CHARACTERIZING DIVERSITY IN A MID-ALTITUDE VILLAGE LANDSCAPE IN GARHWAL HIMALAYA

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CERTIFICATE

The research work embodied in this dissertation entitled "**Characterizing diversity in a mid-altitude village landscape in Garhwal Himalaya**" has been carried out at the School of Environmental Sciences, Jawaharlal Nehru University, New Delhi – 110067. This work is original and has not been submitted in part or in full for any other degree or diploma of any university.

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Deepak Kumar Choudhary

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1. Introduction

The Himalaya lying in the Indian Territory is spread over a length of about 2500 kms and a width of 220 to 330 kms. It covers partially/fully eleven states of India viz., Jammu and Kashmir, Himachal Pradesh, Sikkim, Nagaland, Manipur, Mizoram, Tripura, Meghalaya, Assam, West Bengal and Uttaranchal. Geographical area covered in the state of Jammu and Kashmir and Himachanl Pradesh is commonly referred to as Western Himalaya, Uttaranchal as Central Himalaya, Sikkim and Arunachal Pradesh as Eastern Himalaya and mountain areas in other Indian states as North-Eastern extension ranges. The region is characterized by sparse population, undulating terrain, far-flung small villages difficult to approach, scattered land holdings, shallow and gravelly soil, agropastoral economy, scanty irrigation and lack of technological advancements (Rao and Saxena, 1994). Himalayan region covered in the state of Uttaranchal consist two sub regions viz., Garhwal and Kumaon. The Garhwal Himalaya spread over a geographical area of 29698 km^2 (29^0 26^1 to 30^0 28^1 N latitude and 77^0 49^1 to 80^0 6^1 E longitude) comprises of seven districts out of 13 districts of Uttaranchal state of India. Although the Himalayas cover only 18% of the India's geographical area, it accounts for more than 50% of India's forest cover and 40% of the species endemic to the Indian subcontinent (Semwal et al., 2004).

1.1 Land use diversity in Himalaya

Land use diversity is more pronounced in mountains which occupy a three dimensional space in contrast to the two dimensional spatiality of low lands. Variability in terrain features such as slope and altitude gets manifested as landscape heterogeneity/diversity. Unique geographical location of the Himalaya and geographical processes influencing the region, further magnify the effects of slopes and altitudes (Rao and Saxena, 1994). The land use diversity in Garhwal Himalaya can broadly classified into forest land uses and agricultural land uses.

1.1.1 Forest land uses

The Central Himalaya, with its dramatic differences in altitude and climate supports a great variety of forest ecosystems. Below 1200 m lie tropical and subtropical broad-leaved forests. Between 1000 and 2200 m Pine forests dominate, and from 1500 to 3500 m moist temperate evergreen broad-leaved, and mixed coniferous forests are found. Sub alpine forests occur around 3500 m, with the timberline situated at about 3600 m (Singh et al., 1984a).

Based on the agencies owning the responsibility of forest management and land rights, forests of Central Himalaya are classified as: (i) Reserve Forests, which are owned and managed by Government Forest Department; (ii) Civil Soyam Forests, comprising small forest patches interspersed around settlements – the land ownership rights of these forests are vested with the Revenue Department and management responsibilities with the Forest Department; (iii) Panchayat Forests - the land ownership rights are vested with the Revenue Department and a local institution called Vanpanchayat (comprising 5-10 individuals elected by the people) is empowered to regulate subsistence forest resource uses but require government approval for any commercial extraction; (iv) Cantonment Forests, which are owned and managed by military cantonments; and (v) Private Forests, which are owned and managed by individuals (Maikhuri et al., 2000; Wakeel et al., 2005). The area of private forest is negligible compared to the area of other classes of forests (Anonymous, 1980).

Forest ecosystems have important function from an ecological perspective and provide services that are essential to maintain the life support system on a local and global scale. Green house gas regulation, regional hydrological balance, nutrient cycling, genetic and species diversity as well as recreation are only some examples of the services that forest ecosystem provides. The forests of Himalaya not only support millions of residents in the region but also much more people residing in the Indo-Gangetic plains through water cycle regulation (Bruijnzeel and Bremmer, 1989; Hamilton, 1987). Agriculture is the principal activity in the region, which depends on the natural forest vegetation cover for its sustainability.

Despite great ecological importance, forests of Central Himalaya suffer from degradation and forest loss (Rao and Pant, 2001; Awasthi et al., 2003; Semwal et al., 2004; Wakeel et al., 2005). The position at present is that only 24.9% (7473 km^2) of Garhwal Himalaya is now forested and only 4.1% of the area has a forest with greater than 60% crown cover (Singh et al., 1984a). The situation has deteriorated further since then (Ramakrishnan et al., 1992). Study from the Central Himalayan watershed by Rao and Pant (2001) found that between 1963 and 1980 agricultural expansion took place. The forested and nonforested community lands were cleared and converted to agricultural areas, the driving force for this change being population increase as well as laxity of forest policy implementation. Between 1980 and 1995, there was a decline in expansion of agriculture and forest use was more extractive only, which converted dense forest areas into sparse forested areas and forest blanks (Ghosh et al., 1996, 1997; Singh and Singh, 1991). The demands of fuel, fodder and manure were the driving forces for this. There was a seasonal variation in the nature of resources extracted from the forest. Fire wood being the major source of fuel was extracted throughout the year where as lopping for leaf fodder mostly occurred during months of February – May and leaf litter was collected during winter season when cattle were kept in the sheds (Awasthi et al., 2003). Loss of forest was more prominent in areas where management responsibilities vested with the people's institution than in the areas managed by the Government Forest Department (Wakeel et al., 2005). This could be attributed to weakness of existing people's institutions (Maikhuri et al., 1997a,b), policies discouraging forest resource based economic benefits to the people and people's appreciation for economic development options rather than merely Community property rights (Vandergeest, 1996).

Oak trees, especially in areas controlled by Forest Department are excessively lopped, often reduced to almost bare standing boles. Opening of canopy in oak forest gives way to early successional light demanding pines. As pine resin extraction is in the hands of Forest Department, the Department promoted conversion of oak to pine forests. Conversion of oak to pines due to frequent intense disturbance is widespread in the Himalaya (Singh et al., 1984a; Thadani and Ashton, 1995) and also elsewhere (Gibson et al., 1988).

Studies from the region indicated that to sustain the productivity of each unit of rainfed agricultural land on raised terraces in central Himalaya, 5-17 units of agricultural support land (forests and grazing lands providing manure) are needed (Singh et al., 1984a; Ashish, 1993; Hrabovzsky and Miyan, 1987). The large variation in the support land required may be due to differential carrying capacity of land in the mountain areas where the natural vegetation capacity to produce biomass is highly variable over an elevational gradient (Rao and pant, 2001). If forest decreases, the agriculture in the region becomes unviable. Modification of agriculture to agroforestry and agri-horticulture and introduction of irrigation has showed potential to overcome these constraints, but the environmental costs of this are not fully understood in central Himalaya (Saxena et al., 1990; Rao et al., 1999).

1.1.2 Agricultural land uses

In terms of spatial extent, agriculture is a minor land use (net sown area accounts for only 10% of total area of Himalaya) distributed as the 'patches' in the 'matrix' of forest, but is significant from both ecological and socioeconomic considerations (Semwal et al., 2004). Studies from the central Himalaya by Singh et al. (1984a), Pandey and Singh (1984), Ralhan et al. (1991), and Semwal and Maikhuri (1996) indicate that the agriculture practice requires a massive consumption of forest resources. Traditional crop-livestock mixed farming is the basis of livelihood of local communities and backbone of rural economy (Rao and Saxena, 1996; Tripathi and Sah, 2001).

The traditional hill agroecosystem of the central Himalaya exhibits a great deal of variability in crop diversity, crop composition, crop rotation etc. along an altitudinal transect due to corresponding variations in a number of factors which influence agricultural practices. Thus, the region could be divided into three markedly different agro climatic zones along the elevation gradient. The zone between 500 and 1000 m above mean sea level (amsl) is considered as the lower altitude area, between 1000 and 1800 m amsl as middle altitude and the 1800 and 2600 m amsl and above as the higher altitude area. Rainfed and irrigated land use systems are important in this region in which the former is the predominant form and covers almost 89% of the total agricultural land of the area (Maikhuri et al., 1996).

Mixed and monocropping, particularly in rainfed agroecosystem practiced on sloping terraces, has an extremely long tradition in this region. The cropping patterns generally up to 1800 m amsl, and sometimes 2000 m amsl, are built around two major cropping seasons viz., kharif (Apr-Oct) and rabi (Oct-Apr). Traditional farmers of this region generally cultivate ten to twelve and sometimes more crop species in rainfed agroecosystem to meet all their food requirements throughout the year. The majority of the crops cultivated by them are traditional or under utilized and include *Amaranthus* spp., *Hordeum himalyens, Eleusine coracana, Fagopyrum* spp., *Setaria italica, Echinochloa frumentacea, Macrotyloma uniflorum, Vigna umbellate, Parilla frutescense* etc. From rainfed agriculture generally three crops are taken every two years, while from irrigated land two crops are taken each year. In rainfed agriculture of lower and middle altitudes, the land under mixed cropping of finger millet and pulses in the kharif season remains fallow during rabi season for six months. At higher altitudes, particularly above 2000 m amsl the cropping patterns do not follow the above cropping seasons found at lower and middle altitude, and most of the crops are cultivated between March and October (summer season crops) owing to cold climate condition.

All these traditional under-utilized crops are largely grown along traditional lines. The main characteristic features of the agroecosystems of this region are the use of bullocks for drought power and humans for labour, the use of crop residues to feed livestock during winter months and the use of cow dung and forest litter as a source of farmyard manure to improve and maintain the fertility of agricultural land. In general crops grown under irrigated condition receive higher (25-40 t/ha) amount of farmyard manure than those grown under rainfed condition (15-35 t/ha). It is because of the fact that Irrigated land is more intensely cultivated than the rainfed land. Rabi (winter) season crops receive higher quantity of farmyard manure than kharif (summer) season crops in Rainfed as well as Irrigated agroecosystem (Maikhuri et al., 2001). Human labour, particularly women, play a crucial role in almost all the agricultural activities in this region. Crop rotation is another important feature of rainfed agroecosystems to preserve the fertility of the soil as well as to enhance or maintain crop productivity.

Traditional crops are essential components of diet in many parts of the central Himalaya. These traditional crop verities have evolved over centuries and are well adapted to the particular area. Traditional crops have the potential to provide more dietary energy per hectare than common crops, and some traditional crops, such as amaranth, finger millets, hog millets etc., can be cultivated in different agro-ecological regions across altitudinal gradients, to provide increased food security. From the point of view of nutrition, many of these traditional crops and pulses such as *Amaranthus*, Himalayan barely, *Fagopyrum* spp., *Macrotyloma* and *Vigna* spp. may prove to be superior to common crops and pulses. Traditional pulses (*Macrotyloma* and *Vigna* spp.) have 1.5 to 2.0 times more protein than wheat and 2 to 4 times more protein than rice (Maikhuri et al., 1996, 1997c, 1999, 2001).

Neglect towards traditional crops on the one hand and a massive push towards technologies with ever increasing dependence on resources from outside seems to be one of the reasons for this crisis (Jodha, 1990; Rao and Saxena, 1994; Ramakrishnan et al., 1994). Consequences of this are disastrous both for biological diversity of the region as well as for developing sustainable agroecosystems. The steady erosion of these valuable traditional crops requires immediate steps for their conservation to save them for the future and agricultural sustainability.

1.2 Soil organism

Soil organisms comprise a huge number of species (Giller, 1996) that play a central role in various ecosystem functions like soil organic matter turnover or soil structure dynamics (Dangerfield and Milner, 1996; Lavelle, 1996; Brussard et al., 1997; Setala et al., 1998; Wardle et al., 1998; Wall and Moore, 1999; Barros et al., 2004). Macro-invertebrates occupy prominent place in the Community of soil organisms and play key role in different processes that determine soil fertility. They regulate microbial population responsible for mineralization and humification and consequently influence organic matter cycling and release of nutrients. They contribute to the formation of stable aggregates that may protect a part of soil organic matter from rapid minearlisation and therefore constitute a plant nutrient reserve. They modify texture and physical properties of upper horizons of soil that they inhabit (Lee and Foster, 1991; Doube et al., 1994; Lavelle et al., 1994; Pankhurst et al., 1996;

Edward and Bohlen, 1996). Macro-invertebrate activity may also favour plant growth (Spain et al., 1992; Pashanasi, et al., 1996). The diversity and abundance of macro-invertebrate communities and the selective importance of major groups such as termites, earthworms and ants can therefore be used as indicators of soil fertility and quality (Stork and Eggleton, 1992). These soil biota are responsive to natural stresses as well as to human induced disturbances like agricultural practices, deforestation, pollution and global environmental changes and in turn show negative consequences like loss of primary productivity, loss of cleansing potential for wastes and pollutants, disruption of global elemental cycles and feed back on green house gas fluxes and erosion (Swift and Bignell, 2001).

Although diversity of soil biota can be descrbed in a few size classes and spheres of influence, they must be studied at taxonomic level to fully appreciate structural and functional diversity presented by these organisms, and to understand effects of human induced stress and disturbance on their activities (Brussard et al., 1997). Major taxonomic groups under different size classes of soil organisms are: Microorganisms, Microfauna (invertebrates <0.2 mm diameter), Meso-fauna (0.2 – 2 mm diameter) and Macrofauna (>2 mm) (Swift, et al., 1979).

Microrganisms: Free-living bacteria facilitate elemental immobilization and mineralization, show mutalistic intestinal associations, act as resources for grazing animals and decompose agro-chemicals and xenobiotics. Rhizobial bacteria as symbiosis fix nitrogen and also supply energy to root feeding nematodes and other animals. Non-mycorrhizal fungi help in elemental immobilization and mineralization, act as resource for higher order taxa and facilitate redistribution of nutrients and soil aggregation. Mycorrhizal fungi give competitive advantage to higher plants in different physiological process such as uptake of phosphorus; regulate carbon allocation belowground and form root mycosphere for bacteria. They protect root from diseases and herbivores and serve as high quality resource for microfauna and meso-fauna.

Microfauna: They are only slightly more mobile than microflora. Many are predators of microorganisms and form food webs of great functional importance in specific microhabitats, such as rhizosphere system (Trofymow and Coleman, 1982; Clarholm, 1985; Ingham et al., 1987). Protozoan and nematodes are the examples of microfauna.

Meso-fauna: They are mobile throughout the pores, cracks and interfaces of litter and soil. Some of them are predators of microorganisms but others have developed on 'external rumen' type of digestion (Swift et al., 1979). This consists mainly of stimulating microbial activities in their faecal pellets and re-ingesting this material once microorganisms have released assimilable elements. Common examples of mesofauna are mites, collembola and enchytraeids.

Macrofauna: Earthworms act as ecosystem engineers/bioturbators. They play major role in fragmentation of litter. They enhance microbial growth, host protozoa and other parasites and disperse microorganisms and algae. Termites also act as ecosystem engineers/bioturbators. They enhance microbial growth and act as keystone species for fauna and plants associated with mounds. Ants also act as bioturbators, enhance microbial growth and act as keystone species for fauna and plants associated with ant hills. Beetles act as decomposers of plant and animal matter. They are involved in above ground and root herbivory and dispersion of microorganisms. Centipedes act as predators to animals of lower taxa and millipedes feed on plants residue.

In addition to above, there are orthoptera (eg., grasshoppers, crickets and cockroaches), Arachinda (eg., spider, scorpions) mollusca (eg., snails) and few other taxa that dwell in or near soil, perform miscellaneous functions and participate in detritus food chain (Kuhnelt et al., 1976; Brussard et al., 1997).

1.2.1 Ecological categories of soil macrofauna

The macrofauna can be further divided into three groups, which play different roles in the ecosystem (Bouche, 1977). The epigeics, the anecics and the endogeics.

The epigeics live and feed in surface litter. They include saprofagous arthropods and small pigmented earthworms as well as predators of these species (chilopods, ants and some coleopteras). They progressively fragment litter and participate in decomposition *in-situ*.

Anecics feed on surface litter but build subterranean burrows and nests that provide shelter. This group consists of some large pigmented earthworms and the vast majority of termite species. The main effect of these invertebrates is to remove litter from the litter system and transport it to different environments such as the subsoil or a termite nest, thus changing dramatically the kinetics of decomposition and the spatial distribution of its products.

