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Introduction

Landscape could be defined as a cluster of interacting ecosystems, functioning as an integrated holistic entity, according to some observed patterns (Chorley and Kennedy, 1971; Vink, 1975; Ramakrishnan, 1992, 1996a). Naveh and Liberman (1984), Forman and Godron (1986), Urban et al. (1987) and Naveh (1998a) discussed the distinguishing features of elements/ecosystem types constituting a landscape, interdependence of different elements/ecosystem types and role of humans in modification of these interactions. Landscape ecology originally developed on the interface between physical geography and ecology. Landscape ecology provides a conceptual framework for integrated analysis of landscape processes and patterns for development planning (Egler, 1942; Dansereau, 1957; Vink, 1975; Forman and Godron, 1986, Ramakrishnan, 1992, 1996a). While the theoretical framework has been extensively applied for development planning, conservation and reclamation in European continent, its application has been evaluated only in a few cases in Asian, American and African continents (Naveh and Liberman, 1984).

The interaction of people and nature over time has produced closely interwoven biological, ecological and cultural patterns and processes in the landscape. Therefore, conservation and management of biodiversity at landscape level requires a transdisciplinary system approach with comprehensive and integrative strategies (Naveh and Liberman, 1984; Ramakrishnan, 1992; Bunce et al., 1993). Alarming rate of loss of biodiversity and ecosystem function in recent decades has catalysed efforts on analysis of ecosystems and species diversity at a range of spatial and temporal scales. Traditional societies, for some cultural/religious reasons, often worship some areas and do not allow any consumptive resource use in such areas. Such areas have been referred as sacred groves/sacred forests/sacred landscape. These sacred elements are interconnected with forests where consumptive use are allowed e.g., forest and human managed ecosystems (e.g., agroecosystems) with human integrated into the landscape through village ecosystem. Though many descriptive accounts of sacred species/grove/forest/ecosystem/landscape are available, information on the functional role of sacred ecosystem as an integral component of cultural landscape is only limited (Ramakrishnan et al., 1998). The present study aims to fill this gap.
Institutional and Management regime

Institutions are defined as the set of working rules or rules-in-use (Ostrom, 1990; North, 1993). These institutions do reflect social relations and play a crucial role in determining the sustainability of economic growth/development and sustainable utilization of natural resource base (Arrow et al., 1995).

Resource use decisions made by households and local communities in pursuit of today’s survival and livelihood security are influenced by the policies, institutions and technologies that impact on their lives. Such decisions are the main determinants of links between poverty elimination, improved land care and sustainable livelihoods (Jones, 1999). Institutional changes shape the way societies evolve through time and society’s evolution is ultimately dependent on a finite capacity of ecosystem to support it with essential resources and ecosystem services (Hanna et al., 1996a). Thus, integration of natural sciences with social sciences is essential for realising the goals of sustainable human development (Naveh, 1998b; Watson, 1999).

Mountain communities have tended to overcome natural constraints to production through diversified resource-regeneration practices and also through institutional means enabling intensity of resource use within carrying capacity, and collective risk-pooling and sharing practices (Jodha, 1993; Mountain Agenda, 1997; Prakash, 1997). Berkes (1998) explained how institutional evolution among the Cree society of Eastern subarctic Canada could promote an equilibrium of caribou and beaver population by dividing up a territory and rotating the parts. Whereas, sustainable fish harvest was ensured through: restrictions on gill net mesh size and fishing gear used, minimum fish size, season closures, and prohibition of fishing at times and places when fish are spawning.

Forest management in India

The history of Indian forestry is a history of the State as the sovereign, and the socio-economic consequences of its appropriation of forest resources as a source of revenues. It is also a history of the gradual erosion and loss of entitlements formerly enjoyed by local communities and, as a corollary, their capabilities to command those
assets, which provided critical inputs to local agricultural production systems (Guha and Gadgil, 1989). Such forest regimes based on commercialization and exclusion resulted in degradation of forest ecosystems and denudation of vast tracts of forestlands (Biswas, 1988; Poffenberger and McGean, 1996; Negi et al., 1997). Realizing the state of forest, Government of India recommended a New Forest Policy in 1988, with conservation becoming a priority, along with an emphasis on meeting the subsistence requirements of forest-dependent people. Later, on June 1, 1990 the Ministry of Environment and Forests issued a circular requesting that all states adopt Joint Forest management (JFM): joint management of forest resources by both the Forest Department and by the people living adjacent to forests (SPWD, 1993). Andersen (1995) examined the institutional development within the afforestation of village revenue land and existing institutional flaws of collective forest management and argued for a careful analysis of the kind of rights, of the categories of rightholders as well as the biophysical character of resource itself for successful functioning of these institutions.

An extensive study by Agrawal and Yadama (1996) on forest panchayats, a local institution at village level, for managing and conserving forest in Kumaon region of Central Himalaya identified socio-cultural context, state policies, technological variables, level of market pressure and demographic pressure as major factors. The study emphasizes on desegregating different aspects of institutions and the forms of participation that characterize user behaviour in order to understand resource dynamics.

The Concept of sacred

Social institutions linked to natural resource management evolved by different traditional societies across the globe and potential of traditional ecological knowledge in resolving conservation-development conflicts have been highlighted (Berkes et al., 1989; Gadgil and Guha, 1992; Hanula et al., 1996a; Berkes and Folke, 1998; Ramakrishnan, 1998a; Ostrom et al., 1999). The concept of ‘sacred species, sacred groves and sacred landscape’ belongs to such social institutions linked to natural resource management.
Sacred groves/landscapes

In a landscape dominated by altered/transformed ecosystems, a few small forest patches, protected in the form of sacred groves do exist. The 'Socio-cultural-religious practices' forbidding the use of any resource led to conservation of the unique biodiversity in sacred forest. There are several reports on the existence of sacred groves in the areas differently inhabited by traditional societies all around the world (Ramakrishnan et al., 1998).

