for estimation of carbon stock. Within the larger plots of 10m radius, soil samples are collected from five random points using soil augar and a composite sample was prepared. Volume of the auger is noted for each depth at which the soil was extracted. The soil samples are extracted from<10 cm, 10-20 cm , 20-30 cm, 30-40 cm, 40-50 cm and 50-60 cm depths. The soil samples are kept in polybags and labeled. These samples are sun dried, and stored in labeled bags and brought back to the Lab. After the air drying, dried plant materials, stones and other unwanted objects are removed and the samples are grounded using mortar and pestle to break up the soil particles. The soil/sediments are then passed through 2 mm stainless steel sieve and labeled and stored at room temperature for further analysis. The soil samples are first weighed and then oven dried for 72hrs at 105 ^{0}C and again weighed. Bulk density was calculated following the formula given by Brown (2004). The sieved and dried samples were digested in Microwave Digester prior to further chemical analysis. 0.1 g of the sample is digested with 5 ml of HNO_3 and 2 ml of HCl. The digested sample was filtered and diluted to 50 ml with distilled water. The following physical and chemical parameters of soil samples are analyzed using standard techniques as specified for each parameter:

(a) Soil texture: texture was evaluated in the laboratory by Bouyoucos hydrometer method (Bouyoucos, 1962; Allen, 1989).

(b) Soil pH: pH value was determined using the electrometric method (Jackson, 1967).

(c) Organic carbon: the organic carbon was determined by the Walkley and Black rapid titration method (Jackson, 1967).

(d) Total nitrogen: the micro Kjeldahl method (Jackson, 1967; Pereira *et al.*, 2006) was used for estimating total nitrogen. The Kjeldahl method is based on the principle that the organic matter is oxidized by treating the soil sample with concentrated Sulphuric acid. Nitrogen in the organic nitrogenous compounds is converted into ammonium sulphate during this oxidation. NH_4^+ ions are trapped by acid in the soil released by distilling with NaOH. The liberated NH_4^+ is observed in boric acid and back titrated with standard H_2SO_4. Potassium sulphate is added to raise the boiling point of the mixture during digestion and copper sulphate and selenium powder mixture is added as a catalyst (Pereira *et al.*, 2006).

(e) Available phosphorus: Vanadomolybdo-phosphoric acid Spectrophotometric method was used for phosphorus (Motomizu *et al.*, 1988). In this method the formation of an ion-associate between vanadomolybdophosphate and malachite green in aqueous acidic solution (0.5 M sulfuric acid) enables trace amounts ($0\text{-}1\times10^{-5}$ M) of phosphate to be determined. Molybdophosphoric acid and its reduced product, phosphomolybdenum blue, are used as a light-absorbing species either as they are or after extraction into an organic solvent as a prorogated species as an ion associate with a bulky cation (Motomizu *et al.*, 1988).

(f) Available potassium: Flame photometric method was used for potassium (Reed & Scott, 1961). Flame photometric method uses the principle that an alkali metal salt drawn into a non-luminous flame will ionise, absorb energy from the flame and then emit light of a characteristic wavelength as the excited atoms decay to the unexcited ground state. A photocell detects the emitted light and converts it to a voltage, which can be recorded. Since K+ emits light of different wavelengths, by using appropriate colored filters the emission due to K+ can be specifically measured in the same sample (Reed & Scott, 1961).

For valuation of soil nutrients the replacement cost approach was used (Bann; 1997). This method places a value on the environmental service by estimating the cost of replacing the environmental benefit with alternatives (Dixon & Sherman, 1991). It focuses on the costs of providing man-made substitutes for ecosystem services and regards the value of an ecosystem service as the price of the cheapest alternative (Woodward & Wui, 2001). Since society would not have to pay such costs if the ecosystem service is available, the idea is that such cost savings indicate the economic value of the service. A fundamental prerequisite is however that the substitute provides exactly the same service as the natural resource which is to be valued. Furthermore, the functional relationships between the ecosystem considered, the ecological functions, and the service that leads to a societal value must be capable of being identified (Dehnhardt, 2002). The replacement cost method, which is reliable, has been used extensively for valuing ecosystem services provided by wetlands (Bockstael *et al.* 2000; Freeman, 2003; Sundberg, 2004; Hussain & Badola, 2010). Most studies that focus on nutrient retention function are based on the replacement cost approach (e.g. Breaux *et al.*, 1995; Gren, 1995; Gren *et al.*, 1995; Farber, 1996; Thibodeau & Ostro, 1981; Bystrom, 2000). In this study, the soil nutrients present were related to the cost of equivalent amount of fertilizer to be added.