The endogeics live in the soil, consisting mainly of termites and unpigmented earthworms, they are geophagous and feed on soil organic matter and live or dead roots. Endogeics produce casts and faecal pellets which are the component elements of macroaggregate soil structures. They dig galleries, nests and chambers and eventually egest soil at the surface as earthworm casts, termite sheerings or epigeic nests of ants or termites. These processes have an important influence on the physical organization of the soil (Lavelle et al., 1994).

1.2.2 Factors influencing macrofauna abundance, diversity and community structure

The soil biota are responsive to natural and human induced disturbance and show varying degree of consequences (Swift and Bignell, 2001). Decaens et al., (2004) showed that soil macrofauna are senitive to land use change and this may have implications to soil functioning. Land management affects soil animal population by: (1) altering the quality and quantity of detritus and non-detritus inputs and, (2) by influencing the soil microhabitat in terms of soil physical and chemical qualities (Bardgett and Cook, 1998; Beare et al., 1997; Fragoso et al., 1997; Giller et al., 1997; Barros et al., 2002, 2003; Decaens et al., 2004). Fire influences the quality and amount of plant tissue inputs belowground, which could affect the distribution of earthworms in tall grass prairie soil (Callaham Jr. et al., 2003). In western Amazonia, a reduction of the macroinvertebrate diversity and biomass of pasture in relation to forest was demonstrated (Barros et al., 2004). The plant litter quality is a major driver of decomposer invertebrate communities. Wardle et al. (2006) showed that components of the microflora, meso-fauna, and macrofauna all differed greatly across the eight litter monoculture types. Different litter types also favoured different faunal components.

Agricultural intensification is reported to reduce above and belowground biodiversity, which is accompanied by extinction of species may cause losses of certain key functions and reduce the ability of agricultural system to withstand unexpected periods of stress (Beare et al., 1992; swift et al., 1995; Giller et al., 1997; Matson et al., 1997; Swift and Bignell, 2001). Annual cropping has generally depleted soil faunal communities, especially in the case of earthworms, but termites have been less affected (Lavelle et al., 1994). The changes in soil Community under agriculture can be attributed to a variety of reasons including burning of biomass, tillage practice, diurnal change in temperature and moisture, change in nature of input from organic matter to chemical fertilizer (Critchley et al., 1979; Tian et al., 1993; Pankhurst et al., 1994; Beare et al., 1997). In disturbed systems soil fauna communities are usually dominated by a single or small number of species, highly adapted to the changed environment (Matson et al., 1997).

1.2.3 Soil macrofauna studies in the Himalayan region

Available studies on soil in the Himalayan region are, by and large, focussed on soil physico-chemical properties, soil erosion (Pathak et al., 1984; Scott and Walter, 1993), litter decomposition and nutrient dynamics (Das and Ramakrishanan, 1985; Mehra et al., 1985; Pandey and Singh, 1981; Singh et al., 1984b; Sharma et al., 1994; Rawat and Singh, 1989) and forest fire induced changes (Semwal, 1990). Attempts have also been made to study soil biota, but these are largely confined to arbuscular mycorrhizal funcgi (Chaurasia et al., 2005) and earthworms despite the known prospects of other taxonomic/functional groups of soil organisms.

Studies on earthworm communities from tropical to sub-temperate north-eastern hill region of India revealed miscellaneous trends of changes in diversity and density of earthworms (Mishra and Ramakrishnan, 1988; Bhadauria and Ramakrishnan, 1989, 1991, 1996; Bhadauria et al., 1997, 2000; Tewari and Mishra, 1995). Such studies from Garhwal Himalayas are limited and ecosystem specific, restricted to sub-temperate forest ecosystems

(Bhadauria et al., 2000), or to Rainfed agroecosystem types (Bhadauria et al., 1997). Attempts have also been made to study the impact of ecosystem type, quality of organic inputs and water management on diversity and abundance of earthworms (Sinha et al., 2003). Studies on other taxa of soil invertebrate are explicitly lacking. Efforts looking at soil macrofauna community structure and functions in relation to different land use systems have not been made so far in Garhwal Himalayas.

1.3 Objectives

1. To characterize vegetation structure in different land use types in a mid-altitude village landscape.
2. To quantify the structure of soil macrofauna communities in terms of density across different land use types.

2. Materials and Methods

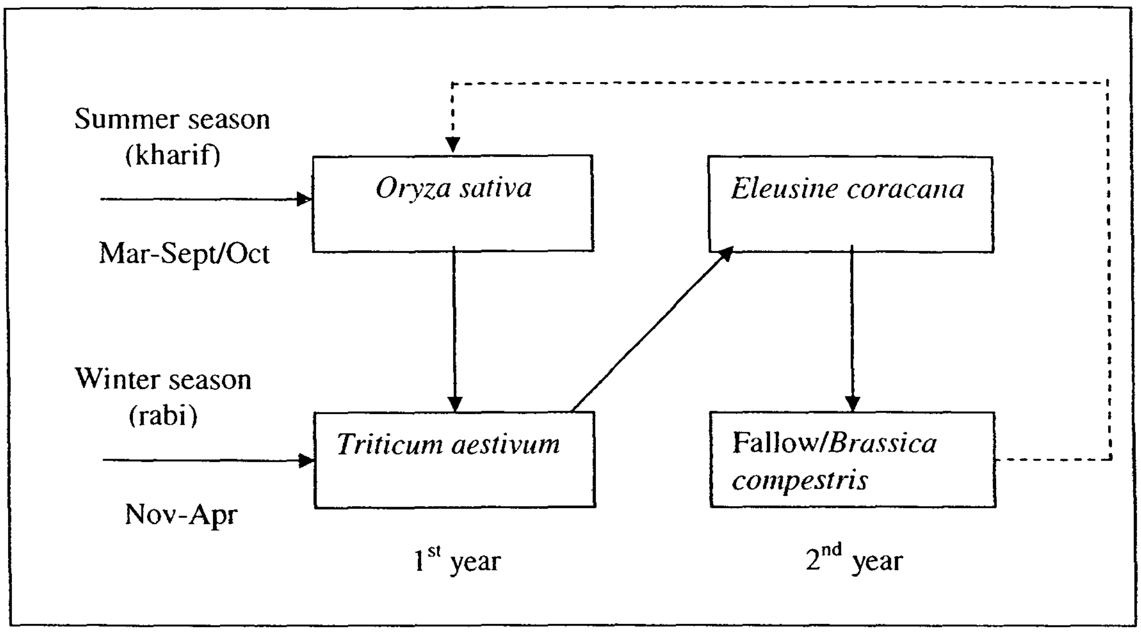
2.1 Study Area

The study was carried out in and around Dadoli village in Rudraprayag district (latitude 30^0 27^1 N and longitude 79^0 5^1 E), Garhwal. The landscape covers an elevation range of 1200 m to 1800 m above mean sea level (amsl) on east facing slope. The year consists of three seasons: dry summer season (April-June), warm rainy season (July-September) and winter season (October-March). This area experiences a typical monsoon climate. Monthly mean minimum and maximum temperatures vary in the range of 6 - 21^0 C and 18 - 35^0 C, respectively. The average annual rainfall is about 1700 mm and about 80% of the total rainfall is received during rainy season. The soil is derived from felspathic quartz schist, quartz muscovite schist and quart chlorite schist and 30-80 cm deep. Altitude gradient of the landscape is 300-600 m/km.

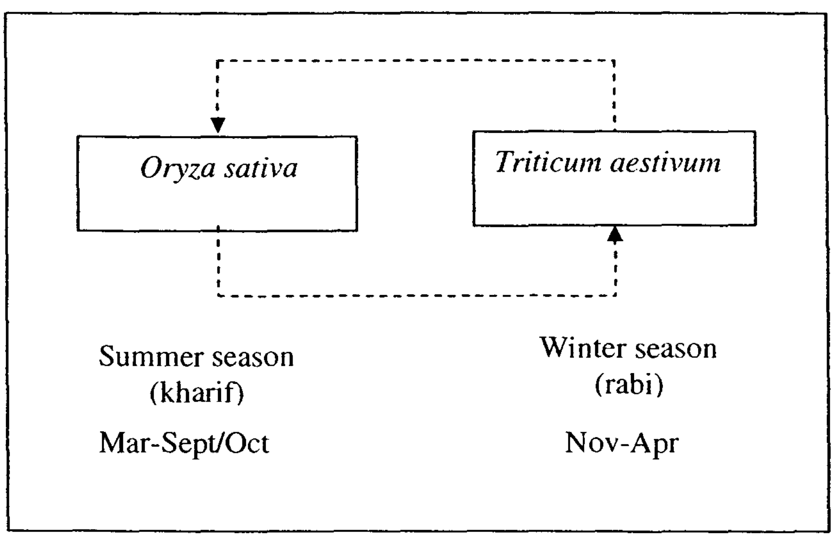
The landscape is differentiated into six land use - land cover types: a) rainfed agricultural land, b) irrigated agricultural land, c) abandoned agricultural land, d) reserve pine forest, e) reserve broad-leaved forest, and f) community broad-leaved forest.

2.1.1 Agricultural practices in village landscape

Two types of agricultural practices are found in village landscape, these are (a) settled rainfed agriculture on terraced slope, and (b) settled irrigated agriculture. Cropping patterns in rainfed land are such that three crops are harvested over a period of two years. Paddy (*Oryza sativa*) is sown in March-April and harvested in September which is earlier than irrigated land where harvested in October. After applying farmyard manure and ploughing wheat (*Triticum eastivum*) is sown in November and harvested in April. In some fields barley is also sown at the same time but harvested around 15 days earlier than wheat. After harvesting wheat, finger millet (*Eleusine coracana*) is sown in May without applying farmyard manure in the field and harvested in October. After harvesting finger millet, field is fallowed for 4 to 5 months. In some fields mustard (*Brassica compestris*) is cultivated during this period. In January they apply farmyard manure in fallowed field and paddy is sown in March. In irrigated land, two crops are harvested in a year: paddy and wheat. Paddy is sown in May, transplanted in July and harvested in October. After applying farmyard manure and ploughing, wheat is sown in November and harvested in April. After wheat harvesting again farmyard manure is applied to the field and paddy is transplanted to the field. Crop rotation can be shown diagrammatically as follows:



Rainfed agroecosystem with two-year rotational cropping patterns



Irrigated agroecosystems with one year rotational cropping patterns

Mixed cropping is practiced in both rainfed land as well as irrigated land. Finger millet mixed with pulses (*Vigna angularis, Glysine soja* etc) are sown in the field and Tor (*Cajanas cajana*) is sown on the side (border and boundaries of the field). Paddy is sown singly but *Vigna mungo* is sown on the margins of the field. Mustard is sown along with wheat in rainfed land. In irrigated land mixed cropping is practiced, but finger millet is not cultivated. Wheat and mustard are sown simultaneously in the field; however, mustard is harvested earlier. In kharif season paddy is sown singly but *Vigna mungo* is sown in the margins of the field.

The forest litter mixed with cattle dung is used as farmyard manure in crop filed. In rainfed land, farmyard manure is applied twice in a year, once before paddy sowing in Jan/Feb and once in October before wheat sowing, but not applied before finger millet sowing. In irrigated land farmyard manure is applied twice in a year, once in may and after wheat harvesting and once in October after harvesting of paddy. In irrigated land more farmyard manure is applied as compared to rainfed land. Seasonally, more farmyard manure is applied during rabi season. 200 to 300 kg of farmyard manure is applied in one nali (200 m^2) of field.

Inorganic fertilizers such as DAP and urea are used by some farmers at the rate of half kg per nali. Use of fertilizer depends on manure availability and financial status of farmer. DAP is applied at the time of sowing where as urea is applied later. Inorganic fertilizer is not applied in finger millet cultivation. They are using fertilizer since 10 to 15 years. 'White grubs; is a pest which damage the paddy crops by cutting root of the paddy. Some farmers are applying pesticide in paddy field to control pest since 4 – 5 years.

There is more yield in irrigated land as compared to rainfed land. In rainfed land, 10 – 15 kg yield of wheat occurs in one nail, where as 25 – 30 kg occurs in irrigated land. Similarly in one nali 30 -35 kg of paddy is harvested in rainfed land as compared to 65 – 70 kg in irrigated land. Finger millet yield in rainfed land occurred 15 – 20 kg per nali. Productivity of the kharif season crop is recorded as being higher than the rabi season crops, particularly in the rainfed agriculture where unavailability of irrigation water seems to be a major constraints.

The village has a number of multipurpose agroforestry tree species growing naturally but managed by the farmers on the boundaries of agricultural fields, particularly on the rainfed and abandoned agricultural land. The species namely *Grewia optiva, Celtis australis, Ficus auriculata, F. semicordata* and *F. subincisa* provide nutritive green fodder mainly during the lean period of the winter months. Some species also provide fibre and fuel wood. Agriculture is practiced strictly along traditional lines in which bullock and human labour play an important role. Female participation in agriculture is high in the entire region, as males from most households migrate for wage earning to plains.

2.1.2 Abandoned Agricultural Land

Some of the rainfed agricultural fields have been abandoned due to uneconomic production from inconveniently located agricultural plots, growing alternative off-farm opportunities and out migration for securing livelihood. These are characterized by broken terraces and a larger number and richness of trees. The tree species establishing in the abandoned fields are similar to those found in the agricultural fields. Abandoned fields are used to graze cows and to collect fodder from trees.

2.1.3 Reserve Pine Forest

Land/resource ownership and management responsibilities are vested in the Government Forest Department. Pine forest is also a major forest type in the Garhwal Himalayas. Pine leaves are unpalatable and pine wood is an inferior quality fuel wood. However, economic benefits from pine forests such as resin and minor timbers are considerable. Pine forests are accused for depletion of soil moisture and degradation of soil quality. Pine is a stress tolerant-fast growing conifer and can survive in poor soil moisture and fertility conditions. Due to slippery nature of leaves and grass does not grow so, people set fire in April-May. Eupatorium invasion also prevents grass from growing in Reserve pine forests.

2.1.4 Reserve Broad-leaved Forest

Land/resource ownership management responsibilities are vested in the Government Forest Department. The forest is dense and dominated by *Rhododendron arboreum*, *Quercus* *leucotrichophora* and *Lyonia ovalifolia* species. Though, there are legal restrictions on resource use, leaf litter collection and tree loping especially of *Quercus leucotrichophora* is common in forest near to settlement. Fodder collection, leaf litter collection, grazing and loping are rotated within this forest and lengths of regeneration period vary from 2-4 years.

2.1.5 Community Broad-leaved Forest

Land/resource management is carried out by village community (Gram Sabha). The forests are dominated by *Q. leucotrichophora* and M. *esculenta*. Since the forest is near to village, the disturbance is high in the forest. Although loping occur only time to time and only one member from a family is allowed, there is no restriction on grazing and leaf litter removal. Cutting of tree is allowed only after permission from Gram Sabha for social functions. Eupatorium invasion is high as compared to reserve broad-leaved forest.

2.2 Sampling

Samples were collected in March-April from each of six land use – land cover types. Sampling quadrats were chosen along random transects running across elevation gradient. Quadrats of 10×10 m^2 were laiddown and one quadrat was separated from other by a distance of 30 - 50 m. In each quadrat regenerating tree and mature tree were counted and circumference at breast height (CBH) were measured for all individuals with CBH >10 cm and species were identified (Gaur, 1999). Woody individuals having CBH <30 cm were classified as regenerating trees and CBH ≥30 cm were classified as mature trees.

In each quadrat one sampling area of 30 cm × 30 cm were demarcated and litter was collected and its soil fauna hand sorted. A trench was then dug to a depth of 30 cm around the 30 cm x 30 cm area to get a soil monolith. Soil monoliths were divided into three layers (0-10, 10-20 and 20-30 cm) and macrofauna were handsorted separately from each layer. Soil fauna from the litter was added with the 0-10 cm soil fauna. All individuals were preserved in 4% formaldehyde (Anderson and Ingram, 1989). Specimens were later identified in the laboratory (Borror et al., 1981) and counted. Soil organisms were separated into 14 broad taxonomical groups. Soil samples were also collected separately from each layer of the monolith, but due to time constraints it has not been analyzed.

2.3 Tree community structure in the village landscape

2.3.1 Frequency and relative frequency of tree species

Frequency refers to the occurrence of a species in a sample is an improvement over a mere listing of species. It is a measure of distribution uniformly, not abundance. Frequency is expressed as a percentage.