Hughes and Chandran (1998) have reviewed the concept of sacred groves in different religions across continents. In the context of Mediterranean region, Hughes (1998) has interpreted the historical evidences and literature about the existence of sacred grove in ancient period, representing every major vegetation type in the region. However, with Christianization of the Roman Empire, the groves lost the religious and economic importance. In Africa, the relict vegetation of sacred grove still holds its significance. The well preserved sacred groves, locally called as Kayas occurring in Kwale and Kilifi District in Kenya, representing coastal forest have been recognized by the Kenya National Museum, and is provided legal/political protection in recent years (Michaloud and Durry, 1998). In Ghana, it is estimated that over 80% of the sacred groves serve as watershed or catchment areas that protect drinking water sources and provide medicinal herbs to people (Michaloud and Durry, 1998). Lebbie and Garies (1995) found 75 species collected from 23 sacred groves of Kpaa Mende in Sierra Leone used in local health care by the indigenous communities and which may also have potential medicinal benefits to the global community. Animistic belief of Dai people of Xishungbanna, Yunna, South West China has an important influence on the preservation and careful management of forests (Apel, 1996).

A network of sacred groves exists in India since time immemorial. They symbolize a way of life in which humans are embedded and interact with nature. They are found in the Khasi hills in Meghalaya, Aravali ranges in Rajasthan, Sarguja, Chanda and Bastar in Madhya pradesh, all along the western Ghat in South India, Chotangpur region in Bihar and elsewhere in the north eastern state of Mizoram (Gadgil and Vartak, 1976; Kheitwan and Ramakrishnan, 1989; Ramakrishnan, 1996b). They are known by
different names, such as *Kavu* in Kerala, *Sindharvana* or *Devarkdu* in Karnataka, *Deorais* in Maharashtra; *Vanis, Kenkris, Oraons* or *Shamlet dehsa* in Rajasthan, *Sarnas* in Bihar and *Safety Forest* in Mizoram. While, the concept of sacred groves is now well recognized the concepts of 'sacred species' and 'sacred landscape' have emerged recently. Sacred species could be viewed as a reductionistic concept of sacred grove through a process of social evolution (Ramakrishnan, 1998).

Attaching sacredness to species and landscape is perhaps more recent in Hindu society, as being part of the post-vedic Hindu ritualism. Thus, the pre-existing ecosystem level concept of sacred grove of the pre-vedic inhabitants of India was extended by the vedic migrants down to the species level on one extreme and to the level of the landscape on the other extreme (Ramakrishnan, 1998). Attaching sacred value to species like *Oak*, olive, apple, fir by considering them to be gods/goddess’s favourite were prevalent in Mediterranean region (Michaloud and Durry, 1998). In Iran, some 158 trees belonging to species like walnut, 'plane-tree', willow, cypress, turpentine have been identified as sacred in 21 provinces based on different faiths and belief of the people (Khaneghah, 1998). Some of the *Ficus* spp. of the fig family are culturally and religiously valued across Asia and Africa (Ramakrishnan, 1998; Khaneghah, 1998; Michaloud and Durry, 1998). There are many other species, which are also culturally valued by the local people in the Central Himalaya, such as *Quercus,* (the Oaks) in the Central Himalaya (Ramakrishnan, 1998; Sinha and Maikhuri, 1998).

The concept of ‘sacred landscape’ could be conceptualized by elaborating the concept of sacred grove representing an undisturbed ecosystem type, interacting with a set of others in the landscape (Ramakrishnan, 1996b; 1998). Thus, the guiding principle in demarcating the boundary for a sacred landscape lies in the identification of the ‘zone of influences’ exhibited by denizens of the localities/regions, who attribute sacred values to the particular ecosystem — forest, a pond, a river, a landscape etc. These values are manifested through a particular-specific cultural practice or a particular-specific belief system. The land, all along the course of the river Ganga from its origin in Garhwal Himalaya, the human habitation and the land-based activities, the temples dating back to antiquity, the sacred cities such as Gangotri, Badrinath, Kedarnath, Rishikesh and Haridwar in the Himalaya and sub-Himalayan tracts, Allahabad and Varanasi in the
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Gangetic alluvial plains, all together representing a set of inter-connected ecosystem types bounded together by the sacred river before its submergence in Bay of Bengal has been conceptualized as an example of a sacred landscape (Ramakrishnan, 1996b, 1998). Ramakrishnan (1996b, 1998) has also elucidated a more concretized sacred landscape ‘Demojong’ in the Sikkim Himalaya, exhibiting holistic expression of the ‘Buddhist’ philosophy of non-violence of kindness to all living beings.

While the occurrence and socio-cultural values attached to the sacred groves are well documented, their role in terms of ecological functions leading to hydrological balance, biodiversity, conservation and direct/indirect economic functions such as recharge of springs, the source of potable water, source of propagules of economic important species, protection of agricultural lands downslope have not been comprehensively analyzed in quantitative terms. A study conducted by Khiewtam (1986), Khiewtam and Ramakrishnan (1993), in a sacred grove of Meghalaya demonstrates the ecological functioning of one sacred grove in the North Eastern India. The present study on a sacred landscape, linking ecological issues with cultural integrity will play an important role in designing strategies for biodiversity conservation and management of this region.

Biodiversity

The Himalayas are a vast mountain system covering partly or fully eight countries of Asia; Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan. India’s recognition as one of the four ‘megabiodiversity’ countries of Asia and as one of the ten largest forested areas in the world derives partly from the Himalayas. The Himalayas, although covering only 18% of the geographical area of India, account for more than 50% of India’s forest cover, and for 40% of the species endemic to the Indian subcontinent.

Biodiversity is a comprehensive word for the degree of nature’s variety, including both the number and frequency of ecosystems, species and genes in a given assemblage (McNeely, 1988). The underlying rationale for evaluation of biodiversity is concerned with the methods and criteria used to draw up priority lists and to identify species and regions which are in need of greatest protection. Whereas, assessments are
undertaken either to identify the nature and extents of impacts on biodiversity or to identify species and habitats sensitive to impacts (Spellerberg, 1996). The relationship between disturbance and diversity has received increasing attention from ecologists and natural resource managers in recent years (Grubb, 1977; Connell, 1978; Grime, 1979; Huston, 1979; Oliver, 1981; Miller, 1982; Rykiel, 1985; Petraitis, et al., 1989; Pickett et al., 1989; Ehrlich and Wilson, 1991; Hansen et al., 1991; Tilman and Downing, 1994; Roberts and Gilliam, 1995; Peltzer, et al., 2000).