The cost of increasing the soil nutrients in degraded areas to the level of control sites was calculated by valuing the fertilizers that if added to the soil in degraded areas would bring their nutrient level to that of control sites. The value of the nutrients present in both sites was derived by multiplying the amount of available nutrient (kg/ha) by the prevailing market price (US$/kg) of the fertilizer with similar chemical compositions.

2. Soil Moisture Content

For the estimation of soil moisture content available methods can be classified into two categories: (i) direct methods (e.g. gravimetric method or thermostat–weight technique) and (ii) indirect methods (e.g. time domain reflectometry, Ground penetrating radar). In direct methods, the soil moisture is determined using the difference between the weights of a soil sample before and after it is dried; in indirect methods, measurements are made through calibrations against other measurable variables that vary with soil moisture content (Evett & Parkin, 2005; Muñoz-Carpena, 2012).

Soil moisture retention: time domain reflectometry

In Time Domain Reflectometry (TDR) the propagation velocity (v) of an electromagnetic energy pulse in the soil is determined. To determine v in soil, very short electrical pulses are sent through a metallic 2 or 3-rod probe. From the travel time t and the length l of the probe, which has been travelled along twice, the propagation velocity $v = 2l/t$ is calculated (Worsching *et al.*, 2006). The velocity of the pulse changes with the change in soil moisture content due to the relatively large dielectric value of water (Malicki *et al.*, 1992; Muñoz-Carpena, 2012). The pulse velocity in the probe is measured and correlated to the soil moisture. A lower velocity indicates a wetter soil. TDR has been used for measuring volumetric soil water content by several workers (Amente *et al.*, 2000; Yu & Drnevich, 2004). TDR is a non-destructive and relatively less labor intensive technique; the instrument used is portable, easy to install and safe to operate. This technique allows reliable measurements of volumetric water content to be made within a short time (Benson & Bosscher, 1999). No soil specific calibrations are required (Topp & Davis, 1985; Zazueta & Xin, 1994; Ferrara & Flore, 2003). This technique gives accurate results within an error limit of ±1% and allows continuous measurements to be obtained over the full soil moisture range (Anisko *et al.*, 1994; Chandler *et al.*, 2004), along with measurements of the electrical conductivity of the soil (Robinson *et al.*, 2003; Thomsen *et al.*, 2007). However, the probe length influences the accuracy of moisture measurement (Richardson *et al.*, 1992). TDR probes are environment sensitive. Thus the measurements could be erroneous due to gaps between the soil and probe (Sakaki *et al.*, 1998). It has limited applicability in highly saline soils (Ferrara & Flore, 2003). The value of soil moisture content retained by natural system can be calculated using replacement cost methods (Dixon & Sherman, 1991; Bann, 1997).

IV. CULTURAL SERVICES

1. Recreational and religious values: Travel cost method

TCM assumes that the value of the site or its recreational services is reflected in how much people are willing to pay to reach it. It is referred to as a ''revealed preference'' method, because it uses actual behaviour and choices to infer values. Thus, people's preferences are revealed by their choices. The basic premise of the travel cost method is that the time and travel cost expenses that people incur to visit a site represent the ''price'' of access to the site. Thus, people's willingness to pay to visit the site can be estimated based on the number of trips that they make at different travel costs (Hecht, 1999). This is analogous to estimating people's willingness to pay for a marketed good based on the quantity demanded at different prices.

The zonal approach travel cost method (ZTCM) was used to collect the data for the evaluation of recreation value (Clawson, 1959; Moeltner, 2003; Badola *et al.*, 2010) of the NDBR. The Travel cost method (TCM) estimates use values for site-specific amenities, specifically the use values that can be obtained by visiting a site. A multi site destination model based structured questionnaire was developed in accordance to UNESCO's manual "Managing Tourism at World Heritage Sites" (Pedersen, 2002) as ignoring the multi destinations leads to overestimation of the consumer surplus (Kuosmanen *et al.*, 2004). Sampling sites were selected on the basis of the visitation rate (Petrosillo *et al.*, 2007). Personal interviews with tourists were conducted at all the selected sites. The sampled population was divided into zones on the basis of the state of origin of the tourists.