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats in which the species occurred}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Frequency of the species}}{\text{Total frequency of all the species}} \times 100$$

2.3.2 Density and relative density of tree species

Density represents numerical strength of a species in the community. The number of individuals of the species in any unit area is its density. Density gives an idea of degree of competition (Sharma, 2000).

$$\text{Density} = \frac{\text{Total number of individuals of the species in all the sampling units}}{\text{Total number of sampling units studied}}$$

The results were multiplied with 100 to convert the data into number of individuals per ha.

$$\text{Relative density} = \frac{\text{Density of the species}}{\text{Total density of all the species}} \times 100$$

2.3.3 Basal area and relative basal area of tree species

Basal area refers to the ground actually penetrated by the stems. It is one of the chief characteristics to determine dominance.

$$\text{Basal area} = \frac{(\text{Circumference at breast height})^2}{4\pi}$$

$$\text{Relative basal area} = \frac{\text{Basal area of the species}}{\text{Total basal area of all the species}} \times 100$$

3. Results

3.1 Tree Community structure in different land use types

Tree community in different land use – land cover types varied in terms of species richness, composition, density and basal area. None of the species were common to all land use – land cover types. Two species viz., *Pyrus pashia*, *Quercus leucotrochophora* were present in maximum four number of land uses, these are rainfed agricultural land, abandoned agricultural land, reserve broad-leaved forest and community broad-leaved forest. Some of the species were confined only to one land use – land cover types. *Juglans regia* was confined only to rainfed agricultural land, *Citrus aurantifolia* to abandoned agricultural land, *Alnus nepaliensis*, *Benthamnidia capitata* and *Prunus cerasoides* to reserve broad-leaved forest. However, none of the species were confined only to irrigated agricultural land, reserve pine forest and Community broad-leaved forest. *Pinus roxburghii* was present only in Reserve pine forest and abandoned agricultural land. Some species like *Bombax ceiba, Celtis australis, Citrus aurantifolia, Ficus auriculata, Ficus semicordata, Ficus suincisa, Grewia optiva, Juglans regia, Litsea monopetala, Spondias pinnata, Toona hexandra* were present only in agricultural land uses including rainfed agricultural land, irrigated agricultural land and abandoned agricultural land. Some species like *Alnus nepaliensis, Benthamidia capitata, Lyonia ovalifolia, Prunus cerasoides, Rhododendron arboretum* were present only in broad-leaved forests. Abandoned agricultural land had the highest species richness (15), followed by rainfed agricultural land (12), reserve broad-leaved forest (10), community broad-leaved forest (7), irrigated agricultural land (3) and reserve pine forest (1) (Table 2).

3.1.1 Rainfed Agricultural Land

In rainfed agricultural land, the highest number of individuals were those with less than 30 cm circumference at breast height (CBH) follwed by 30-60 cm, 60-90 cm, 90-120 cm and ≥150 cm CBH classes. There was no tree in the CBH range of 120-150 cm. *Celtis australis* constitute highest number of individuals having <30 cm, 60-90 cm, 90-120 cm CBH, *Grewia optiva* having 30-60 cm CBH. Only *Celtis australis* and *Juglans regia* were found having CBH≥150 cm (Table 4).

3.1.2 Irrigated Agricultural Land

In irrigated agricultural land highest number of individuals have CBH<30 cm, followed those with CBH 30-60 cm. None of the individuals having CBH more than 60 cm were found. *C. australis* and *G. optiva* had CBH <30 cm and *S. pinnata* had CBH in the girth class of 30-60 cm (Table 5).

3.1.3 Abandoned Agricultural Land

In abandoned agricultural land highest number of individuals were less than 30 cm in CBH followed by 30-60 cm, 60-90 cm, 90-120 cm, 120-150 cm and ≥150 cm. *Q. leucotrichophora* constitute highest number of individuals having CBH <30 cm, 30-60 cm, 60-90 cm and 90-120 cm, whereas, *C. australis* constitute highest number of individuals having CBH 120-150 cm, *C. australis* and *T. hexandra* were the only two species having CBH≥150 cm (Table 6).

3.1.4 Reserve Pine Forest

In reserve pine forest highest number of individuals were found with CBH≥150 cm, followed by those with 30-60 cm. Equal number of individuals were found having CBH 60-90 cm and 90-120 cm. None of the individuals were found having CBH less than 30 cm and 90-120 cm. *P. roxburghii* was the only species found in the Reserve pine forest (Table 7).

3.1.5 Reserve Broad-leaved Forest

In reserve broad-leaved forest highest number of individuals were found in the CBH class of 30-60 cm, followed by <30 cm, 60-90 cm, 90-120 cm, 120-150 cm and ≥150cm. *M. esculenta* was most abundant in the CBH class of less than 30 cm. *Q. leucotrichophora* in 30-60 cm, *R. arboreum* in 60-90 cm, 90-120 cm and 120-150 cm, *Q. leucotrichophora* and *R. arboretum* were equally abundant in the girth class of ≥150 cm (Table 8).

3.1.6 Community Broad-leaved Forest

In community broad-leaved forest highest number of individuals were found having CBH less than 30 cm followed by 30-60 cm, 60-90 cm, 90-120 cm and 120-150 cm. *Q. leucotrichophora* was the most abundant species in all the girth classes except ≥150 cm in which none of the individuals were found (Table 9).

3.2 Tree density in different land use types

Density of regenerating tree species were highest in community broad-leaved forest, followed by reserve broad-leaved forest, abandoned agricultural land, rainfed agricultural land and Irrigated agricultural land. Regenerating trees were absent in Reserve pine forest. *C. australis* constitute highest number of regenerating individuals in Rainfed agricultural land, *Q. leucoprichophora* in Abandoned agricultural land and community broad-leaved forest, and *M. esculenta* in reserve broad-leaved forest (Table 10).

Density of mature tree species were highest in reserve broad-leaved forest followed by community broad-leaved forest, abandoned agricultural land, rainfed agricultural land, reserve pine forest and irrigated agricultural land. *G. optiva* was the most abundant mature tree species in rainfed agricultural land, *Q. leucotrichophora* in abandoned agricultural land, community broad-leaved forest and reserve broad-leaved forest. *P. roxburghii* and *S. pinnata* was the only mature tree species found in reserve pine forest and irrigated agricultural land respectively (table12).

3.3 Basal area in different land uses

Basal area of *C. australis* was highest in rainfed agricultural land, *Q. leucotrichophora* in Abandoned agricultural land as well as community broad-leaved forest and *R. arboreum* in reserve broad-leaved forest. In reserve pine forest only *P. roxburghii* was present and the basal area was 72.9 m^2/ha, in Irrigated agricultural land although three species were present but only *S. pinnata* had basal area up to one decimal point, other two species viz., *C. australis* and *G. optiva* had very low CBH so does not have basal area up to one decimal point. In rainfed agricultural land although *F. subincisa* and *T. hexandra* were present but had zero basal area up to one decimal point. In abandoned agricultural land also some species like *F. subincisa, L. monopetatla, M. esculenta, S. ramosissima* were present but basal area was zero. Of all the six land uses types studied reserve broad-leaved forest had highest basal area followed by reserve pine forest, community broad-leaved forest, abandoned agricultural land, rainfed agricultural land and irrigated agricultural land.

In rainfed agricultural land around 78% of the basal area was contributed by only three species viz., *C australis, J. regia* and *G. optiva*. In Abandoned agricultural land 76% of the basal area is contributed by three species namely *Q. leucotrichophora, C. australis* and *T. hexandra*. In Reserve broad-leaved forest about 80% of the basal area is contributed by three species namely *R. arboreum, Q. leucotrichophora* and *L. ovalifolia*. In Community broad-leaved forest about 88% basal area is contributed by *Q. leucotrichophora, M. esculenta* and *R. arboreum* (table 14).

3.4 Density of soil macrofauna in different land uses

The highest density of macrofauna was recorded in reserve pine forest (422.2 individuals/m^2) followed by Reserve broad-leaved forest (296.6 individuals/m^2), abandoned agricultural land (280.5 individuals/m^2), rainfed agricultural land (275.7 individuals/m^2), irrigated agricultural land (192.6 individuals/m^2) and community broad-leaved forest (154.2 individuals/m^2). The high density in Reserve pine forest was due to large number of Isoptera, Coleoptera larvae and Hymenoptera. In rainfed agricultural land, irrigated agricultural land, reserve broad-leaved forest and community broad-leaved forest Coleoptera larvae were most abundant whereas density of Isoptera was the highest in abandoned agricultural land and reserve pine forest.

3.4.1 Earthworms

Earthworms were most abundant in abandoned agricultural land followed by reserve pine forest, community broad-leaved forest, rainfed agricultural land, reserve broad-leaved forest and irrigated agricultural land. In community broad-leaved forest 75% of the individuals were found in 0-10 cm, in reserve pine forest 85% in 10-20 cm layer and in rainfed agricultural land 80% and in abandoned agricultural land 65% individuals were found in 20-30 cm soil depth. Earthworms were not found in 0-10 cm soil depth in rainfed agricultural land and in 20-30 cm in reserve broad-leaved forest (Fig.1).

3.4.2 Diplopoda

Diplopoda were present only in forest land uses i.e., community broad-leaved forest, Reserve broad-leaved forest and reserve pine forest but not in agricultural land uses. In community broad-leaved forest and reserve broad-leaved forest they were present in 0-10 cm whereas in reserve pine forest in 10-20 cm soil depth. (Fig.2)

3.4.3 Chilopoda

Chilopoda were present in all land uses except in irrigated agricultural land. They were most abundant in reserve broad-leaved forest followed by rainfed agricultural land, abandoned agricultural land, community broad-leaved forest and reserve pine forest. In community broad-leaved forest and reserve pine forest, Chilopods were found only in 0-10 cm soil layer, and about 90% of the individuals in reserve broad-leaved forest were found in 0-10 cm soil layer. They were not recorded in 20-30 cm soil depth in any of the land uses except rainfed agricultural land(Fig.3).

3.4.4 Aranae

Aranae were found in all land uses except in reserve pine forest. They were most abundant in reserve broad leaved forest followed by community broad-leaved forest, irrigated agricultural land, abandoned agricultural land and rainfed agricultural land. More than 60% individuals of Aranae were found in 0-10 cm soil depth in all the land uses. In 20-30 cm soil depth, they were found only in abandoned agricultural land (Fig.4).

3.4.5 Orhtoptera

Orthoptera were most abundant in irrigated agricultural land followed by community broad-leaved forest, reserve broad-leaved forest, reserve pine forest, rainfed agricultural land and abandoned agricultural land. Orthopterans were found only in 0-10 cm soil depth in reserve broad-leaved forest and abandoned agricultural land, whereas in other land uses 45% to 95% individuals were present in 0-10 cm soil layer. Less than 15% individuals were found in 20-30 cm soil depth in reserve pine forest, rainfed agricultural land and irrigated agricultural land, and were absent in other land uses in 20-30 cm soil depth(Fig.5).

3.4.6 Dermaptera

Dermaptera were most abundant in Reserve broad-leaved forest followed by community broad-leaved forest and Rainfed agricultural land, whereas absent in other land uses. In broad-leaved forests they were mainly found in litter layer which is added with 0-10 cm soil depth. In reserve broad-leaved forest they were also found in 20-30 cm soil depth (Fig.6).

3.4.7. Isoptera

Density of Isoptera were highest in reserve pine forest followed by abandoned agricultural land, rainfed agricultural land, reserve broad-leaved forest and irrigated agricultural land whereas, not found in community broad-leaved forest. In reserve pine forest almost 75% of the individuals were found in 20-30 cm soil depth whereas in abandoned agricultural land almost 85% of the individuals were found in 0-10 cm soil layer. In reserve broad-leaved forest and irrigated agricultural land individuals were limited only to 0-10 cm soil depth (Fig.7).

3.4.8 Hemiptera

Hemiptera were most abundant in irrigated agricultural land followed by reserve broad-leaved forest, rainfed agricultural land, reserve pine forest, abandoned agricultural land and community broad-leaved forest. In rainfed agricultural land, abandoned agricultural land and community broad-leaved forest individuals were found only in 0-10 cm soil depth whereas in irrigated agricultural land, 93%; Reserve broad-leaved forest, 93%; and reserve pine forest, 67% of the individuals were found in 0-10 cm soil depth. Some individuals in irrigated agricultural land and reserve broad-leaved forest were found in 10-20 cm soil depth and some individuals in irrigated agricultural land and reserve pine forest were also found in 20-30 cm soil depth (Fig.8).

3.4.9 Coleoptera Larvae

Density of Coleoptera larvae were highest in rainfed agricultural land followed by reserve broad-leaved forest, irrigated agricultural land, reserve pine forest, community broad-leaved forest and abandoned agricultural land. Although they were found in all the three layers in all the land uses, most of the individuals were present in 0-10 cm soil depth in all the land uses except rainfed agricultural land in which highest number of individuals were found in 10-20 cm soil depth (Fig.9).

3.4.10 Coleoptera Adults

Density of Coleoptera adults were highest in irrigated agricultural land followed by reserve broad-leaved forest, rainfed agricultural land, reserve pine forest, abandoned agricultural land and community broad-leaved forest. In community broad-leaved forest all the individuals were found in 0-10 cm soil depth. Like coleoptera larvae, adult forms were also most abundant in 0-10 cm soil depth except in abandoned agricultural land where it was most abundant in 10-20 cm soil depth. Some individuals in agricultural land uses viz., rainfed agricultural land, irrigated agricultural land and abandoned agricultural land were also found in 20-30 cm soil layer (Fig.10).

3.4.11 Lepidoptera Larvae

Lepidoptera larvae were most abundant in Irrigated agricultural land followed by reserve broad-leaved forest, abandoned agricultural land, community broad-leaved forest, reserve pine forest and rainfed agricultural land. In all the land uses they were present only in 0-10 cm soil depth except in irrigated agricultural land where they were found in all the three layers (Fig.11).

3.4.12 Diptera Larvae

Density of Diptera larvae were highest in reserve broad-leaved forest followed by irrigated agricultural land, reserve pine forest, abandoned agricultural land, community broad-leaved forest and rainfed agricultural land. In community broad-leaved forest they were found only in 0-10 cm soil depth. They were abundant in 0-10 cm soil layer in all the land uses except in reserve pine forest where they were most abundant in 10-20 cm soil depth. They were also found in 20-30 cm soil layer in reserve broad-leaved forest and abandoned agricultural land (Fig.12).

3.4.13 Hymenoptera

Hymenoptera were most abundant in reserve pine forest followed by abandoned agricultural land, rainfed agricultural land, community broad-leaved forest, reserve broad-leaved forest and irrigated agricultural land. In irrigated agricultural land they were found only in 0-10 cm soil layer. In reserve pine forest, community broad-leaved forest and reserve broad-leaved forest they were found to be most abundant in 0-10 cm soil layer, whereas in abandoned agricultural land and rainfed agricultural land they were found abundantly in 20-30 cm soils layer (Fig.13).

3.5 Vertical distribution of the macrofauna in different land uses

The vertical distribution of macrofauna showed two different patterns. The community broad-leaved forest, reserve broad-leaved forest and irrigated agricultural land uses had a clear concentration of invertebrates in the upper 10 cm of soil, whereas distribution in rainfed agricultural land, abandoned agricultural land and reserve pine forest was much deeper with still high populations in 10-20 cm and 20-30 cm strata.

In the rainfed agricultural land, 43% of the individuals were found in 0-10 cm and 37% in 10-20 cm soil layer, where coleoptera larvae, Isoptera and hymenoptera were the most abundant groups in these two layers. Hymenoptera were the most abundant group in 20-30 cm soil layer. In the irrigated agricultural land, 84% of the organisms were found in 0-10 cm, and Coleoptera larvae and Hemiptera were the most abundant groups; 13% of the macrofauna were found in 10-20 cm soil layer and coleoptera larvae and Orthoptera were the most abundant groups. In abandoned agricultural land, 61% of the individuals were found in 0-10 cm soil layer, and Isoptera, coleoptera larvae and hymenoptera were the most abundant groups; 18% of the macrofauna were found in 10-20 cm soil layer, and Isoptera and hymenoptera were the most abundant groups; 21% of the macrofauna were found in 20-30 cm soil layer and Hymenoptera and Earthworms were the most abundant groups.