Agriculture land is constantly increasing as the human population increases at the expense of forestlands and other lands. Ambiguous definitions and standards, indeterminate areas of responsibility and differences in data collection strategies lead to omission and commission problems for conducting global and national assessments (Lund and Iremonger, 2000). Off late, both the extent and quality of natural forests are deteriorating at an alarming rate and this is a major concern to the sustainability of the environmental and socio-economic benefit from the Himalayan ecosystems (Eckholm, 1975; Ives and Messerli, 1989; Singh and Singh, 1992; Ramakrishnan et al., 1996a; Buch-Hansen, 1997). Biodiversity conservation, carbon sequestration and forest products (fiber, wood and fuel) are three primary use of forests (Lund and Iremonger, 2000). Besides, Forests are the store-house of a broad range of industrial, pharmaceutical products including several medicinal plants and wild relatives of many food plants (Swaminathan and Jana, 1992). As forests and other ecosystems become increasingly affected by human activities, integration of biological diversity and resource management objectives is needed to maintain the process necessary for the continued productivity of managed systems (Ehrlich and Wilson, 1991; Probst and Crow, 1991; Burton et al., 1992; Angermeier and Karr, 1994; Costanza et al., 1997).

Thus, a qualitative and quantitative assessment of forest biodiversity and man-forest biodiversity linkages is important. The present study is aimed at understanding some of these aspects in selected forest communities in Hariyali sacred landscape.

Forest Ecosystems Dynamics

Many studies are available on forest ecosystem structure across the altitudinal and a disturbance gradients in Himalaya (Toky and Ramakrishnan, 1983a, b; Saxena, et
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al., 1984; Khiewtam, 1986; Singh and Singh, 1986, 1987; Tiwari and Singh, 1987; Rana et al., 1989a, b; Sundriyal et al., 1994a; Garkoti and Singh, 1995). However, practical utility of ecological studies in resolving the problem related to ecosystem management and conservation of biodiversity (Franklin, 1993; Stohlgren, 1994; Stohlgren et al., 1997) has not been evaluated. In the Himalaya, an elevational transect includes vegetation from tropical monsoon forest to alpine meadow and scrub (Singh and Singh, 1992). Rawal and Pangtey (1994) classified the forest vegetation of Indian Central Himalaya (1500-4000 m) under three types: low to mid-montane sclerophyllous forests, broad-leaved forests, mid-montane deciduous forests and high montane mixed stunted forests. Singh and Singh (1992) have summarized data on forest characteristics from the foothills to timberline in the Indian Central Himalaya. Pine and Oak are the two predominant forest types in the Central and Western Himalaya distributed over 1200 and 2200 m elevation (Singh et al., 1984a).

The basal area of forest communities was 30-48 m² ha⁻¹ in Gola river catchment (Saxena and Singh, 1982a), 37 m² ha⁻¹ for Quercus leucotrichophora forest community and 34 m² ha⁻¹ for Quercus floribunda forest community (Rawat and Singh, 1988a) in area of Central Himalayan region. Standing tree density and basal area are reported in the range of 370-1405 trees ha⁻¹ and 11.6 to 191.5 m² ha⁻¹, respectively for different forest types present in Nanda Devi Biosphere Reserve in Garhwal Himalaya (Maikhuri et al., 2000). Singh et al. (1994) reviewed different forest types in Central Himalaya. They reported average density and basal area of forest dominated by Pinus roxburghii as 442 trees ha⁻¹ and 31.4 m² ha⁻¹; for broad-leaved evergreen forest as 922 trees ha⁻¹ and 56.3 m² ha⁻¹ and that of forest dominated by deciduous trees as 425 trees ha⁻¹ and 34.9 m² ha⁻¹. The Shannon-Wiener diversity index (H) values, based on tree density, ranged from 0.4 to 3.6 for individual stands and averages for forest types varied from ≈0.4 to ≈2.8 in Kumaun region (Singh et al., 1994). Spatial heterogeneity in community structure is attributed to the interplay of edaphic variation and past human activity (Clark et al., 1995).

In a forest stand, comparison of size class distribution of tree species can provide insight in understanding the nature and intensity of disturbances (Khan et al., 1987; Sundriyal and Bisht, 1988). Kubota (1995) found natural disturbances as the
primary cause of variation in stand structure in coniferous forest of Japan. Structural attributes of forest, such as basal area also have its influence on litter fall. A positive relationship between litter fall and basal area has been observed in a number of stands (Mehra et al., 1985; Sumida, 1991). However, a comparative quantitative analysis of forest types differing in terms of management regimes is lacking from this region.