The total cost of travel was calculated for each visit by using the total cost of travel, the monetary value of the time spent in travel to get to site and at site and money spent at the site for stay, food, hiring of guides and procurement of local products. The regression analysis between visits and travel cost was done to get an equation that relates visits per capita to travel costs (Badola *et al.*, 2010).

CONCLUSION

Measurement of ecosystem services is complicated (Kremen, 2005). For ensuring its utility in policy, it should have an integrated and interdisciplinary approach including socio-economic aspects. Carrying out such studies is difficult and tedious in terms of logistics, time frame, financed and scientific challenge, but we need to use discretion in selection of methods and not just get carried away by the sophisticated economic models. Economic valuation of a particular ecosystem service will effectively contribute to its better use and conservation only if it rests on robust scientific data. To select the methods for the present analysis we used the criteria of cost effectiveness, accuracy, spatial scale, operational ease, impact on surrounding environment and time efficiency. Cost effectiveness is defined as the comparative cost involved in the purchase, operation and maintenance of the apparatus used for a particular method; accuracy refers to the degree to which results are free from instrumental errors, spatial scale is the geographic area covered (point readings vs larger areas); time efficiency refers to the time taken to generate one reading of a particular parameter used to assess and quantify a service (a surrogate parameter can be used for few services e.g. soil moisture). Criteria were selected keeping in mind the condition of economically developing countries with limited access to resources, unskilled manpower and fragile and accessibility in the mountain region.

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The Hills are Alive with the Sound of Hydropower Projects

By: Pariva Dobriyal, Ashi Qureshi and Archi Rastogi, India

During our field visits to Nanda Devi Biosphere Reserve, we reach the site of the Chipko Movement and find enormous change in the village life.

Dhan Singh of Lata village fondly remembers the time when his village was capable of acting like one large unit to protect their collective forest resource. Their village has collectively fought off timber mafia, contractors and elicited responses from the government. This is the site of the famous Chipko movement, after all.

But these are stories of the past. Dhan Singh was about 10 years at that time. Hydroelectric power plants, immigrant labourers, and the market-based economy have created class issues and the village finds itself broken into several units. The youngsters no longer wish to stay. “Our life was dependent on the forests, but the forests are gone and our lives are no longer the same”, says Dhan Singh.

For Hills to Climb and Forests to Dwell

Forests have always been the centre of life for local communities living in the villages around the Nanda Devi Biosphere Reserve (NDBR). NDBR is a part of Western Himalayas and situated in Uttarakhand, a northern state of India. Local people are worshippers of Nanda Devi, the patron Goddess who is a daughter of the local peasants, and the forests are her blessings to the communities. Every 12 years the communities organize a massive celebration for her famous homecoming. The association with forests is not merely emotional. Forests provided the fuelwood and fodder for the cattle. Cattle were the main source of livelihood, and forests were the providers of life. This was what drove the women to ward off the contractors who came to cut the forests in 1974. The women would rather lay their lives then let the forests fall. Their struggles became famous as the Chipko movement, winning these villages worldwide recognition. But recognition made things worse.

After the forests became famously protected by the communities, they were subsequently declared protected by the government. The villagers now found themselves deprived of the same resource that they had protected with their lives. Suddenly, there was no more access to fodder, fuel or grazing lands for the cattle. “Even the traditional pilgrimage for Nanda Devi was suspended”, recalls Dhan Singh. The retaliatory ‘*Jhapto Chheeno*’ movement (literally, ‘snatch and grab’) started in the late 1990s to reclaim rights over the natural resources: the forests and grasslands that were not only significant for religion but also the main focus of lives and livelihoods. The violent nature of the protest only indicates how desperately the villagers were driven. After the movement, the annual pilgrimage was allowed again. But the damage was permanent. The conflicts between the management of NDBR and the communities have lasted. The new generation finds itself unable to relate to the forests anymore. “Forests are property of the government now,” says Chandan Lal. His sons have migrated to the plains to work as labourers.

Changed Life

The village elders remember the time when they would grow their own food and felt independent. “The yield of crops has gone down, and we are forced to use chemical fertilizers, which are very costly and will also damage the soil in future,” says Baisakhi Devi from Tapovan village. Her village is now dependent on government schemes for provisions. Worse, the sense of community ownership has declined. “Loss of rights has cut our emotional bonds with the forests”, says Dhan Singh.