Among all the six land uses, only in reserve pine forest maximum density of macrofauna was found in 20-30 cm soil layer. 46% of the individuals were found in 20-30 cm soil layer, and Isoptera was the most abundant group; 40% of the macrofauna were found in 0-10 cm soil layer, where Coleoptera larvae, Hymenoptera and Isoptera were the most abundant group. In 10-20 cm soil layer, hymenoptera, earthworms and Isoptera were the most abundant groups.

The macrofauna distribution in reserve broad-leaved forest and community broad-leaved forest was almost similar to that in irrigated agricultural land uses however taxa contribution was different. In reserve broad-leaved forest, 84% of the macrofauna was found in upper 10 cm soil layer, where Coleoptera larvae, Isoptera and Diptera were the most abundant groups; whereas in community broad-leaved forest, 88% of the individuals were found in upper 10 cm soil layer in which coleoptera larvae and hymenoptera were the most abundant groups. In Reserve broad-leaved forest 13%, and in community broad-leaved forest, 9% of the macrofauna were found in 10-20 cm soil layer, where Coleoptera larvae were the dominant group. Only 3% of the individuals were found in 20-30 cm soil layer in reserve broad-leaved forest and community broad-leaved forest (Fig.15).

Table 1: Uses and ecological features of tree species of different land uses in a mid-altitude village landscape

Local name	Botanical name	Family	Uses and ecological features
Ainyar	*Lyonia ovalifolia*	Ericaceae	Wood used as fuel; young leaves poisonous to cattle; medicinal
Akhrot	*Juglans regia*	Juglandaceae	Fruits edible and also provide wine; wood is hard, excellent for furniture, carved works, gun stocks and vaneers; leaves mixed with stored grains as fungicides, an insecticide, an important tree of social forestry
Amara	*Spondias pinnata*	Anacardiaceae	Fruits edible, also made into pickle; flowers useful source of bee forage in apiculture; important tree for social forestry
Banj	*Quercus leucotrichophora*	Fagaceae	Wood used as construction, plough and bed sticks as well as fuel; leaves used fodder; fruites eaten by monkeys and bears; decomposed leaves used as organic manure; an important tree of social forestry
Bhamora	*Benthamidia capitata*	Cornaceae	Fruits edible also preferred by wildlife; wood used in agricultural implements
Bhimal	*Grewia optiva*	Tiliaceae	Bark fiber extensively used for ropes, nets, saps, brushes, brooms etc.; sticks after filling of the barks used to lit fire; leaves provide good fodder; fruits edible and medicinal; an important agroforestry tree
Burans	*Rhododendron arboreum*	Ericaceae	Wood used for fuel and charcoal; flowers eaten raw or made into sauce, jellies, jams and refreshing drinks, flowers useful as bee forage
Channchri	*Ficus subincisa*	Moraceae	Leaves and branches used as fodder; fruits edible
Kaphal	*Myrica esculenta*	Myricaceae	Fruits edible, raw or made into refreshing drinks; wood used as fuel and implements
Katmora	*Litsea monopetala*	Lauraceae	Leaves chiefly used for silkworm farming; occasionally as fodder
Khaina	*Ficus semicordata*	Moraceae	Leaves and twigs lopped for fodder; fibre obtained from the barks; fruits edible; an important agroforestry tree
Kharik	*Celtis australis*	Ulmaceae	Fruits edible; leaves provide good fodder; wood used for making small article and important tree of agroforestry
Lodh	*Symplocos ramosissima*	Symplocaceae	Leaves used as fodder; flowers visited by bees for nectar and pollen
Mole	*Pyrus pashia*	Rosaceae	Leaves and twigs as fodder; ripe fruits edible; flowers used in apiculture; believed to check soil erosion in landslide zones

Table 1 continued...

Local name	Botanical name	Family	Uses and ecological features
Nimbu	*Citrus aurantifolia*	Rutaceae	Frequently used for lime juice; as pickles; raw or made into various products; flowers useful source of bee forage
Panyyan	*Prunus cerasoides*	Rosaceae	Branches for walking sticks; leaves as fodder and ripe fruits edible; flowers useful source of bee forage; plant regarded as sacred used in several rituals of locals.
Pine	*Pinus roxburghii*	Pinaceae	Wood used for construction; resin in varnishes and turpentine; saw-dust with honey used in asthma and bronchitis
Semal	*Bombax ceiba*	Bombacaceae	Flower buds as vegetables; fibres of seeds used for stiffing cushions and pillows; wood light in weight used for packing cases, boats, matchsticks etc; an important tree for social forestry
Timla	*Ficus auriculata*	Moraceae	Leaves made into cup an plates, also provide good fodder for cattle and elephants; ripe fruits edible, unripe fruits made into vegetable
Toon	*Toona hexandra*	Meliaceae	Wood priced for construction purposes, furniture and other articles
Ust	*Alnus nepalensis*	Betulaceae	Wood used for carpentry and construction; bark used in local medicine; fast growing tree used as soil binder
Others (Philku, Chheena)	Botanical identification could not be completed		Leaves used for fodder

Table 2: Frequency of tree species in a mid-altitude village landscape (RA, Rainfed Agriculture; IA, Irrigated Agriculture; AA, Abandoned Agriculture; RPF, Reserved Pine Forest; RBF, Reserved Broadleaved Forest; CBF, Community Broadleaved Forest).

Tree species	RA	IA	AA	RPF	RBF	CBF
Alnus nepalensis	0.0	0.0	0.0	0.0	30.0	0.0
Benthamidia capitata	0.0	0.0	0.0	0.0	20.0	0.0
Bombax ceiba	4.5	0.0	6.3	0.0	0.0	0.0
Celtis australis	68.2	5.6	37.5	0.0	0.0	0.0
Citrus aurantifolia	0.0	0.0	6.3	0.0	0.0	0.0
Ficus auriculata	18.2	0.0	37.5	0.0	0.0	0.0
Ficus semicordata	9.1	0.0	18.8	0.0	0.0	0.0
Ficus subincis	9.1	0.0	6.3	0.0	0.0	0.0
Grewia optiva	54.5	5.6	25.0	0.0	0.0	0.0
Juglans regia	4.5	0.0	0.0	0.0	0.0	0.0
Litsea monopetala	9.1	0.0	6.3	0.0	0.0	0.0
Lyonia ovalifolia	0.0	0.0	0.0	0.0	90.0	94.1
Myrica esculenta	0.0	0.0	12.5	0.0	70.0	100.0
Pinus roxburghii	0.0	0.0	12.5	100.0	0.0	0.0
Prunus cerasoides	0.0	0.0	0.0	0.0	20.0	0.0
Pyrus pashia	4.5	0.0	50.0	0.0	60.0	64.7
Quercus leucotrichophora	13.6	0.0	43.8	0.0	100.0	100.0
Rhododendron arboreum	0.0	0.0	0.0	0.0	100.0	64.7
Simplocos ramosissima	0.0	0.0	12.5	0.0	60.0	41.2
Spondias pinnata	0.0	5.6	6.3	0.0	0.0	0.0
Toona hexandra	4.5	0.0	18.8	0.0	0.0	0.0
others	4.5	0.0	0.0	0.0	10.0	64.7

Table 3: Relative frequency of tree species in a mid-altitude village landscape (RA, Rainfed Agriculture; IA, Irrigated Agriculture; AA, Abandoned Agriculture; RPF, Reserved Pine Forest; RBF, Reserved Broadleaved Forest; CBF, Community Broadleaved Forest).

Tree species	**RA**	**IA**	**AA**	**RPF**	**RBF**	**CBF**
Alnus nepalensis	0.0	0.0	0.0	0.0	5.4	0.0
Benthamidia capitata	0.0	0.0	0.0	0.0	3.6	0.0
Bombax ceiba	2.2	0.0	2.1	0.0	0.0	0.0
Celtis australis	33.3	33.3	12.5	0.0	0.0	0.0
Citrus aurantifolia	0.0	0.0	2.1	0.0	0.0	0.0
Ficus auriculata	8.9	0.0	12.5	0.0	0.0	0.0
Ficus semicordata	4.4	0.0	6.3	0.0	0.0	0.0
Ficus subincisa	4.4	0.0	2.1	0.0	0.0	0.0
Grewia optiva	26.7	33.3	8.3	0.0	0.0	0.0
Juglans regia	2.2	0.0	0.0	0.0	0.0	0.0
Litsea monopetala	4.4	0.0	2.1	0.0	0.0	0.0
Lyonia ovalifolia	0.0	0.0	0.0	0.0	16.1	17.8
Myrica esculenta	0.0	0.0	4.2	0.0	12.5	18.9
Pinus roxburghii	0.0	0.0	4.2	100.0	0.0	0.0
Prunus cerasoides	0.0	0.0	0.0	0.0	3.6	0.0
Pyrus pashia	2.2	0.0	16.7	0.0	10.7	12.2
Quercus leucotrichophora	6.7	0.0	14.6	0.0	17.9	18.2
Rhododendron arboreum	0.0	0.0	0.0	0.0	17.9	12.2
Spondias pinnata	0.0	33.3	2.1	0.0	0.0	0.0
Symplocos ramosissima	0.0	0.0	4.2	0.0	10.7	7.8
Toona hexandra	2.2	0.0	6.3	0.0	0.0	0.0
others	2.2	0.0	0.0	0.0	1.8	12.2

Table 4: Tree population structure (No. of individuals/ha) in rainfed agriculture in a mid-altitude village landscape

Tree species	Girth classes					
	<30 cm	30-60 cm	60-90 cm	90-120 cm	120-150 cm	≥150cm
Alnus nepalensis	0.0	0.0	0.0	0.0	0.0	0.0
Benthamidia capitata	0.0	0.0	0.0	0.0	0.0	0.0
Bombax ceiba	0.0	4.5	0.0	0.0	0.0	0.0
Celtis australis	77.3	27.3	36.4	18.2	0.0	4.5
Citrus aurantifolia	0.0	0.0	0.0	0.0	0.0	0.0
Ficus auriculata	0.0	0.0	9.1	13.6	0.0	0.0
Ficus semicordata	0.0	9.1	0.0	0.0	0.0	0.0
Ficus subincisa	9.1	0.0	0.0	0.0	0.0	0.0
Grewia optiva	13.6	90.9	13.6	9.1	0.0	0.0
Juglans regia	0.0	0.0	0.0	0.0	0.0	4.5
Litsea monopetala	9.1	0.0	4.5	0.0	0.0	0.0
Lyonia ovalifolia	0.0	0.0	0.0	0.0	0.0	0.0
Myrica esculenta	0.0	0.0	0.0	0.0	0.0	0.0
Pinus roxburghii	0.0	0.0	0.0	0.0	0.0	0.0
Prunus cerasoides	0.0	0.0	0.0	0.0	0.0	0.0
Pyrus pashia	4.5	4.5	0.0	0.0	0.0	0.0
Quercus leucotrichophora	22.7	4.5	9.1	4.5	0.0	0.0
Rhododendron arboreum	0.0	0.0	0.0	0.0	0.0	0.0
Spondias pinnata	0.0	0.0	0.0	0.0	0.0	0.0
Symplocos ramosissima	0.0	0.0	0.0	0.0	0.0	0.0
Toona hexandra	4.5	0.0	0.0	0.0	0.0	0.0
others	22.7	0.0	0.0	0.0	0.0	0.0
Total	163.6	140.9	72.7	45.5	0.0	9.1

Table 5: Tree population structure (No. of individuals/ha) in irrigated agriculture in a mid-altitude village landscape.

Tree species	Girth classes					
	<30 cm	30-60 cm	60-90 cm	90-120 cm	120-150 cm	≥150cm
Alnus nepalensis	0.0	0.0	0.0	0.0	0.0	0.0
Benthamidia capitata	0.0	0.0	0.0	0.0	0.0	0.0
Bombax ceiba	0.0	0.0	0.0	0.0	0.0	0.0
Celtis australis	5.6	0.0	0.0	0.0	0.0	0.0
Citrus aurantifolia	0.0	0.0	0.0	0.0	0.0	0.0
Ficus auriculata	0.0	0.0	0.0	0.0	0.0	0.0
Ficus semicordata	0.0	0.0	0.0	0.0	0.0	0.0
Ficus subincisa	0.0	0.0	0.0	0.0	0.0	0.0
Grewia optiva	5.6	0.0	0.0	0.0	0.0	0.0
Juglans regia	0.0	0.0	0.0	0.0	0.0	0.0
Litsea monopetala	0.0	0.0	0.0	0.0	0.0	0.0
Lyonia ovalifolia	0.0	0.0	0.0	0.0	0.0	0.0
Myrica esculenta	0.0	0.0	0.0	0.0	0.0	0.0
Pinus roxburghii	0.0	0.0	0.0	0.0	0.0	0.0
Prunus cerasoides	0.0	0.0	0.0	0.0	0.0	0.0
Pyrus pashia	0.0	0.0	0.0	0.0	0.0	0.0
Quercus leucotrichophora	0.0	0.0	0.0	0.0	0.0	0.0
Rhododendron arboreum	0.0	0.0	0.0	0.0	0.0	0.0
Spondias pinnata	0.0	5.6	0.0	0.0	0.0	0.0
Symplocos ramosissima	0.0	0.0	0.0	0.0	0.0	0.0
Toona hexandra	0.0	0.0	0.0	0.0	0.0	0.0
others	0.0	0.0	0.0	0.0	0.0	0.0
Total	11.1	5.6	0.0	0.0	0.0	0.0

Table 6: Tree population structure (No. of individuals/ha) in abandoned agriculture land in a mid-altitude village landscape

Tree species	Girth classes					
	<30 cm	30-60 cm	60-90 cm	90-120 cm	120-150 cm	≥150 cm
Alnus nepalensis	0.0	0.0	0.0	0.0	0.0	0.0
Benthamidia capitata	0.0	0.0	0.0	0.0	0.0	0.0
Bombax ceiba	0.0	6.3	0.0	0.0	0.0	0.0
Celtis australis	6.3	6.3	0.0	18.8	12.5	6.3
Citrus aurantifolia	12.5	0.0	0.0	0.0	0.0	0.0
Ficus auriculata	25.0	12.5	0.0	0.0	0.0	0.0
Ficus semicordata	0.0	12.5	6.3	0.0	0.0	0.0
Ficus subincisa	25.0	0.0	0.0	0.0	0.0	0.0
Grewia optiva	37.5	18.8	18.8	6.3	0.0	0.0
Juglans regia	0.0	0.0	0.0	0.0	0.0	0.0
Litsea monopetala	12.5	0.0	0.0	0.0	0.0	0.0
Lyonia ovalifolia	0.0	0.0	0.0	0.0	0.0	0.0
Myrica esculenta	18.8	0.0	0.0	0.0	0.0	0.0
Pinus roxburghii	62.5	0.0	6.3	0.0	6.3	0.0
Prunus cerasoides	0.0	0.0	0.0	0.0	0.0	0.0
Pyrus pashia	62.5	37.5	0.0	0.0	0.0	0.0
Quercus leucotrichophora	550.0	62.5	68.8	25.0	0.0	0.0
Rhododendron arboreum	0.0	0.0	0.0	0.0	0.0	0.0
Spondias pinnata	0.0	0.0	6.3	0.0	0.0	0.0
Symplocos ramosissima	12.5	0.0	0.0	0.0	0.0	0.0
Toona hexandra	6.3	6.3	0.0	0.0	0.0	6.3
Others	0.0	0.0	0.0	0.0	0.0	0.0
Total	831.3	162.5	106.3	50.0	18.8	12.5

Table 7: Tree population structure (No. of individuals/ha) in reserve pine forest in a mid-altitude village landscape.