Regeneration

Studies of gap dynamics have contributed significantly to the understanding of the role of small-scale disturbances in forest ecosystems. These studies suggest that intermediate levels of canopy removal have positive effects on regeneration (Bazzaz and Pickett, 1980; Denslow, 1987; Platta and Strong, 1989; Tsujimura and Akiu, 1992; Chandrashekhara and Ramakrishnan, 1994; Thadani and Ashton, 1995; Coates, 2000; Cássia and Mesquita, 2000). The inadequate regeneration of banj Oak (*Quercus leucotrichophora*) in the Himalaya has been reported in India for over 50 years (Troup, 1921; Saxena and Singh, 1982a; Singh and Singh, 1986, 1992). Oaks regenerate by seedlings and as well as through sprouting, but the relative importance of these two modes of regeneration differ among species (Larsen and Johnson, 1998). They suggest that natural regeneration of most Oak forest in North America depends on the accumulation of advance reproduction beneath the parent stand over successive acorn crops and the creation and maintenance of the condition that favour such accumulation. Thadani and Ashton (1995) studied the regeneration of this species in three forests under different tenurial and disturbance regimes of Central Himalaya. They found an average of 1400 seedlings ha\(^{-1}\); the seedlings number averaged only 510 seedlings ha\(^{-1}\), in sanctuary forest that was most protected compared to 2000 seedlings ha\(^{-1}\) in lesser protected private and reserve forests. Moreover, seedlings abundance varied inversely with the number of adult banj Oak. Singh *et al.* (1995) observed that basal area of trees was negatively correlated with sapling and seedling species diversities. Study on regeneration pattern in a sub-tropical forest of Mamlay watershed in the Sikkim Himalaya by Sundriyal *et al.* (1994a) showed the number of regenerating species to be much higher than the total number of species, which attained tree stratum. Negi *et al.* (1996) show the importance of open microsites and masting of *Q. floribunda* in regeneration and maintenance of Oak forest in Kumaun Himalaya. Khan *et al.* (1986), in sub-tropical forest of Meghalaya, India, showed that
survival of seedlings and sprouts was higher at the forest periphery than under the dense canopy, signifying the role of light in forest regeneration. Finzi and Canham (2000) showed that variation in light availability explained 21-79% of the variation in sapling growth of six species studied in southern New England forest. Occurrence of a good seed crop in Oaks, a ‘mast year’, is reported once every 2-3 years (Troup, 1921). Regeneration of Oaks have been sporadic and poor due to anthropogenic pressure (Upreti et al., 1995), acorn herbivory by Himalayan langoor (Presbytis entellus), and acorn worm (Calandra sculpturata) (Kaushal, 1989). Mature forest remnants in managed landscape assume importance in that they serve as seed sources for regeneration in surrounding ecosystems poor in woody species (Guevara et al., 1986).

Difficulty in the regeneration of Oaks has been reported by researchers in the USA (Downs and McQuilkin, 1944; Merritt, 1979; Abrams, 1992; Loftis and McGee, 1993), Europe (Pigott, 1983). Proposed causes of regeneration failure include: the lack of viable seeds due to insect or animal predation (Marquis et al., 1976), unfavourable microsites (Kittredge and Ashton, 1990) and grazing of seedlings by domesticated animals (Pigott, 1983) or deer (Marquis et al., 1976; Tilgman, 1989).

**Litter fall and decomposition**

Litter fall is a fundamental ecosystem process as it represents an essential flow in organic production-decomposition cycle (Meentemeyer et al., 1982). In the forests of Central Himalaya the litter fall from woody vegetation (trees and shrubs) ranges from 4.2 to 7.6 t dry wt. ha⁻¹ yr⁻¹ (Singh and Singh, 1992). Generally, these values are higher than 5.4 t dry wt. ha⁻¹ yr⁻¹, reported as the mean value for warm temperate forests by Bray and Gorham (1964). Annual litter fall for certain temperate broadleaf forests across the globe are mentioned in Rawat and Singh (1989) and for different forest types of Himalaya by Singh and Singh (1992).

Leaf litter and woody litter form 60-80% and 14-31% of the total litter fall, respectively in the Central Himalayan region (Singh and Singh, 1992). Leaf fall is seasonal in the Central Himalaya, with 37-53% of annual leaf falls in the peak month, generally April or May (Singh and Singh, 1987). This concentration of leaf shedding is
similar to dry tropical forests but differs from evergreen tropical forests, in which leaf fall is relatively consistent throughout the year (Reich, 1995).

Substrate quality is an important factor influencing the decomposition rate of litter (Meentemeyer, 1978; Klemmedson, 1992; Gallardo and Merino, 1993; Cadisch and Giller, 1997). Lignin, a slower decomposing component of litter and lignin/nitrogen ratio has a marked influence among substrate quality (Meentemeyer, 1978; Aber and Melillo, 1982; Gallardo and Merino, 1993; Stump and Binkley, 1993; Arunnachalam et al., 1998). These observations suggest that intrinsic qualities of leaf litter may be associated with soil nutrient characteristics of the forest along with synergetic effect of other factors (Climate, topography, reinstitution of nutrient by tree etc.). Pandey and Singh (1982) reported that 59% of variability in weight loss is explained by nitrogen and lignin content amongst six species of Central Himalaya. Study by Singh et al. (1990) shows that species diversity and fungal counts on the common leaf litter (Q. leucotrichophora) placed along an elevational gradient are markedly affected by the environmental change brought about by the native leaf litter. This effect was most obvious in the Chir Pine forest where the leaf litter of the native dominant species (P. roxburghii) was distinctly more resistant to decay, than those of other sites, making the soil environment of the site markedly different from that of other sites. Decomposition and nutrient release from different mixtures of Oak and Pine leaf litter showed that increasing amount of Oak caused faster release of N, S, Ca and Mg, signifying the role of substrate quality (Klemmedson, 1992). Epiphytes, which account for a lower proportion of litter production is known to influence the decomposition rate; Knops et al. (1996) found that it slowed the decomposition of Oak leaves on the forest floor.

Among environmental factors, the number of rainfall events is better correlated with the percentage dry matter loss than with the total amount of precipitation. Water-soluble fraction, C:N ratio and the polyphenol:N ratio of the residues are well correlated with number of rainfall events (Vanlauwe et al., 1995).

Edaphic conditions play an important role in development of different forest types (Eyre, 1968; Pastor et al., 1984; Fulton and Prentice, 1997; Namikawa et al.,
Among the different ecosystem parameters measured, nutrients in leaf fall correlated best with differences in soil nutrients across different stands of tropical tree plantations and secondary forests of similar age in Puerto Rico (Lugo, 1992). Effect of thinning of canopy may significantly influence accumulated carbon and nitrogen in the forest floor (Vesterdal et al., 1995). Vetaas and Chaudhary (1998) evaluated the relationship between environmental variables and species composition at different scales in a Central Himalaya mixed Quercus forest of Nepal. They found that elevation was the over-riding complex gradient (2000-3000 m), with loss-on-ignition, total nitrogen, and relative radiation covarying. Among soil nutrients, available phosphorus was most important factor independent of elevation, whereas, pH and nitrogen had minor independent influences. Plant-soil relationship was stronger for field layer species as compared to canopy species, which may relate to rapid changes over a short spatial extent both for the field layer species and environment (Webster, 1985; Palmer, 1990; Vetaas and Chaudhary, 1998). While, reviewing the relationship between soil and species composition in tropical rain forests, Sollins (1998) identified the following factors in decreasing order of importance: P availability, Al toxicity, drainage, water-holding capacity and availability of K, Ca, and Mg. However, he reiterates that correlation between species presence/abundance and soil properties are only first step in understanding causal relations between soil properties and plant species distribution, which need to be confirmed based on experimental trials.