Earlier the forests were a source of fuel and fruit bearing trees. But the government schemes focused on growing pine and other coniferous species, which are non-native. The wood of the pine does not burn well in *chulhas* (traditional earthen stoves), nor are its needles edible for the cattle and cannot be used as manure in the fields. The villagers are forced to buy LPG from the markets and fodder from the agricultural fields. All of these add monetary pressures to their frail economy. The forest that once provided the villages with sources of life is now a strange entity.

While the links with the forests have weakened, urban aspirations have also increased among the communities. Local people, especially the women-folk used to weave beautiful traditional woolen cloths and carpets. But the market for such locally made wool-products has declined, because of the wide availability of the cheaper synthetically made substitutes. “The tourists now prefer cheap industrially manufactured products”, rues Bachhan Singh, a resident of Malari village.

Hydropower projects are mushrooming in valleys of this landscape known for significant rivers like Bhagirathi, Alaknanda and their tributaries. The projects have impacted agriculture and also the forests. The incoming labourers also add to the competition for the already sparse natural resources in these mountainous regions. “Because of their consistent blasting, the houses now have cracks”, complains Bhuwan Singh from Dhak village. The nature of employment has indeed changed because of these hydropower projects. There are encouraging examples like Deepak Farshwan, who was able to afford his education because of his job with the L&T power project. He is now able to provide for his family. But such employment is not permanent and is available only to few.

The Dark Ages

Nearly 80 year old, Pauni Devi thinks this a sign of Kalyug, the dark period. “Nanda (the Goddess) had gifted us with her possessions especially the forest and water resources. But we have failed her. The forests have been destroyed. Nanda is not happy with the current state of her belongings. That is why she is punishing us”, Pauni Devi says. One of the few surviving participants of the Chipko movement, she hopes the Goddess will forgive them soon.

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ICIMOD

Special issue on youth action for climate change through art

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FOR MOUNTAINS AND PEOPLE

Contents

Using Art to Communicate Climate Change

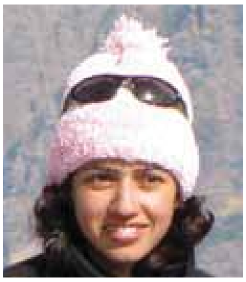
Art in all its forms is a powerful means of communication. The arts help overcome barriers of language and culture, and they provide a creative pathway for debating and exploring global problems. For young people concerned with climate change, the arts offer a way to reach out and raise awareness among their friends, in their communities, and in the world beyond.

This issue of the Asia-Pacific Mountain Courier is devoted to artistic means of expression related to youth and climate. It builds on the previous issue on youth and climate published in November 2010, which focused on youth views, understanding, and climate change activities (www.icimod.org/publications/index.php/search/publication/727).

The contributions include posters, photo essays, illustrations, and other art works. They are drawn from youth leaders and youth motivators affiliated to several networks promoting youth engagement in sustainability, climate action, and the mountain agenda. Many of the contributions are drawn from the Youth Forum – Empowering Youth with Earth Observation Information for Climate Actions, held from 1 to 6 October 2010 at

Warming or Warning?

Pariva Dobriyal, India



The Earth is heating up. This affects nature as well as our ancient culture, with the impacts of climate change being more evident locally than globally. Western Himalayan mountain communities are a good example. Climate change has affected their health, culture, and social life, both directly and indirectly. Less access to natural resources has led to increased intracommunity competition, ultimately affecting the social fabric in a negative way. The shifting of vegetation towards higher altitudes, with a low regeneration rate, and changes in the flowering and fruiting season, has deprived people of many resources. As a result, they have to cover larger distances to obtain resources like fodder and fuelwood. This causes health problems such as backache. By spending most of the time in resource gathering, people give less time to their family, their health, and their children's education, which ultimately affects their family and social life. Due to the rise in the average temperature, people in the western Himalayas have changed the habit of wearing hand-woven fabric made of sheep wool. Today, people mostly wear cotton clothes. Resource depletion due to climate change has affected their mental health by making them worried about short-term resource availability. Their lifestyle has also changed: their small houses with small windows and doors, slate roofs, mud walls and floors, designed for low temperatures, are being replaced by bigger cement houses. Changes in rainfall and snowfall patterns have adversely impacted the agricultural yield, resulting in economic insecurity for local communities.