Tree species	Girth classes					
	<30 cm	30-60 cm	60-90 cm	90-120 cm	120-150 cm	≥150cm
Alnus nepalensis	0.0	0.0	0.0	0.0	0.0	0.0
Benthamidia capitata	0.0	0.0	0.0	0.0	0.0	0.0
Bombax ceiba	0.0	0.0	0.0	0.0	0.0	0.0
Celtis australis	0.0	0.0	0.0	0.0	0.0	0.0
Citrus aurantifolia	0.0	0.0	0.0	0.0	0.0	0.0
Ficus auriculata	0.0	0.0	0.0	0.0	0.0	0.0
Ficus semicordata	0.0	0.0	0.0	0.0	0.0	0.0
Ficus subincisa	0.0	0.0	0.0	0.0	0.0	0.0
Grewia optiva	0.0	0.0	0.0	0.0	0.0	0.0
Juglans regia	0.0	0.0	0.0	0.0	0.0	0.0
Litsea monopetala	0.0	0.0	0.0	0.0	0.0	0.0
Lyonia ovalifolia	0.0	0.0	0.0	0.0	0.0	0.0
Myrica esculenta	0.0	0.0	0.0	0.0	0.0	0.0
Pinus roxburghii	0.0	40.0	10.0	0.0	10.0	200.0
Prunus cerasoides	0.0	0.0	0.0	0.0	0.0	0.0
Pyrus pashia	0.0	0.0	0.0	0.0	0.0	0.0
Quercus leucotrichophora	0.0	0.0	0.0	0.0	0.0	0.0
Rhododendron arboreum	0.0	0.0	0.0	0.0	0.0	0.0
Spondias pinnata	0.0	0.0	0.0	0.0	0.0	0.0
Symplocos ramosissima	0.0	0.0	0.0	0.0	0.0	0.0
Toona hexandra	0.0	0.0	0.0	0.0	0.0	0.0
Others	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	40.0	10.0	0.0	10.0	200.0

Table 8: Tree population structure (No. of individuals/ha) in reserve broad-leaved forest in a mid-altitude village landscape.

Tree species	Girth classes					
	<30 cm	**30-60 cm**	**60-90 cm**	**90-120 cm**	**120-150 cm**	**≥150cm**
Alnus nepalensis	0.0	0.0	30.0	20.0	0.0	0.0
Benthamidia capitata	0.0	20.0	0.0	0.0	0.0	0.0
Bombax ceiba	0.0	0.0	0.0	0.0	0.0	0.0
Celtis australis	0.0	0.0	0.0	0.0	0.0	0.0
Citrus aurantifolia	0.0	0.0	0.0	0.0	0.0	0.0
Ficus auriculata	0.0	0.0	0.0	0.0	0.0	0.0
Ficus semicordata	0.0	0.0	0.0	0.0	0.0	0.0
Ficus subincisa	0.0	0.0	0.0	0.0	0.0	0.0
Grewia optiva	0.0	0.0	0.0	0.0	0.0	0.0
Juglans regia	0.0	0.0	0.0	0.0	0.0	0.0
Litsea monopetala	0.0	0.0	0.0	0.0	0.0	0.0
Lyonia ovalifolia	30.0	220.0	110.0	50.0	0.0	0.0
Myrica esculenta	230.0	160.0	30.0	20.0	0.0	0.0
Pinus roxburghii	0.0	0.0	0.0	0.0	0.0	0.0
Prunus cerasoides	0.0	0.0	10.0	10.0	10.0	0.0
Pyrus pashia	150.0	10.0	10.0	10.0	0.0	0.0
Quercus leucotrichophora	210.0	610.0	180.0	0.0	0.0	10.0
Rhododendron arboreum	120.0	260.0	220.0	70.0	40.0	10.0
Spondias pinnata	0.0	0.0	0.0	0.0	0.0	0.0
Symplocos ramosissima	150.0	20.0	0.0	0.0	0.0	0.0
Toona hexandra	0.0	0.0	0.0	0.0	0.0	0.0
others	60.0	0.0	0.0	0.0	0.0	0.0
Total	950.0	1300.0	590.0	180.0	50.0	20.0

Table 9: Tree population structure in community broad-leaved forest in a mid-altitude village landscape.

Tree species	Girth classes					
	<30 cm	30-60 cm	60-90 cm	90-120 cm	120-150 cm	≥150cm
Alnus nepalensis	0.0	0.0	0.0	0.0	0.0	0.0
Benthamidia capitata	0.0	0.0	0.0	0.0	0.0	0.0
Bombax ceiba	0.0	0.0	0.0	0.0	0.0	0.0
Celtis australis	0.0	0.0	0.0	0.0	0.0	0.0
Citrus aurantifolia	0.0	0.0	0.0	0.0	0.0	0.0
Ficus auriculata	0.0	0.0	0.0	0.0	0.0	0.0
Ficus semicordata	0.0	0.0	0.0	0.0	0.0	0.0
Ficus subincisa	0.0	0.0	0.0	0.0	0.0	0.0
Grewia optiva	0.0	0.0	0.0	0.0	0.0	0.0
Juglans regia	0.0	0.0	0.0	0.0	0.0	0.0
Litsea monopetala	0.0	0.0	0.0	0.0	0.0	0.0
Lyonia ovalifolia	247.1	135.3	41.2	0.0	0.0	0.0
Myrica esculenta	511.8	211.8	76.5	29.4	5.9	0.0
Pinus roxburghii	0.0	0.0	0.0	0.0	0.0	0.0
Prunus cerasoides	0.0	0.0	0.0	0.0	0.0	0.0
Pyrus pashia	147.1	29.4	0.0	0.0	0.0	0.0
Quercus leucotrichophora	629.4	235.3	264.7	58.8	11.8	0.0
Rhododendron arboreum	382.4	152.9	41.2	0.0	0.0	0.0
Spondias pinnata	0.0	0.0	0.0	0.0	0.0	0.0
Symplocos ramosissima	76.5	0.0	0.0	0.0	0.0	0.0
Toona hexandra	0.0	0.0	0.0	0.0	0.0	0.0
Others	288.2	17.6	0.0	0.0	0.0	0.0
Total	2282.3	782.4	423.5	88.2	17.6	0.0

Table 10: Density (No. of individuals/ha) of regenerating tree species (CBH<30 cm) in a mid-altitude village landscape (RA, Rainfed Agriculture; IA, Irrigated Agriculture; AA, Abandoned Agriculture; RPF, Reserve Pine Forest; RBF, Reserved Broadleaved Forest; CBF, Community Broadleaved Forest).

Tree species	RA	IA	AA	RPF	RBF	CBF
Alnus nepalensis	0.0	0.0	0.0	0.0	0.0	0.0
Benthamidia capitata	0.0	0.0	0.0	0.0	0.0	0.0
Bombax ceiba	0.0	0.0	0.0	0.0	0.0	0.0
Celtis australis	77.3	5.6	6.3	0.0	0.0	0.0
Citrus aurantifolia	0.0	0.0	12.5	0.0	0.0	0.0
Ficus auriculata	0.0	0.0	25.0	0.0	0.0	0.0
Ficus semicordata	0.0	0.0	0.0	0.0	0.0	0.0
Ficus subincisa	9.1	0.0	25.0	0.0	0.0	0.0
Grewia optiva	13.6	5.6	43.8	0.0	0.0	0.0
Juglans regia	0.0	0.0	0.0	0.0	0.0	0.0
Litsea monopetala	9.1	0.0	12.5	0.0	0.0	0.0
Lyonia ovalifolia	0.0	0.0	0.0	0.0	30.0	247.1
Myrica esculenta	0.0	0.0	18.8	0.0	230.0	517.6
Pinus roxburghii	0.0	0.0	62.5	0.0	0.0	0.0
Prunus cerasoides	0.0	0.0	0.0	0.0	0.0	0.0
Pyrus pashia	4.5	0.0	62.5	0.0	150.0	147.1
Quercus leucotrichophora	22.7	0.0	550.0	0.0	200.0	629.4
Rhododendron arboreum	0.0	0.0	0.0	0.0	130.0	382.4
Spondias pinnata	0.0	0.0	0.0	0.0	0.0	0.0
Symplocos ramosissima	0.0	0.0	12.5	0.0	150.0	76.5
Toona hexandra	4.5	0.0	6.3	0.0	0.0	0.0
others	22.7	0.0	0.0	0.0	60.0	294.1
Total	163.6	11.1	837.5	0.0	950.0	2294.1

Table 11: Relative Density of regenerating tree species (CBH<30 cm) in a mid-altitude village landscape (RA, Rainfed Agriculture; IA, Irrigated Agriculture; AA, Abandoned Agriculture; RPF, Reserve Pine Forest; RBF, Reserve Broad-leaved Forest; CBF, Community Broadleaved Forest).

Tree species	RA	IA	AA	RPF	RBF	CBF
Alnus nepalensis	0.0	0.0	0.0	0.0	0.0	0.0
Benthamidia capitata	0.0	0.0	0.0	0.0	0.0	0.0
Bombax ceiba	0.0	0.0	0.0	0.0	0.0	0.0
Celtis australis	47.2	50.0	0.7	0.0	0.0	0.0
Citrus aurantifolia	0.0	0.0	1.5	0.0	0.0	0.0
Ficus auriculata	0.0	0.0	3.0	0.0	0.0	0.0
Ficus semicordata	0.0	0.0	0.0	0.0	0.0	0.0
Ficus subincisa	5.6	0.0	3.0	0.0	0.0	0.0
Grewia optiva	8.3	50.0	5.2	0.0	0.0	0.0
Juglans regia	0.0	0.0	0.0	0.0	0.0	0.0
Litsea monopetala	5.6	0.0	1.5	0.0	0.0	0.0
Lyonia ovalifolia	0.0	0.0	0.0	0.0	3.2	10.8
Myrica esculenta	0.0	0.0	2.2	0.0	24.2	22.6
Pinus roxburghii	0.0	0.0	7.5	0.0	0.0	0.0
Prunus cerasoides	0.0	0.0	0.0	0.0	0.0	0.0
Pyrus pashia	2.8	0.0	7.5	0.0	15.8	6.4
Quercus leucotrichophora	13.9	0.0	65.7	0.0	21.1	27.4
Rhododendron arboreum	0.0	0.0	0.0	0.0	13.7	16.7
Spondias pinnata	0.0	0.0	0.0	0.0	0.0	0.0
Symplocos ramosissima	0.0	0.0	1.5	0.0	15.8	3.3
Toona hexandra	2.8	0.0	0.7	0.0	0.0	0.0
Others	13.9	0.0	0.0	0.0	6.3	12.8

Table 12: Density (No. of individuals/ha) of mature tree species (CBH≥30 cm) in a mid-altitude village landscape (RA, Rainfed Agriculture; IA, Irrigated Agriculture; AA, Abandoned Agriculture; RPF, Reserve Pine Forest; RBF, Reserve Broad-leaved Forest; CBF, Community Broadleaved Forest).

Tree species	RA	IA	AA	RPF	RBF	CBF
Alnus nepalensis	0.0	0.0	0.0	0.0	50.0	0.0
Benthamidia capitata	0.0	0.0	0.0	0.0	20.0	0.0
Bombax ceiba	4.5	0.0	6.3	0.0	0.0	0.0
Celtis australis	86.4	0.0	43.8	0.0	0.0	0.0
Citrus aurantifolia	0.0	0.0	0.0	0.0	0.0	0.0
Ficus auriculata	22.7	0.0	12.5	0.0	0.0	0.0
Ficus semicordata	9.1	0.0	18.8	0.0	0.0	0.0
Ficus subincisa	0.0	0.0	0.0	0.0	0.0	0.0
Grewia optiva	113.6	0.0	37.5	0.0	0.0	0.0
Juglans regia	4.5	0.0	0.0	0.0	0.0	0.0
Litsea monopetala	4.5	0.0	0.0	0.0	0.0	0.0
Lyonia ovalifolia	0.0	0.0	0.0	0.0	380.0	176.5
Myrica esculenta	0.0	0.0	0.0	0.0	210.0	317.6
Pinus roxburghii	0.0	0.0	12.5	260.0	0.0	0.0
Prunus cerasoides	0.0	0.0	0.0	0.0	30.0	0.0
Pyrus pashia	4.5	0.0	37.5	0.0	30.0	29.4
Quercus leucotrichophora	18.2	0.0	156.3	0.0	800.0	570.6
Rhododendron arboreum	0.0	0.0	0.0	0.0	600.0	194.1
Spondias pinnata	0.0	5.6	6.3	0.0	0.0	0.0
Symplocos ramosissima	0.0	0.0	0.0	0.0	20.0	0.0
Toona hexandra	0.0	0.0	12.5	0.0	0.0	0.0
others	0.0	0.0	0.0	0.0	0.0	17.6
Total	268.2	5.6	343.8	260.0	2140.0	1305.9

Table 13: Relative Density of mature tree species (CBH≥30 cm) in a mid-altitude village landscape (RA, Rainfed Agriculture; IA, Irrigated Agriculture; AA, Abandoned Agriculture; RPF, Reserve Pine Forest; RBF, Reserve Broad-leaved Forest; CBF, Community Broadleaved Forest).

Tree species	RA	IA	AA	RPF	RBF	CBF
Alnus nepalensis	0.0	0.0	0.0	0.0	2.3	0.0
Benthamidia capitata	0.0	0.0	0.0	0.0	0.9	0.0
Bombax ceiba	1.7	0.0	1.8	0.0	0.0	0.0
Celtis australis	32.2	0.0	12.7	0.0	0.0	0.0
Citrus aurantifolia	0.0	0.0	0.0	0.0	0.0	0.0
Ficus auriculata	8.5	0.0	3.6	0.0	0.0	0.0
Ficus semicordata	3.4	0.0	5.5	0.0	0.0	0.0
Ficus subincisa	0.0	0.0	0.0	0.0	0.0	0.0
Grewia optiva	42.4	0.0	10.9	0.0	0.0	0.0
Juglans regia	1.7	0.0	0.0	0.0	0.0	0.0
Litsea monopetala	1.7	0.0	0.0	0.0	0.0	0.0
Lyonia ovalifolia	0.0	0.0	0.0	0.0	17.8	13.5
Myrica esculenta	0.0	0.0	0.0	0.0	9.8	24.3
Pinus roxburghii	0.0	0.0	3.6	100.0	0.0	0.0
Prunus cerasoides	0.0	0.0	0.0	0.0	1.4	0.0
Pyrus pashia	1.7	0.0	10.9	0.0	1.4	2.3
Quercus leucotrichophora	6.8	0.0	45.5	0.0	37.4	43.7
Rhododendron arboreum	0.0	0.0	0.0	0.0	28.0	14.9
Spondias pinnata	0.0	100.0	1.8	0.0	0.0	0.0
Symplocos ramosissima	0.0	0.0	0.0	0.0	0.9	0.0
Toona hexandra	0.0	0.0	3.6	0.0	0.0	0.0
others	0.0	0.0	0.0	0.0	0.0	1.4

Table 14: Basal area of tree species (m^2/ha) in a mid-altitude village landscape (RA, Rainfed Agriculture; IA, Irrigated Agriculture; AA, Abandoned Agriculture; RPF, Reserve Pine Forest; RBF, Reserve Broad-leaved Forest; CBF, Community Broadleaved Forest).

Tree species	RA	IA	AA	RPF	RBF	CBF
Alnus nepalensis	0.0	0.0	0.0	0.0	3.1	0.0
Benthamidia capitata	0.0	0.0	0.0	0.0	0.4	0.0
Bombax ceiba	0.1	0.0	0.1	0.0	0.0	0.0
Celtis australis	4.5	0.0	5.8	0.0	0.0	0.0
Citrus aurantifolia	0.0	0.0	0.1	0.0	0.0	0.0
Ficus auriculata	1.4	0.0	0.2	0.0	0.0	0.0
Ficus semicordata	0.1	0.0	0.4	0.0	0.0	0.0
Ficus subincisa	0.0	0.0	0.0	0.0	0.0	0.0
Grewia optiva	2.7	0.0	1.9	0.0	0.0	0.0
Juglans regia	3.0	0.0	0.0	0.0	0.0	0.0
Litsea monopetala	0.2	0.0	0.0	0.0	0.0	0.0
Lyonia ovalifolia	0.0	0.0	0.0	0.0	12.1	4.2
Myrica esculenta	0.0	0.0	0.0	0.0	5.9	10.0
Pinus roxburghii	0.0	0.0	1.4	72.9	0.0	0.0
Prunus cerasoides	0.0	0.0	0.0	0.0	2.9	0.0
Pyrus pashia	0.1	0.0	0.5	0.0	1.5	0.4
Quercus leucotrichophora	0.9	0.0	6.4	0.0	19.1	22.3
Rhododendron arboreum	0.0	0.0	0.0	0.0	28.2	5.1
Spondias pinnata	0.0	0.1	0.3	0.0	0.0	0.0
Symplocos ramosissima	0.0	0.0	0.0	0.0	0.7	0.1
Toona hexandra	0.0	0.0	3.5	0.0	0.0	0.0
Others	0.0	0.0	0.0	0.0	0.0	0.5
Total	13.0	0.1	20.6	72.9	73.9	42.6

Table 15: Relative Basal area of tree species in a mid-altitude village landscape (RA, Rainfed Agriculture; IA, Irrigated Agriculture; AA, Abandoned Agriculture; RPF, Reserve Pine Forest; RBF, Reserve Broad-leaved Forest; CBF, Community Broadleaved Forest).