In a comparative study on nitrogen content of leaves from broad-leaved and coniferous forest in Korea, nitrogen content in broad leaves is about 1.5 times higher than in Korean Pine needles. Besides, there are also results showing that nitrogen content per ha in the litters of a Pine forest is only 57.5% of that in a broad-leaved forest nearby (Chen et al., 2000). A possible approach to minimise nutrient deficiency is to maintain coniferous-broad-leaved forest for silvicultural practice. Thus, optimization of stands structure is the economic way to increase soil fertility and forest productivity.

**Complex Agroecosystems Dynamics**

Agroecosystems are human manipulated ecosystems, with a select composition of biodiversity to raise a variety of products for livelihood (Ramakrishnan, 1992, 1996c; Swift et al, 1996). A high level of crop diversity in traditional agroecosystem is
maintained through rotation of crops in small fields in time and space together with coexistence of mono and mixed cropping practices. Traditional values of diversified production system and emphasis on storage of surplus food production in good climatic year have been derived from the necessity of local production based food security, in difficult terrain subjected to diverse environmental risks, uncertainties and the concern for optimal utilization of environmental resources (Gliessman et al., 1981; Altieri, 1983, 1991; Richards, 1985; Paoletti and Pimental, 1992; Swift et al., 1996; Tsegaye, 1997).

Traditional agroecosystem of the Central Himalaya is complex. Crop husbandry, animal husbandry and forests constitute interlinked production system. Inaccessibility, environmental heterogeneity and ecological fragility have contributed to the evolution of diverse subsistence production systems, sustained with organic matter and nutrient derived from the forest (Pandey and Singh, 1984; Singh et al., 1984b; Ralhan et al., 1991; Ramakrishnan et al., 1996a; Ives et al., 1997; Nautiyal et al., 1998).

Many attempts have been made to understand the functioning of these complex agroecosystem taking different units ranging from a crop-field to a village ecosystem (Ralhan et al., 1991; Maikhuri et al., 1996; Semwal and Maikhuri, 1996; Nautiyal et al., 1998). However, a comparative account of agroecosystems with respect to different resource regime, taking a village-landscape as a unit, is lacking from this region. Thus, the present study deals with crop yields, biomass productivity, and ecoenergetic analysis of major crops and agroecosystem under Pine and Oak dominated resource in a landscape of Garhwal Himalaya assumes significance.

**Biodiversity in traditional agroecosystems**

The biodiversity of agroecosystems have been broadly classified into two components i.e. *planned* biodiversity (the crops and livestock) and *associated* biodiversity (above ground and below ground biodiversity, which influences the productivity of the former) (Swift et al., 1996; Perfecto et al., 1997). Swift et al. (1996) have hypothesized four different pathways of change in total agroecosystem biodiversity with respect to differential agricultural management practice and with differing implications for conservation. Complex (multi species) agroecosystem being directly transformed to modern agriculture (mono cropping, plantation etc.) is a major observed trend and leading to ecological unsustainability (Matson et al., 1997; Vandermeer et al.,
This trend is a result of farmer's/community's decision based on economic, cultural aesthetic values being tempered by pressures toward homogenization of production system (Swift et al., 1995; Vandermeer et al., 1998). For an instance, in Sudan, farmers are shifting to the more intensive technologies involving improved cultivars and fertilization in the absence of the area-expansion option (Ahmed and Sanders, 1998).

In spite of wide differences observed with respect to inputs and outputs in agriculture, there is a striking similarity between high-input and low-input agriculture. In both cases, food security totally depends on the availability of fresh water, fertile soil, pollination, natural recycling of nutrients and pollutants, biological pest control, and nitrogen fixation. These are services can not be substituted by injection of technical capital, and are heavily dependent on biodiversity (Ehrlich et al., 1993; Kendall and Pimental, 1994). Thus, maintaining and conserving biodiversity in traditional agroecosystems, especially in Himalayan context become more critical due to its fragility and inaccessibility.

**Agroforestry trees**

Rainfed agriculture on slopes is generally practiced as simultaneous agroforestry, where crops and trees are intermixed. Agroforestry trees are important sources of fodder, which in turn are converted into valuable plant nutrients, mostly by livestock (Carson, 1992; Yadav, 1992). Selection of tree species is mainly based on ecological knowledge of tree crop interactions and its fodder value; Thapa et al. (1995) listed 90 tree species valued by local people in eastern hills of Nepal. In subsistence hills agriculture, there exists a complementary relationship among trees, crops and livestock, where trees and crops provide fodder and bedding materials to livestock and in turn livestock provide draught power and manure. Animal excreta combined with large quantities of forest products collected for animal bedding and fodder accounts for a considerable proportion of nutrient supply to crops (Yadav, 1992; Nautiyal et al., 1998; Neupane and Thapa, 2001). Moreover, agroforestry trees act as surface mulch that replenish nutrients, conserve soil moisture and improves soil organic matter content by tapping water and nutrients leached from the surface (Carson, 1992; Young, 1997; Sharma et al., 1994, 1998; Maikhuri et al., 1997a). Kaur et al. (2000) have shown significance of
agroforestry trees (*Acacia, Eucalyptus* and *Populus*) in reclamation of alkaline soil in Karnal (India) by improving soil carbon, microbial activity and nitrogen availability.