Tree species	RA	IA	AA	RPF	RBF	CBF
Alnus nepalensis	0.0	0.0	0.0	0.0	4.1	0.0
Benthamidia capitata	0.0	0.0	0.0	0.0	0.6	0.0
Bombax ceiba	0.8	0.0	0.5	0.0	0.0	0.0
Celtis australis	34.6	0.0	28.2	0.0	0.0	0.0
Citrus aurantifolia	0.0	0.0	0.5	0.0	0.0	0.0
Ficus auriculata	10.8	0.0	1.0	0.0	0.0	0.0
Ficus semicordata	0.8	0.0	1.9	0.0	0.0	0.0
Ficus subincisa	0.0	0.0	0.0	0.0	0.0	0.0
Grewia optiva	20.8	0.0	9.2	0.0	0.0	0.0
Juglans regia	23.1	0.0	0.0	0.0	0.0	0.0
Litsea monopetala	1.5	0.0	0.0	0.0	0.0	0.0
Lyonia ovalifolia	0.0	0.0	0.0	0.0	16.4	9.8
Myrica esculenta	0.0	0.0	0.0	0.0	8.0	23.4
Pinus roxburghii	0.0	0.0	6.8	100.0	0.0	0.0
Prunus cerasoides	0.0	0.0	0.0	0.0	4.0	0.0
Pyrus pashia	0.8	0.0	2.4	0.0	2.0	0.8
Quercus leucotrichophora	6.9	0.0	31.1	0.0	25.8	52.4
Rhododendron arboreum	0.0	0.0	0.0	0.0	38.2	12.0
Spondias pinnata	0.0	100.0	1.5	0.0	0.0	0.0
Symplocos ramosissima	0.0	0.0	0.0	0.0	0.9	0.2
Toona hexandra	0.0	0.0	17.0	0.0	0.0	0.0
others	0.0	0.0	0.0	0.0	0.0	1.3

Table 16: Density (standard error) of soil macrofauna in different land uses of a village landscape of Garhwal Himalayas (RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest)

Land uses	Earthworms	Diplopoda	Chilopoda	Araneae	Orthoptera	Dermaptera	Isoptera	Hemiptera	Coleoptera Larvae	Coleoptera Adults	Lepidoptera Larvae	Diptera Larvae	Hymenoptera	Others
RA	10.6 (2.6)	0.0 (0.0)	5.6 (2.2)	1.5 (0.8)	7.6 (2.8)	1.0 (0.7)	45.5 (28.3)	4.0 (1.9)	126.3 (46.6)	12.6 (3.0)	0.5 (0.5)	2.0 (1.6)	56.1 (35.6)	2.5 (1.0)
IA	4.3 (2.2)	0.0 (0.0)	0.0 (0.0)	5.6 (2.1)	16.1 (4.6)	0.0 (0.0)	2.5 (2.5)	35.2 (16.3)	89.5 (20.5)	17.9 (3.3)	4.3 (2.2)	9.9 (3.6)	4.3 (2.0)	3.1 (1.2)
AA	29.9 (14.4)	0.0 (0.0)	2.8 (2.2)	3.5 (1.7)	2.8 (1.2)	0.0 (0.0)	120.9 (74.7)	2.8 (1.6)	32.6 (7.0)	8.3 (2.6)	1.4 (1.0)	2.8 (1.6)	61.1 (22.5)	11.8 (6.8)
RPF	16.7 (15.5)	1.1 (1.1)	1.1 (1.1)	0.0 (0.0)	7.8 (4.1)	0.0 (0.0)	215.5 (158.0)	3.3 (2.4)	80.0 (18.1)	10.0 (3.1)	1.1 (1.1)	3.3 (2.4)	80.0 (37.4)	2.2 (2.2)
RBF	5.6 (4.5)	1.1 (1.1)	22.2 (12.6)	11.1 (5.0)	10.0 (5.8)	21.1 (6.3)	30.0 (30.0)	16.6 (8.7)	90.0 (19.4)	17.8 (5.5)	2.2 (2.2)	36.7 (9.1)	23.3 (10.3)	8.9 (2.8)
CBF	14.4 (7.6)	1.3 (0.9)	2.6 (1.5)	9.2 (2.2)	15.0 (3.9)	4.6 (1.9)	0.0 (0.0)	0.7 (0.7)	57.5 (11.3)	5.9 (1.7)	1.3 (0.9)	2.6 (1.5)	34.0 (11.4)	5.2 (1.9)

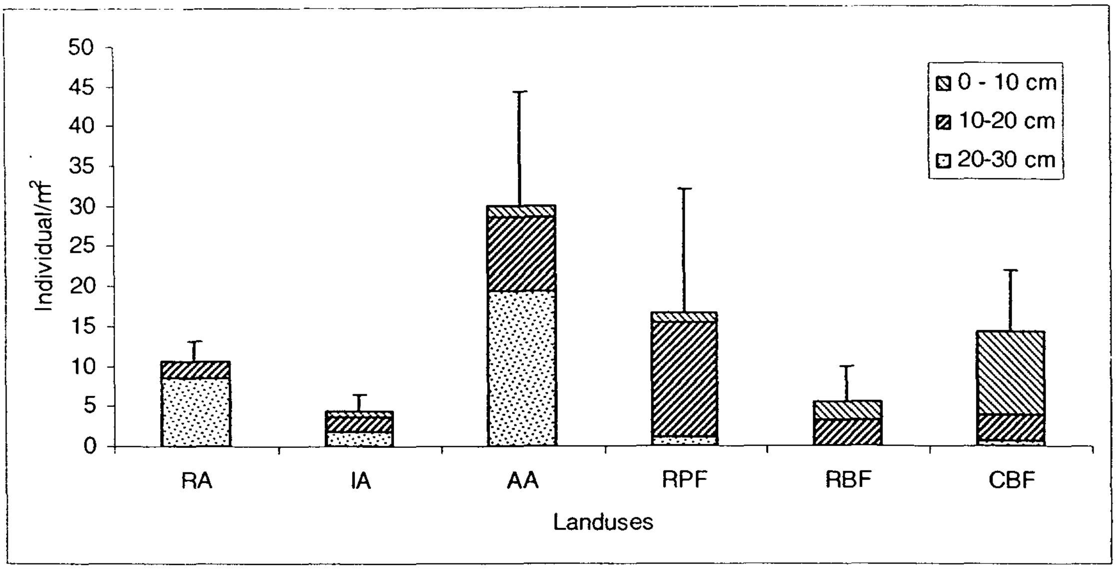


Fig. 1: Density of Earthworms (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

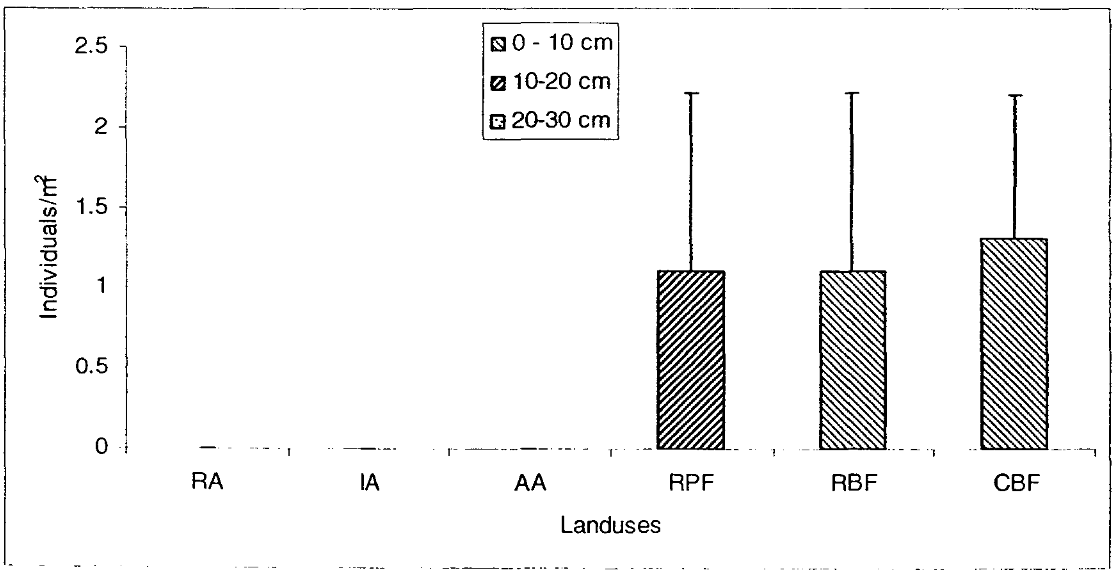


Fig. 2: Density of Diplopoda (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

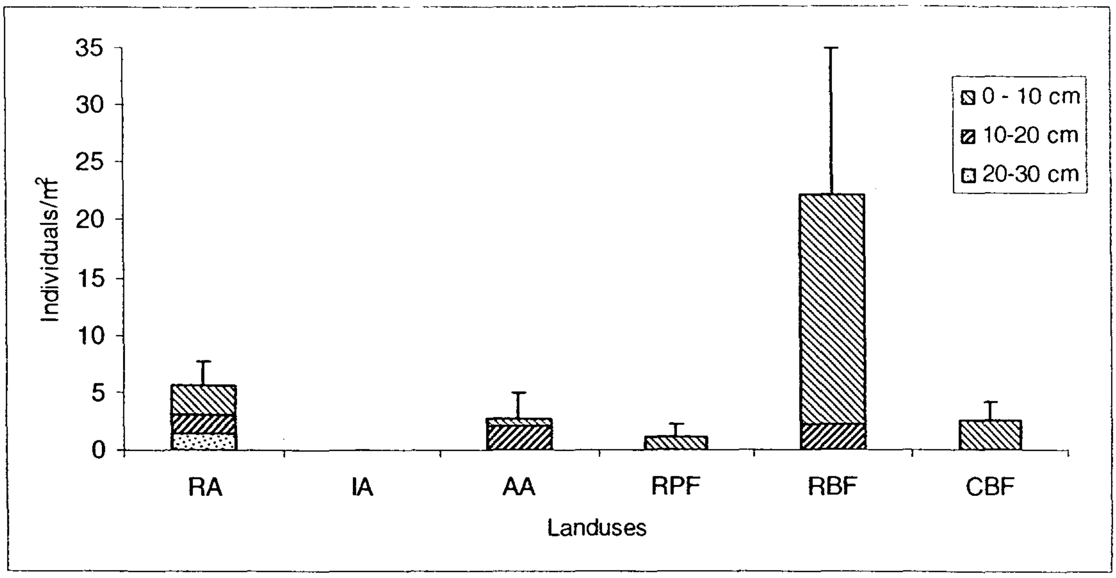


Fig. 3: Density of Chilopoda (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest)

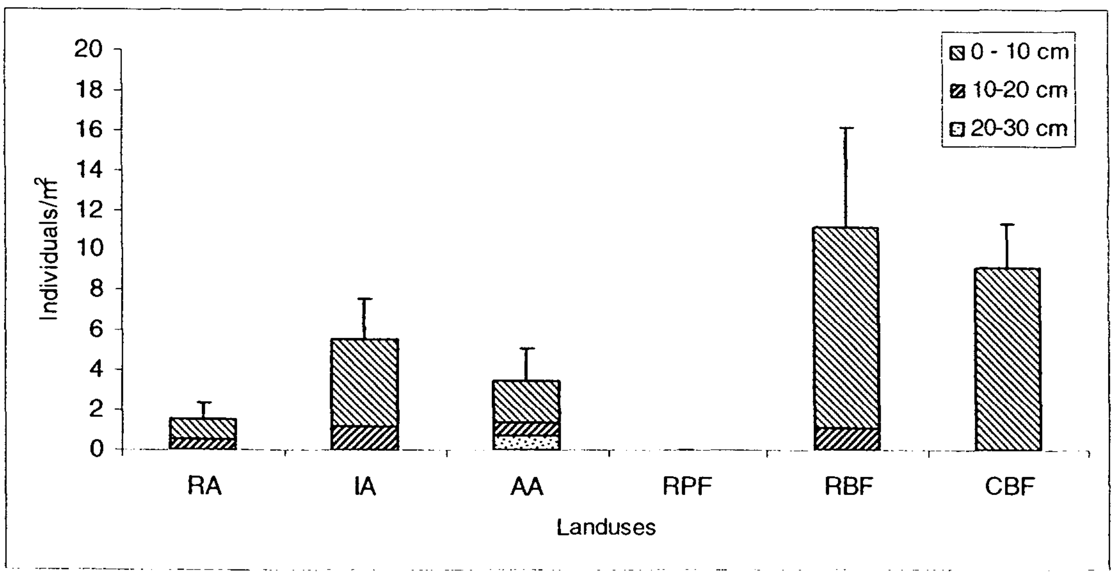


Fig. 4: Density of Araneae (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

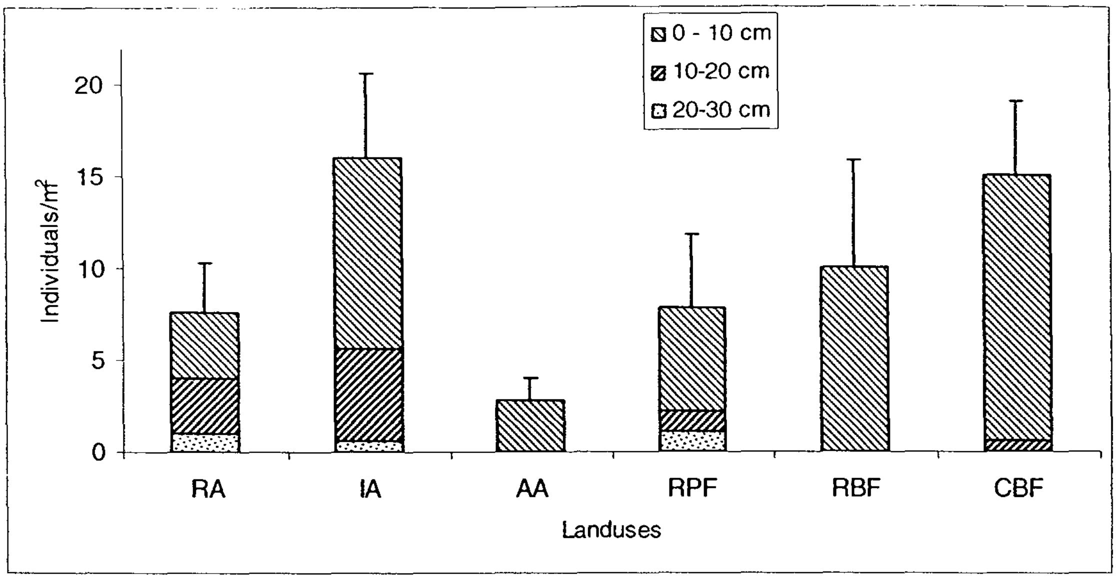


Fig. 5: Density of Orthoptera (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

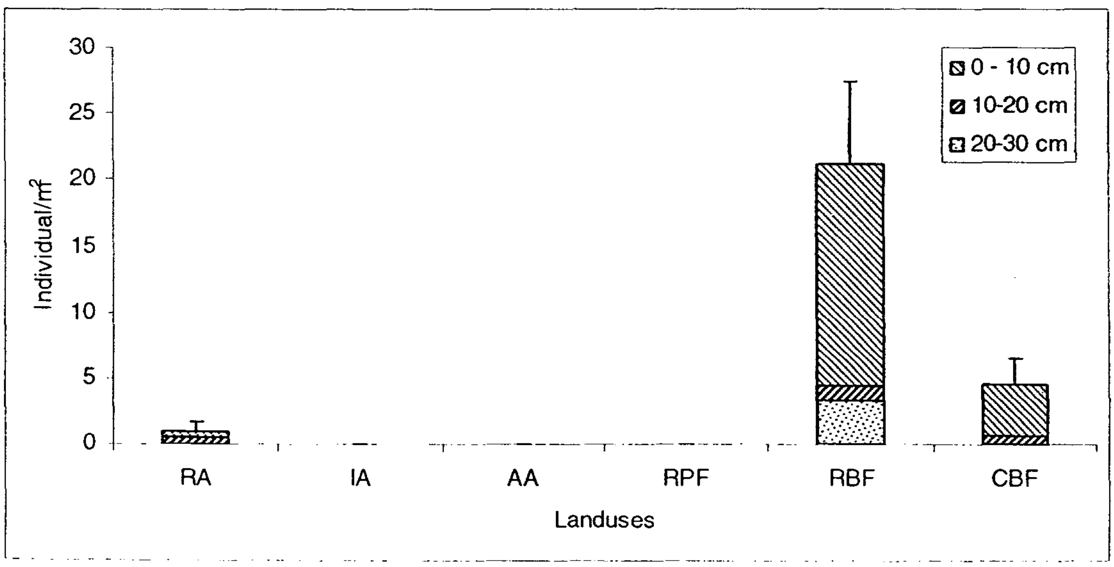


Fig. 6: Density of Dermaptera (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

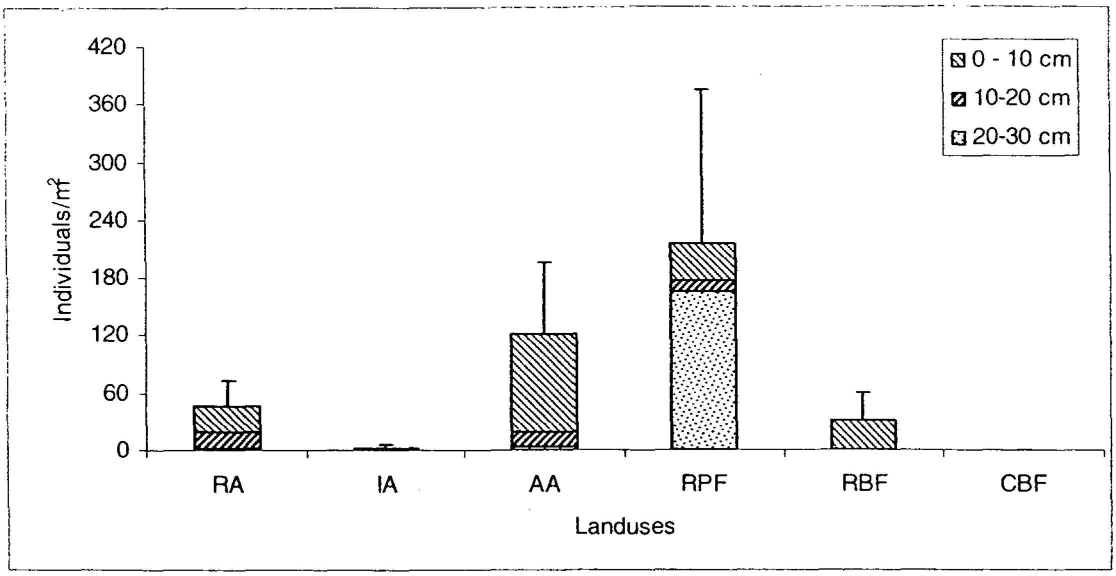


Fig. 7: Density of Isoptera (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

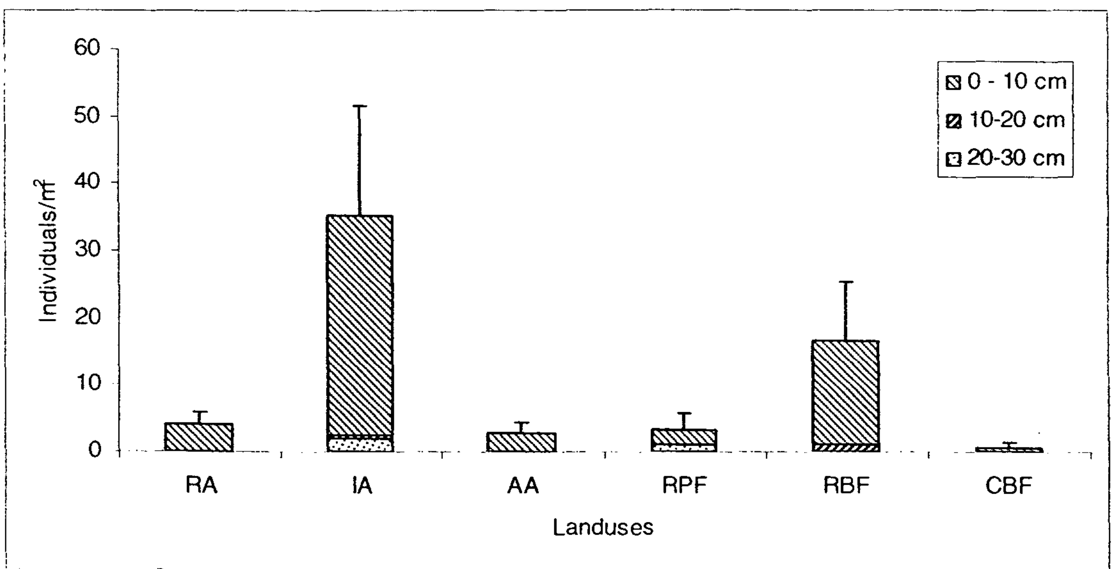


Fig. 8: Density of Hemiptera (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

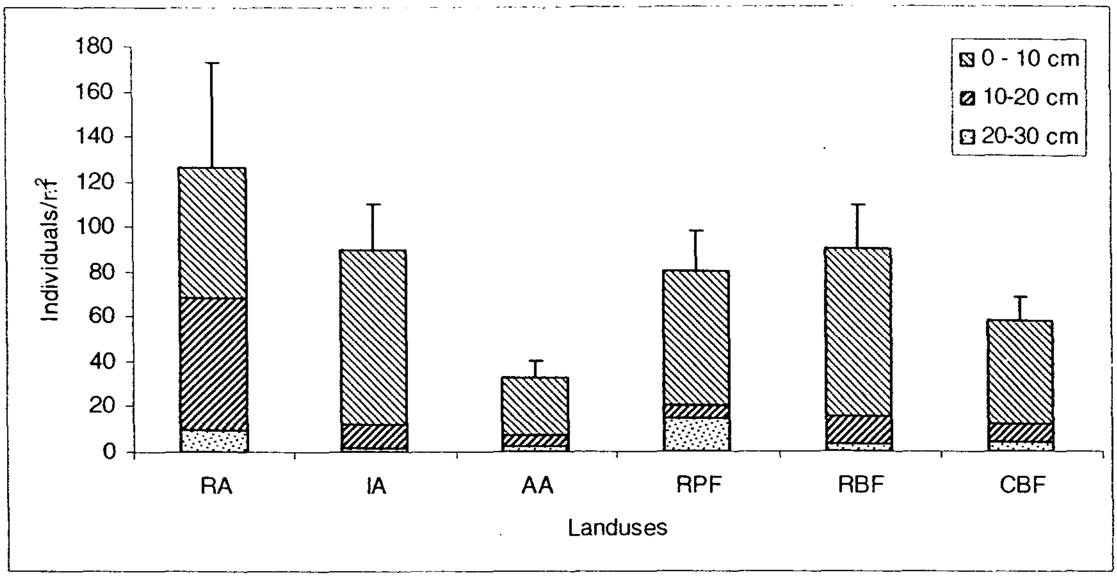


Fig. 9: Density of Coleoptera Larvae (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

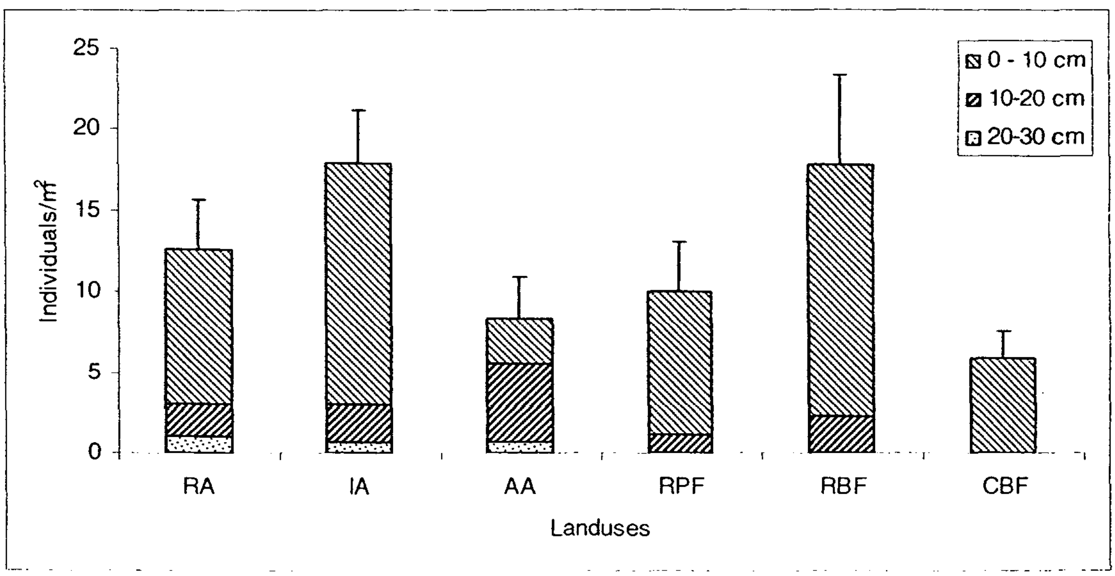


Fig. 10: Density of Coleoptera Adults (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

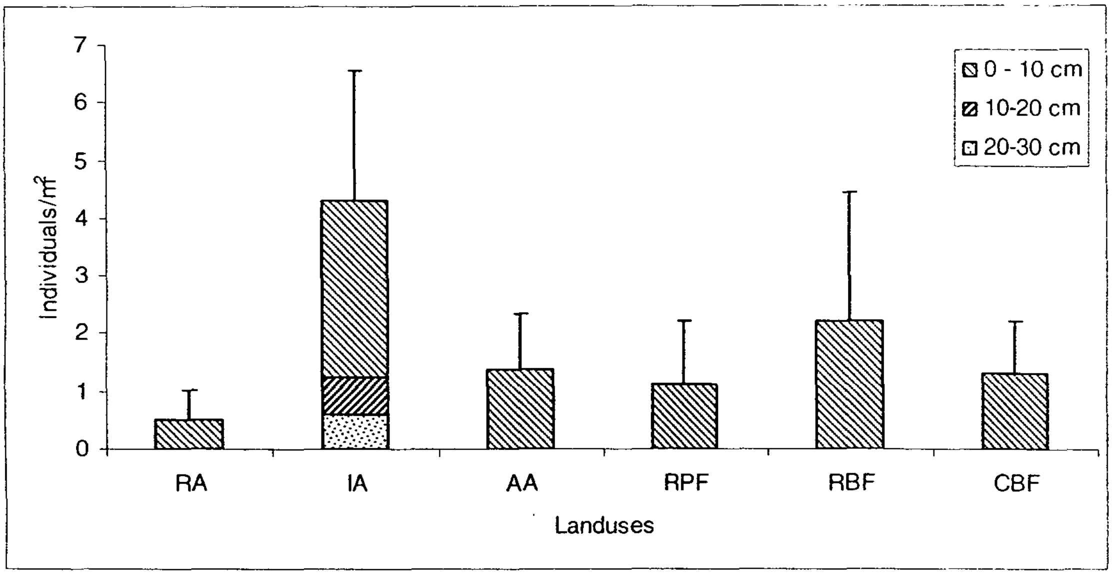


Fig. 11: Density of Lepidoptera Larvae (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

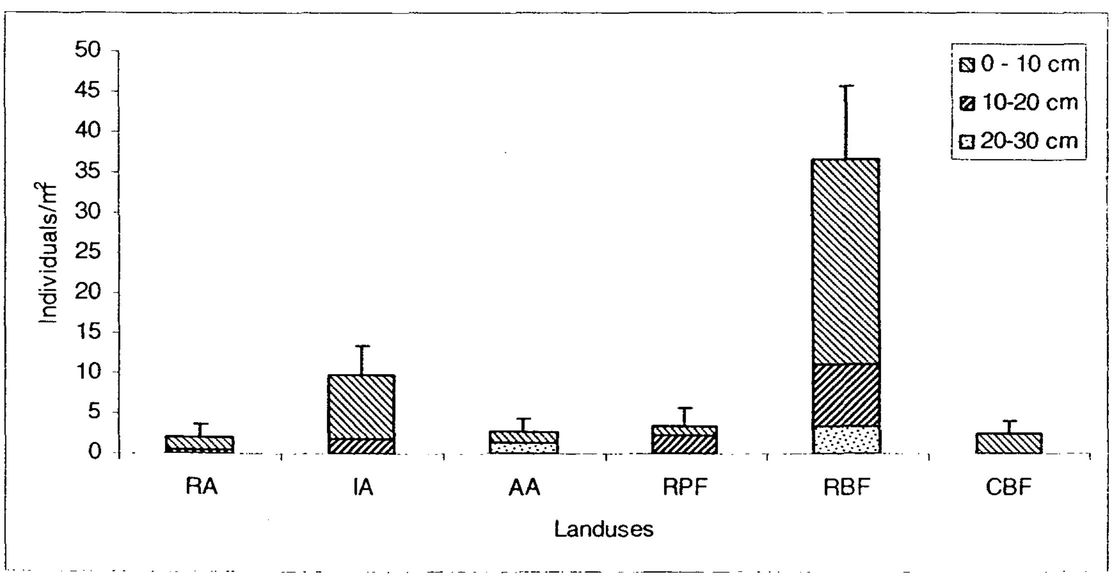


Fig. 12: Density of Diptera Larvae (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

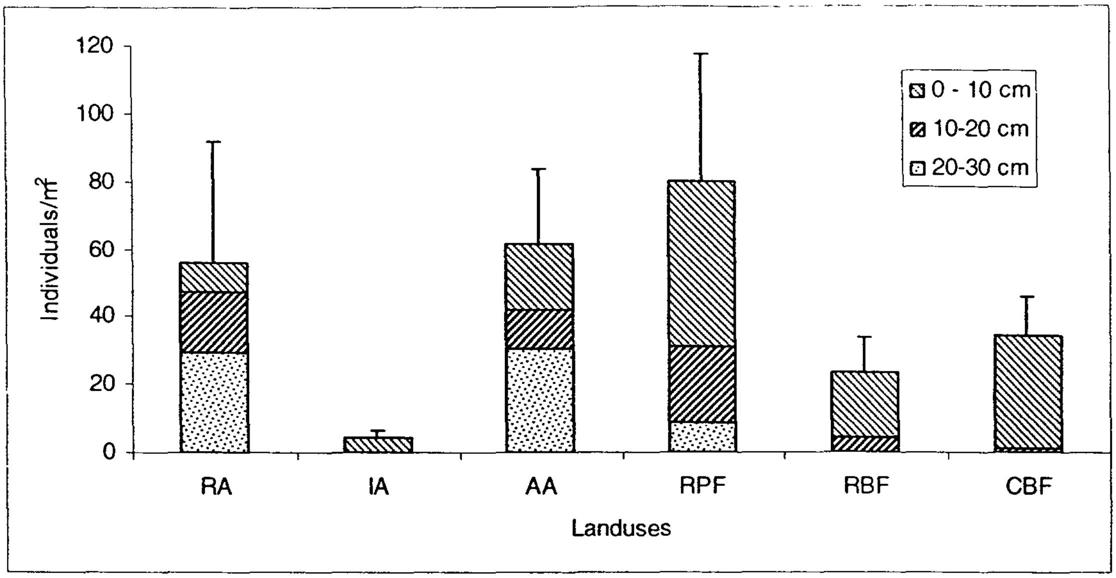


Fig. 13: Density of Hymenoptera (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