In the hills, where farmers are confronted with dwindling food supply due to population growth and declining crop yields, agroforestry can contribute significantly to the improvements in household economic conditions, eventually enabling farmers to fulfill their food demand (Avila, 1991; Evans, 1991; Thapa and Weber, 1994; Maikhuri *et al.*, 1997a; Nautiyal *et al.*, 1998). It has been shown that agroforestry practices can improve food production (Vonmaydell, 1991; Sanchez *et al.*, 1997a) and be more profitable than conventional practices over the long run (Kurtz *et al.*, 1991; Neupane and Thapa, 2001).

**Ecoenergetic efficiency**

Energy analysis of agricultural ecosystems seems to be a promising approach to investigate and assess environmental problems and their relations to sustainability (Giampietro *et al.*, 1992; Ramakrishnan, 1993). Traditional agriculture generally shows a high output/input energy ratio (Ramakrishnan, *et al.*, 1992). However, over the last decades, technical progress in agriculture has lowered the efficiency in the use of energy inputs per unit of crop output (Pimental and Pimental, 1996). Energy in agriculture is closely linked to an integrated network of environmental endowments, human decisions, and market mechanisms (Dougherty, 1994). Besides, energy flow within systems represents a common denominator across systems and times and as such offers a unique opportunity for comparative studies (Spedding, 1979; Ramakrishnan, 1992). Dazhong and Pimental (1990) made a detailed energy input/output analysis of crop production in traditional organic, commune and state-farm systems in Hailun country in north-eastern China. They concluded that although the state-farm systems are using three times more fossil energy than the commune system, the crop yield in the state farm system were only 13% higher. This suggests more judicious use of energy for agroecosystem management. However, a review of trends in agricultural practices in different countries show that the socio-economic, demographic characteristics and actual productivity of labour and land are compelling people to move toward high-energy-input and labour-saving technologies (Giampietro, 1997).
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Internationally, many calculations of energy output/input ratios of different agricultural ecosystems have been made (Norman, 1978; Dazhong and Pimentel, 1984; Bansal et al, 1988; Schroll, 1994). These output/input ratios are difficult to compare because they are calculated at different temporal/spatial scale under varied climate, types of soil, technology and political conditions. Similar analysis on energetics/eco-energetics and biomass utilization pattern of the existing traditional hill agroecosystems in Central Himalaya are also carried out by different workers (Ralhan et al., 1991; Semwal and Maikhuri, 1996; Maikhuri et al., 1996; Nautiyal et al., 1998). Common to all these studies is that farmyard manure is the major constituent of total energy inputs to agroecosystems. Hence, quality and quantity of farmyard manure will be an important determinant for ecological efficiencies of these traditional agroecosystems. This forms the basis of the present study for analysing agroecosystems differing in respect of quality and quantity of manure inputs.

Village Ecosystem Analysis

The concept of village as an ecosystem, with all its ramification involving agriculture, animal husbandry and the domestic sector enmeshed with the forest resources, and integrating human within would be appropriate to understand the resource budgeting under different subsystems of the village under the subsistence economy (Ramakrishnan, 1992).

Traditional agriculture practices in Central Himalaya, has in recent times fallen into disrepute because of qualitative and quantitative degradation of natural resources, population pressure and changing socio-economic conditions. This has disrupted the functioning of the village ecosystem and also the traditional linkages between the local communities and the forest resources on which they depend.

In fact, many of the studies that have looked at traditional societies have considered only a specific component of the village system, such as agriculture, animal husbandry or the domestic sector (Spedding, 1975; Chandra et at., 1976). Only a few studies have considered the village landscape as a functional unit (Reddy, 1981; Mishra and Ramakrishnan, 1982; Singh et al., 1984b; Maikhuri and Ramakrishnan, 1990; Nautiyal et al., 1998). This integrated approach to understanding the functioning of
traditional societies living in village clusters would involve: (i) the traditional land
management practices for agriculture and animal husbandry, (ii) the linkages between
different land use systems in the landscape and (iii) the self-sufficiency/dependency of
the village communities as they now operate (Ramakrishnan, 1992).

**Nutrient management**

Supplementing the nutrient requirement of crops through organic manure
plays an important role in sustaining soil fertility, and crop productivity and reducing
Nutrient management in traditional agroecosystems of hill region was primarily
through use of organic manure, multiple cropping and crop rotation. However, use of
inorganic fertilizer under irrigated systems along with crop-intensification and
introduction of cash crops has also started (Singh *et al.*, 1997; Maikhuri *et al.*, 2001).
Chataurbedi (1985) showed that rapid deforestation of hill-slopes resulted in the
alteration of the hydrological cycle and in a tremendous amount of soil loss.
Similarly, Arya *et al.* (1985) found hill-slope soils in India suffered substantial loss of
nitrogen in water.

With no significant difference in physical properties of soil between different
ecosystems, the differences in biological and chemical properties of soil observed can
be attributed either to the resource input (quantity as well quality) or management
practices, rather to inherent soil properties (Murage *et al.*, 2000). In a comparative
study on nutrient status of soil between hill-slope, where agriculture was practiced
and adjoining forest land in southwestern Nigeria suggested that continuous cropping
practice on hill-slope agroecosystem lead to degradation in structural as well nutrient
parameters of soil (Ekanade, 1997). Compton *et al.* (1998) found higher bulk density,
lower C:N ratios, and slightly lower carbon concentrations in the surface mineral soil
in ploughed soil as compared to forested/unploughed land. Introduction of cash crops
as an alley crop, with least possible tillage may promote to reverse the process of soil
degradation. Mulching with crop byproducts is another possible method to increase
soil organic matter and improve nutrient status (Ekanade, 1997). Similar correlation
between application of FYM and enrichment of soil organic matter and nitrogen is
also observed under soils of Askov in Denmark (Christensen, 1988) and semi-arid
part of northern Tanzania (Solomon et al., 2000). Whilst, Swamy and Ramakrishnan (1987) has shown soil-nutrient enrichment through recycling of weed biomass in north-eastern India. Patra et al. (2000) indicated that combined application of inorganic fertilizers with organics help in increasing the availability of nutrients and crop yield and provides a significant effect to the succeeding crops. Market forces also influence the nutrient balance of a farm. A study by Jager et al. (1998) in three districts of Kenya showed that a high market influence was correlated with a more negative N and K balance. A regional survey of management and crop type and soil organic matter content (SOM) carried out in Netherlands showed that SOM was a function of crop type and land use history (Pulleman et al., 2000).