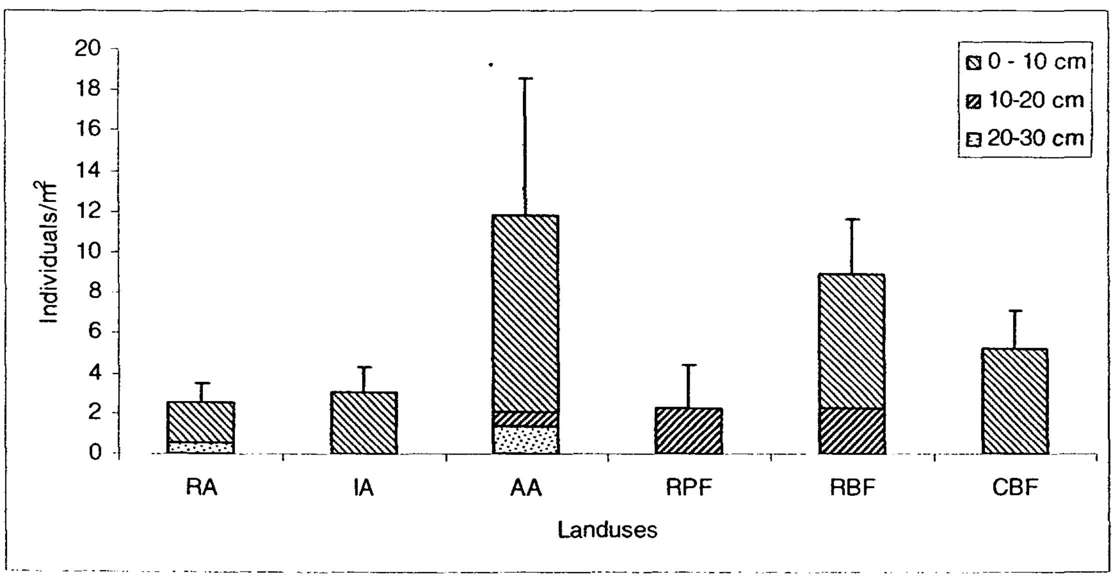


Fig. 14: Density of others (individuals/m^2) in different land uses of a village landscape of Garhwal Himalayas (Bars showing standard error; RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

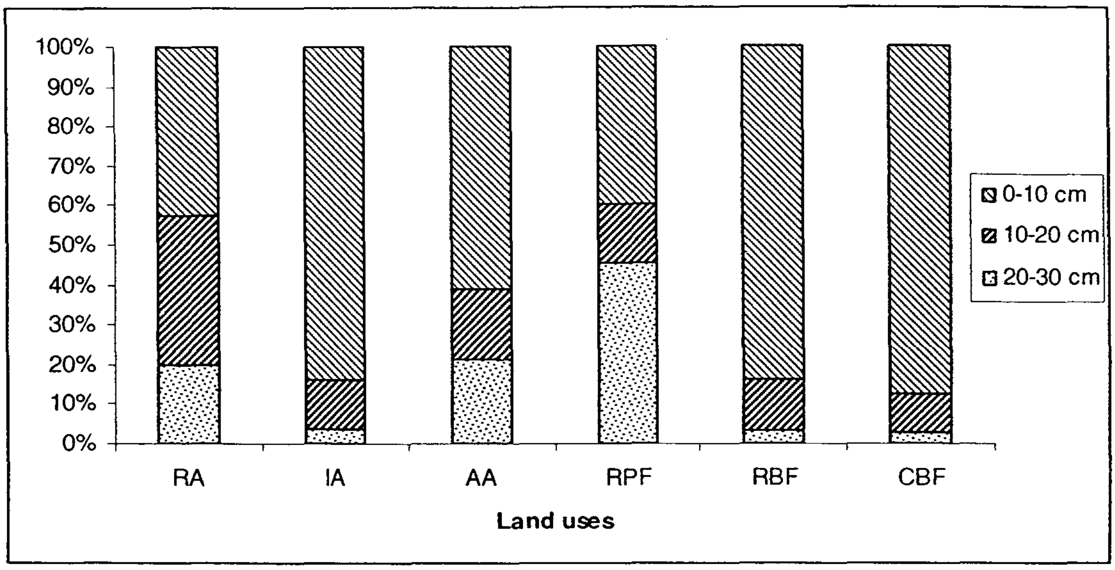


Fig. 15: Vertical distribution of macrofauna in different land uses of a village landscape of Garhwal Himalayas (RA - Rainfed Agriculture; IA - Irrigated Agriculture; AA - Abandoned Agriculture; RPF - Reserve Pine Forest; RBF - Reserve Broadleaved Forest; CBF - Community Broadleaved Forest).

4. Discussion

4.1 Tree community structure in forest land uses

Climax vegetation of the study area is described as 'Montane Wet Temperate Forest' distinguished by the dominance of broad-leaved evergreen *Q. leucotrichophora* trees without buttresses, epiphytic lichens and mosses on tree trunk and branches, and almost complete absence of lianas. Compared to other ecological zones in the Himalaya, the temperate forest zone is very favourable for human settlements and hence disturbances such as, lopping, fire and grazing are quite common in these forests. Policies have allowed use of forest resources free of any cost of meeting subsistence needs and not for economic gains from market to local people. Selective felling was allowed to government agencies till 1976 but subsequently it was banned. The study by Wakeel et al., (2005) found that reduction of crown density (a change from dense to degraded forest) was the major change observed in government managed forest, conversion to annual crop cultivation was predominant in people managed forest. Studies from the region indicate that to sustain the productivity of each unit of rainfed agricultural land on raised terraces in central Himalayas 5-17 units of agricultural support land (forest and grazing lands providing manure) are needed (Singh et al., 1984a; Ashish, 1993; Hrabovzsky and Miyan, 1987). Deforestation and degradation will hamper the sustainability of agriculture in village landscape. Modification of agriculture to agroforestry and agrihorticulture and introduction of irrigation has showed potential to overcome these constrains but the environmental costs of this are not fully understood in central Himalaya (Saxena et al., 1990; Rao et al., 1999).

The present study showed that density and basal area of mature tree species was high in Reserve broad-leaved forest as compared to community broad-leaved forest. Although *Q. leucotrichophora* was most abundant in both the forests, second most abundant species varied. *R. arboreum* and *M. esculenta* were the second most abundant species in Reserve broad-leaved forest and Community broad-leaved forest respectively. This might happen due to different disturbance level, percentage canopy cover and altitudinal difference. In Reserve broad-leaved forest, disturbance was low and canopy cover was high (personal observation). It was also situated about 200 m above the Community broad-leaved forest.

Regenerating tree density was inversely related to mature tree density in reserve and community broad-leaved forest. Low regeneration in reserve broad-leaved forest is associated with the overstories with a high basal area, stem density and canopy coverage. Inadequate light in the understorey also influenced regeneration establishment. Tenurial differences have a considerable influence on oak regeneration (Thadani and Ashton, 1995). Forests under different tenurial categories differ in their management with respect to lopping and grazing activities. In Reserve broad-leaved forest high canopy closure is detrimental to establishment of regenerating individuals.

Studies by some workers in the Himalaya and elsewhere indicated that oak forests were being replaced by pine forests and such changes sometimes formed intermediate stages before natural forests were converted to degraded areas or agricultural lands (Singh et al., 1984a; Gibson et al., 1988; Singh and Singh, 1992; Thadani and Ashton, 1995). To allow good fodder growth, pine forests in the region are subjected to annual ground burning. Due to annual ground burning in reserve pine forest regenerating individuals were not found and the mature individuals were also damaged near ground surface.

4.2 Agriculture and Agro-forestry System

Traditional subsistence agriculture with low external inputs is now on transition towards intensive production in this region (Ramakrishnan et al., 1992; Semwal and Maikhuri, 1996; Maikhuri et al., 2001). Participatory discussion with farmers in the study area revealed that they are applying fertilizers as well as pesticides (particularly in rice to save from 'white grubs') in agricultural lands. They also revealed that due to application of fertilizer, yield as well as diversity of pulses has been decreased. Loss of agro-biodiversity will not be sustainable in long run.

Over large areas in western and central Himalayas, fodder trees like *G. optiva, C. australis, Q. leucotrichophora,* and *F. auriculata* are deliberately introduced or selectively protected and grown on field/terrace margins (Ralhan et al., 1991; Semwal and Maikhuri, 1996; Toky et al., 1989). Traditionally, farmers have devised specific lopping schedules such that the negative effects of trees on associated understorey annual crops get minimized. Agroforestry tree species (mature tree component) were markedly different from forest tree species. Agroforestry species like *G. optica*, *C. australis* and *F. auriculata* did not occur at all the forests. Maikhuri et al., (1997a) observed the occurrence of most agroforestry tree species as isolated individuals in forest gaps and suggested that these species possess adaptive traits especially suited to early successional environments as in agricultural land use. Occurrence of tree species like *P. pashia* and *Q. leucotrichophora* which were also observed in forest land use is suggestive of their wide ecological amplitude.

Species richness, density of regenerating individuals, density of mature individuals and basal area were highest in abandoned agricultural land and lowest in irrigated agricultural land of all the three agricultural land uses. Farmers promoted growth of agroforestry tree in abandoned agricultural land to meet the demand of fodder, fibre and fuel wood however, they did not allow to grow in irrigated agricultural land since intensive agriculture were practiced.

Lower density of regenerating individuals in agroforestry land as compared to that in forests is obviously linked to effects of agricultural management activities/more favourable micro-environments for regeneration in forest. Presence of forest species like *M. esculenta, S. ramosissima* as regenerating individuals but not as mature tree suggests that these species are either unable to survive in open environments or are selectively eliminated by farmers because of their inferior quality of fodder/other multipurpose products and poor recovery following lopping.

4.3 Spatial variability of soil macrofauna

Land use diversity and soil management options can have dramatic effects upon soil invertebrate communities (Beare et al., 1997; Fragoso et al., 1997; Giller et al., 1997, Barros et al., 2002, 2003; Decaens et al., 2004; Rossi and Blanchart, 2005). Belowground diversity because of its impact on soil quality could be a key factor in determining stability and resilience of ecosystem (Saxena et al., 2005). The structure of decomposer habitats is strongly influenced by the composition, diversity and architecture of vegetational cover, factors which are likely to influence the structure of the decomposer communities. Plant litter quality has long been recognized as an important driver of decomposer communities and the ecosystem processes that they drive (Swift et al., 1979; Cadisch and Giller, 1997). Wardle et al. (2006) found that components of the microflora, mesofauna and macrofauna all differed greatly across the 8 litter monoculture types. Thus plant litter quality is major driver of decomposer invertebrate communities.

Earthworms, an important macrofauna group, contribute to distribution of surface litter, spatial heterogeneity and microbial activity (Bohlen et al., 1997). Changes in land use pattern and vegetation structure result in significant differences in microhabitat conditions such as physico-chemical properties and soil temperature which in turn alter the earthworm population structure (Bhadauria and Ramakrishnan, 1991; Hendrix et al., 1992; Blanchart and Julka, 1997; Jordan et al., 1997; Bhadauria et al., 2000). The present study showed that among forest land uses reserve pine forest had highest earthworm density (16.7 ind./m^2) followed by community broad-leaved forest (14.4 ind./m^2) and reserve broad-leaved forest (5.6 ind./m^2). Our results showed similar trend as obtained by Sinha et al. (2003). They also found more earthworm density in pine forest as compared to broad-leaved forest. A maximum of 50 earthworms/m^2 was reported from the pine forest of Meghalaya in north-Eastern India by Reddy and Alfred (1978). The density reported is much higher than the present study. This might have happened due to different climatic conditions and different species of pine. Among broad-leaved forest, community broad-leaved forest has higher density (specially in 0-10 cm soil layer) as compared to reserve broad-leaved forest. This difference might have occurred due to differences in vegetation structure (litter resource quality) disturbance level and frost, which is common during winter in Reserve broad-leaved forest due to higher altitude. Among agricultural land uses, Abandoned agricultural land had highest density (29.9 ind./m^2) of earthworms. This might have occurred due to high agroforestry tree density, high quality organic matter input (e.g., cow dung) and absence of ploughing. Kale (2005) reported that abandonment of agricultural land use accompanies a dramatic increase in earthworm population. Rainfed agricultural land had higher density (10.6 ind./m^2) of earthworms as compared to Irrigated agricultural land. This difference may be attributed to the effect of crop rotation and agroforestry practices under Rainfed agricultural land which are distinct from Irrigated agricultural land. Lofs-Holmin (1983) also reported on changes in population structures linked to crop rotation practices. Our results are in concurrence with Sinha et al. (2003) who also found more density in Rainfed agroecosystem than Irrigated agriculture. Due to tillage earthworms were not found in 0-10 cm soil layer in rainfed agricultural land and was low in Irrigated land. Burning of litter and crop by-products prior to field preparation could eliminate earthworms from the surface layer.

The reduction or elimination of litter cover as a result of burning can markedly reduce microhabitat availability and hence the density and diversity of decomposer arthropods (Warren et al., 1987). In this study, it was found that Chilopoda, Aranae, Dermaptera, Hemiptera, Coleoptera larvae, Coleoptera adults, Lepidoptera larvae, Diptera larvae were less abundant in community broad-leaved forest as compared to reserve broad-leaved forest. This could be attributed to litter removal from community broad-leaved forest, which markedly reduces microhabitat availability.

Density of macrofauna was highest in Reserve pine forest (422.2 ind./m^2), 51% of which is accounted by Isoptera. Such factors as poor litter quality, occurrence of vacant niches, increased temperature and reduced moisture at the soil surface may explain the high abundance of Isoptera in pine forest. Coleoptera larvae were most abundant in rainfed as well as irrigated agricultural lands. Since the macrofauna collection was made during wheat cropping, this high density could be attributed to rhizophagous populations of coleoptera larvae.

4.4 Vertical distribution of soil macrofauna

Vertical distribution of macrofauna varied with the type of land use, depending on the abundance and quality of the surface litter layer. Although, in irrigated agricultural land, reserve broad-leaved forest and community broad-leaved forest 84%-88% of the macrofauna were found in 0-10 cm soil layer, the community structure was different. This could be attributed to the quality of the surface litter layer and disturbance level in different land uses. Contrary to other land uses, highest 46% of the individuals were found in 20-30 cm soil layer in Reserve pine forest of which 86% of the individuals were contributed by Isoptera only. Since the Isoptera are anecic / endogeic, the high abundance in lower layer is natural. In rainfed agricultural land roughly equal proportion of individuals were found in 0-10 and 10-20 cm soil layer. This might have happened due to high density of Coleoptera larvae in 10-20 cm soil layer, whose distribution is common in deeper layer in agricultural land. In abandoned agricultural land 61% of the individuals were found in 0-10 cm of which 60% is contributed by Isoptera. Thomas et al. (2004) found that the pool of species that colonized the newly abandoned rice field was different from the one inhabiting natural grassland. The present study also show due to abandonment of rainfed agricultural land community structure of macrofauna changed.

5. Conclusion

The major conclusions arising from this study carried out in a mid-altitude village landscape where the different ecosystems are intimately interconnected are

i. *P. pashia* and *Q. leucotrichophora* had wide ecological amplitude as these two species were found in most of the land uses.

ii. In Reserve pine forest, due to annual occurrence of forest fire, regenerating individuals were absent and mature trees were also hollowed at the base, making them vulnerable to fall due to wind. These two factors may lead to elimination of Reserve pine forest.

iii. Despite the fact that, the density of *M. esculenta* was highest among the regenerating trees in Reserve broad-leaved forest, *Q. leucotrichophora* and *R. arboreum* were the species with highest density among mature trees. There is also possibility that mature tree community structure may change in near future.

iv. *Q. leucotrichophora* was most abundant regenerating tree species in abundant agricultural land. This infers that people promoted regeneration of *Q. leucotrichophora*, since it is of high value (fodder, fuel wood and manure) to local people.

v. Since the mature tree density and basal area were low in community broad-leaved forest, this leads to inference that community broad-leaved forest was more degraded than the reserve broad-leaved forest. At the same time, regenerating tree density is higher in community broad-leaved forest compared to reserve broad-leaved forest. This shows that, provided better management practices, community broad-leaved forest can be restored from its present degraded status.

vi. Abandonment of Rainfed agricultural land had increased tree species richness as well as macrofaunal density, particularly of earthworms, isoptera and hymenoptera.

vii. Different land uses lead to changes in vegetational characteristics with subsequent modification in microhabitat conditions, which in turn affect macrofauna community.

viii. Due to degraded status and higher level of disturbance (compared to reserve broad-leaved forest) soil macrofaunal density was lowest in community broad-leaved forest among all land uses.

ix. Among the agricultural land uses it was found that land use intensification leads to was declined in the density of major groups of soil macrofauna (viz., Earthworm, Isoptera and Hymenoptera) i.e., density was in the decreasing sequence from abandoned agricultural land to rainfed agricultural land to irrigated agricultural land. Various management practices (such as crop rotation, irrigation, tillage, man power input) are taken as parameters of land use intensification.

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