Quality of farmyard manure (FYM)

Predicting nutrient contribution is a critical issue to developing organic matter technologies, which have immediate impact and are farmer acceptable. Recent work has shown the value of chemical characteristics to assess quality of the organic resources and nutrient availability (Palm, 1995). The percent of N, lignin and polyphenol, C:N, lignin:N, Polyphenol:N and (lignin+polyphenol):N ratios are the major determinants of chemical composition (Mafongoya et al., 1997). High quality organic inputs are low in lignin and polyphenol and high in percent N with low quality materials having the opposite characteristics (Palm et al., 1996).

Addition of low quality organic inputs may, over time, increase soil organic C, but without necessarily increasing the productivity of the cropping systems. A study by Goyal et al. (1992) on cropping system in India, showed that wheat straw combined with urea substantially reduced yields, whereas Sesbania green manure combined with urea enhanced yields compared with application of urea applied alone.

Higher nitrogen and lower lignin concentration in Oak leaves as compared to Pine needles (Singh and Singh, 1992) is likely to result in similar differences in FYM derived from Oak-based and Pine-based resource, respectively. Lower C/N ratio and lignin percentage of Oak-based FYM as compared to Pine-based FYM makes them qualitatively superior over Pine-based FYM. Such difference requires a focussed research in order to achieve better synchrony between nutrient release from FYM and
nutrient-uptake by crops through their management linked to time and quantity of FYM-application for different crops (Myers et al., 1994). Moreover, in the context of Himalayan region where nutrient status/replenishment of different naturally and human managed ecosystems is a function of organic residues derived locally. A better understanding of the ecology of earthworms is needed to improve soil fertility.

**Role of soil organisms**

The inclusion of soil organisms in ecological theories is a modern approach that could potentially provide a better understanding of the structure and functioning of below-ground ecosystems (Ohtonen et al., 1997). Soil organisms alter the physical, chemical and biological properties of soil in innumerable ways and occupy the spatial heterogeneity of resource. Thus, identification of functional groups of soil organisms within sphere of influence needed highest research priority. Various research papers have discussed the role of functional groups with respect to their functional attributes in ecosystem processes (Beare et al., 1995; Brussaard et al., 1997). Soil macrofauna could be used as an indicator of soil health only when correlation between soil macrofauna and soil fertility attributes are established (Lobry de Bruyn, 1997).

**Role of earthworms**

Earthworms, which inhabit soils and litter layers in most landscapes, can offer an important tool to evaluate different environmental transformations and impacts (Paoletti, 1999). Earthworms have a critical influence on soil structure and improving the physical conditions of plant growth and nutrient uptake. Rarely has a direct link been established between the improvement of soil structure attributes by earthworms and enhanced plant productivity. Nevertheless, it is generally agreed that earthworms improve soil structure to the benefit of soil productivity (Barley, 1959; Lee and Foster, 1991). Earthworm's role in soil fertility maintenance as an important consumer/decomposer of organic matter is well established (Satchell, 1947; Dash, 1978; Senapati and Dash, 1984). Blair et al. (1995) recognized the importance of earthworms in affecting soil organic matter dynamics and nutrient cycling processes. Besides, earthworms are useful in land improvement and reclamation (Edward and Bater, 1992).
Earthworms can affect soil microflora and fauna populations directly and indirectly by three mechanisms: (i) comminution, burrowing and casting; (ii) grazing; (iii) dispersal. These activities together change the soil's physico-chemical and biological status and may cause drastic shifts in the density, diversity, structure and activity of microbial and faunal communities within the drilosphere (Brown, 1995). While much information on the role of earthworm in maintenance of temperate soil fertility is available (Edwards and Lofty, 1978; Syers and Springelt, 1984; Lee, 1985), their role in natural ecosystem function in particular is least understood (Dash and Patra, 1979; Krishnamoorthy and Vahranbhaiah, 1986).

The study of the relationship between earthworms and soil factors is difficult because of the great complexity of the environment in which they live, which is the result of the interaction of biotic and abiotic variables that are difficult to measure and are generally very variable. However, based on an autecological study, it can be concluded that the main factors influencing distribution for the majority of earthworm species were pH, calcium, magnesium, C/N ratio and organic matter levels of the soil (Briones et al., 1995). Briones et al. (1992, 1995) analyzed earthworm communities from meadows, river banks and woodlands in Spain and concluded that pH, calcium, magnesium, aluminum, C:N ratio, organic matter content, soil texture and moisture were the most important factors explaining the composition of the earthworm community. Bhadouria and Ramakrishnan (1989) found that population size of earthworms was significantly correlated with soil moisture, temperature and organic matter.

Of the soil textural variables, silt content was most highly correlated with earthworm biomass and earthworm abundance. Number of individuals was related to quantity and quality of plant residues inputs and standing stocks of soil organic carbon (Hendrix, et al., 1992). Study by Steingberg et al. (1997) on earthworm abundance and nitrogen mineralization rates along an urban-rural Oak forest stands showed significantly higher abundance and biomass of earthworms in urban than in rural stands.
Diversity and density of earthworms

Fragoso and Lavelle (1992) concluded that the average number of species in tropical rain forests (6.5 spp.) was not significantly different from that in temperate deciduous forests (5.7 spp.). Earthworm biodiversity can be studied from the taxonomic (native or exotic) and functional (epigeic, endogeic, anecic) point of view (Fragoso et al., 1997). Earthworm diversity is affected when natural systems are modified and the number of native species decrease significantly from natural to managed ecosystem (Fragoso et al., 1997).

In a survey of 42 farm sites, comprising grassland and two types of horticultural farms, abundance, biomass and species richness were significantly higher in grassland soils than in horticultural soils, with no epigeic species found in horticultural soils (Didden, 2001). Moreover, the differences between the various farm types were probably related to the intensity of management practices, such as soil tillage, harvesting and crop protection measures, that result in less soil organic matter of lower quality (Didden, 2001). Forest management practices (like tillage, removal of litter and log, harvesting practices) which in turn change the soil properties and alter the earthworm's habitat and activity (Edward and Lofty, 1982; Pizl, 1992; Jordan et al., 1997, 1999).

There are many studies on earthworm communities and its linked ecosystem processes, but largely confined to tropical/sub-temperate north-eastern hill region of India (Mishra and Ramakrishnan, 1988; Bhaduria and Ramakrishnan, 1989, 1991, 1996; Tewari and Mishra, 1995). Such studies from Central Himalaya are limited and are ecosystem-specific, restricted to sub-temperate forest ecosystem (Bhaduria et al., 2000) or to rainfed agroecosystem types (Bhaduria et al., 1997). The present study on earthworm biodiversity in a landscape consisting of different ecosystem types is aimed to study from the taxonomic (native or exotic), functional (epigeic, endogeic, anecic) and its correlation to soil characteristics point of view. This will enable in understanding the implications of different management regimes.

Studies on density, biomass of earthworms and production of their cast from different age of pineapple plantation from N. E. India showed that variation in these
parameters were statistically significant with time and plantation age (Tewari and Mishra, 1995).

Laboratory study carried on the growth and cocoon production by the earthworm *Drawida nepalensis*, a common occurring species of Central Himalaya indicated its better suitability to Pine litter than Oak litter through its higher growth and cocoon production (Kaushal et al., 1995).

A comparative analysis of earthworm communities in forest ecosystems with different degree of disturbances in Central Himalaya showed that process of deforestation leads to decline in the density of endemic species and the dominance by exotics (Bhadauria et al., 2000).

From functional point of view, epigeic and anecic species do not appear to be as widespread in agroecosystems and their dependence on a litter layer for survival implies that litter management practices must be implemented for their role in soil function to be important (Fragoso et al., 1997).

**Context**

The problems of resource scarcity and environmental degradation are common in the present situation of fast growing human population, all over the developing world, and in the Himalayan region too (Ramakrishnan, 1994). During recent past, a variety of changes in traditional Himalayan agroecosystem have emerged in response to population pressure, technological innovations, market forces and land tenure management policies etc. (Maikhuri et al., 2001). Negative trends in agroecosystems such as declining crop yields, expansion of agriculture on marginal land (Eckholm, 1975; Singh et al., 1984b; Rao, 1997), declining carrying capacity of the rangeland (Negi, 1990; Rao, 1997) weed infestation (Saxena and Ramakrishnan, 1984) loss of crop genetic diversity (Maikhuri et al., 1991, 1996, 1997b; Singh et al., 1997) and social disintegration (Ramakrishnan, 1992) have emerged as threat to sustainable livelihood. Severity of these problems and their implications vary a lot within the Himalaya because of a huge physical, biological and socio-economic diversity (Ramakrishnan et al., 1996b; Ives et al., 1997). Mountain features, specificities and
implication for reorienting development have been interpreted in different ways, especially since the last two decades, in order to stress the importance of location specific developmental planning (Allan et al., 1988; Ives and Messerli, 1989: Sanwal, 1989; Jodha, 1990a, b; Stadelbauer, 1991; Ramakrishnan, 1992; Scott and Walter, 1993). Himalayan region owes special attention due to its fragility and considerable damages inflicted on it over a period of time, whatever be the causal factors (Rao and Saxena, 1994; Ramakrishnan et al., 1995). The Himalayan environment influences not only the people living in this region but also many more living in the adjoining plains, as it determines the water flow and sedimentation through river systems; the Indo-Gangetic plains supports one of the most thickly populated and most productive regions of South Asia (Ives and Messerli, 1989; Bandyopadhyay et al., 1997).

A number of ecosystem level studies have been attempted in the Central Himalayan region emphasizing upon different aspects of agroecosystems (Singh et al., 1984b; Ralhan, et al., 1991; Maikhuri et al., 1996; Semwal and Maikhuri, 1996) and forest ecosystems (Pandey et al., 1982; Saxena and Singh, 1982a, b; Saxena et al., 1984; Rawat and Singh, 1988 a, b; Rana et al., 1989a, b). There are only a few examples of studies at landscape level in the context of Indian subcontinent, such as that from north eastern India by Ramakrishnan (1992, 1996d). Ramakrishnan (1993) emphasizes a landscape as a unit for developmental processes to be initiated with short-term and long-term strategies as appropriate for ensuring maximum people's participation. Watershed as a landscape unit for interdisciplinary studies is an approach taken by some as in the Sikkim Himalaya (Rai et al., 1994; Rai, 1995; Sundriyal and Sharma, 1996) and Central Himalaya (Saxena et al., 1994; Rao and Pant, 2001; Tripathi and Sah, 2001). What is called for is considering the landscape as a development unit for an interdisciplinary analysis in the Central Himalayan system, as elsewhere in the mountains. Though the problem of deforestation and declining yield in agroecosystems are common all across the Himalaya, the problems are more intense in the mid-elevational zone because of high population pressure (Singh et al., 1984b). In the Central Himalaya, the grazing pressure is 2-3 times higher than the actual carrying capacity of the land. It has been estimated that, about 9000 square kilometre area of the Central Himalaya is severely affected by the overgrazing (Pandey et al., 1982). Apart from providing direct inputs to agroecosystem functions and a variety of products obtained for sustainable livelihood
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(fuelwood, NFTP, timber etc.) the forests are valued for their unique and enormous biodiversity and ecosystem services (maintaining hydrological balance, preventing soil erosion, carbon sequestration etc.). Thus, interaction between different agroecosystem and natural ecosystem types with human integrated within, at the scale of a landscape assumes significance for designing sustainable natural resource management and livelihood strategies. The present landscape study, on a component of the Garhwal Himalayan system attempts to analyse the landscape level patterns and processes, of a typical mid-altitude rural landscape in Garhwal Himalayas.