ASSESSMENT OF LAND USES AND THEIR PRODUCTIVITY STATUS IN PARMAR UNIVERSITY, NAUNI

THESIS

by

MEENAKSHI GUPTA

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CERTIFICATE-I

This is to certify that the thesis entitled "**Assessment of land uses and their productivity status in Parmar University, Nauni**". submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **FORESTRY (SILVICULTURE)** to Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni – Solan is a faithful record of bonafied research work carried out by **Ms Meenakshi Gupta (F-99-5-M)** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of the investigation has been fully acknowledged.

PLACE : Nauni-Solan
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CERTIFICATE-II

This is to certify that the thesis entitled ""**Assessment of land uses and their productivity status in Parmar University, Nauni**", submitted by **Ms Meenakshi Gupta (F-99-5-M)** in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **FORESTRY (SILVICULTURE)** to Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni – Solan has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the External Examiner.

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INTRODUCTION

INTRODUCTION 1

The increasing pressure of growing population, demand for food, fodder and fuelwood combined with other developmental activities have led to rapid changes in land use and land cover patterns, ultimately affecting the productivity status of land particularly in a country like ours. Thus planning for development of natural resources without endangering the environment is a issue that world is facing today (Kachhwaha, 1985; Sharma, *et al.*, 1989; Khorram and John, 1991). Information on the rate and kind of changes in the use of land resources is essential for proper management and regulation of existing resources and their proper planning for future sustainable use. Land use data are needed in the analysis of environmental processes and problems, that must be understood if living conditions and standards are to be maintained and further improved above current level. Similarly, growing stock estimation is necessary to access the status and conditions of growth of plantation and other forest resources required for future planning. Remote sensing technology integrated with GIS as well as field surveys has emerged as an efficient and powerful tool in providing reliable information on various natural resources of a region in a spatial format essential for planning (Roy *et al.*, 1991).

Landuse information is an important input for planning, decision making and for this reason it is being gathered by various levels of

government from many years. The information regarding existing land resources and their uses is having crucial and strong influence for future development of land plans. Landuse change data represents a base by which change is measured. It is necessary for both developing land use policies and monitoring their effectiveness as land use includes everything for which land is used by residents of a country. Land cover refers more to the vegetational and artificial constructional covering the land surface (Burley, 1971).

As per land capability classification, land can be put to various uses. In hills, previously subsistence type of farming was prevalent but now clearing of forests for various other uses especially horticulture has led to a fast changing scenario of land use.

According to Lindgren (1985), the man's use of land is an extremely dynamic process. Changes in landuse and landcover are taking place continuously in all categories. However, the optimum use of land requires that the land resources be well characterized, their spatial relations be delineated and their capacities for likely uses be determined (Swindale, 1991).

The characterization of land resources in relation to different land use types is the pre-requisite for putting the lands to their potential use. A systematic characterization of soils is also of prime importance for evolving suitable agronomic practices and predicting their behaviour in relation to different systems of land use.

The capability classes and sub-classes indicate the suitability of soils for crops, pastures, forests and wildlife along with degrees of limitations to such uses and subsequently their full potential. Systematic

studies on the characterization of soils is of prime importance in realizing their full potential by putting them under suitable use.

Decisions in the management of forests needs quantitative and qualitative information regarding the activities involving forest land, plants, animals and human using these resources. The structure and growth of future stands depend upon site conditions, regeneration, establishment and phytosociological aspects. The associating species in a community plays important role at different canopy levels.

The correct and reliable estimation of forest distribution, periodic assessment of growing stock and demand for forest products is required to develop effective plans for conservation, management of natural resources and for setting forest policy. In the light of above, the present study is being taken over at a micro-level in the University Main Campus to monitor the present land uses and to study socio-ecological pattern in the light of land covers with the following objectives :

OBJECTIVES

- To study land use classification
- To study vegetal covers of different land uses
- To study productivity status of different land uses

Chapter-2
REVIEW OF LITERATURE

REVIEW OF LITERATURE 2

The relevant literature pertaining to the study has been reviewed under the following heads :

2.1 Land use types

Rapid growth of human population during recent years and absence of any viable means of livelihood other than uneconomic crop farming have led to the uncontrolled exploitation of land areas, consequent degradation and depletion of limited biophysical resources in the Lesser Himalayan Region. The need for sustainable development, therefore, makes it imperative to adopt a comprehensive land use policy based on land capacity analysis that is scientific and practical (Bisht and Tiwari, 1996).

Since the beginning of human civilization, mankind has lived in a close relationship with nature. While, mankind and his interdependence on environment is of greater consideration than that of any other organism; his restless pursuit of progress, comfort and security has resulted in increased stress on the environment which led to land use / land cover changes over a period of time. Information on existing land use / cover, its spatial distribution and changes are essential pre-requisite for planning (Dhinwa *et al.*, 1992). Thus land use planning and land management strategies hold key for development of any region (Anon., 1992).

According to Khorram and Katibah (1984) landsat data provide a quick and cost effective way of mapping a large area under vegetation land cover.

In a study Stone (1988) reported that photo interpretation typing has become a fundamental information source for forest management. This typing has been widely used to assist wood inventory stratification, operational planning, vegetation and distribution mapping and site productivity assessment. Olson *et al.* (1999) described that long term forest planning process targets a desired future condition using GIS to store and analyse site specific resource data. Monitoring and adaptive management will be needed to evaluate the effectiveness of the selected plan to continue and improve and land management.

Weir *et al.* (1988) have described about the useful application of GIS in forest land management. There is ample opportunity for increasing utilization of these methodologies in developing countries (Dengo, 1989).

Parwal *et al.* (1994) stated that use of remote sensing techniques along with GIS reduces the field work. They used landsat TM FCC and SPOT Panchromatic data on 1:50,000 scale for interpretation of forest cover type associated land uses and density information. The GIS technique was used for stock information comparison which indicated that available information on stock maps can be revised using remote sensing and GIS with limited field work.

2.2 Phytosociological study

Study of natural biotic community is basic pre-requisite to understand the structural and functional attributes specific to locate for better landscape management. Plant communities are of prime importance

because of being first trophic level in the food link and in edaphic and climatic conditions of the areas (Joshi and Tiwari, 1990).

Singh *et al.* (1991) studied the phytosociological behaviour of shrubs growing under different forest communities at different elevations. There was distinct variation in the physiological attributes with elevation and forest overstorey.

The photosynthetic potential of forest with trees in their natural environment is a function of leaf temperature which reveals that photosynthetic rate under different light intensities strongly depend on leaf to air temperature differences. Temperate tree species were found to have higher rate of photosynthesis as well as transpiration characters than evergreen slow growing trees (Purohit, 1993).

Floristic composition and phytosociology has long been of principal interest especially to the ecologists. Floristic composition refers to a measure of species diversity in a community. Its study forms one of the fundamental pre-requisite to classify the flora into different systematic types of any ecosystem e.g. forest, agricultural land, rangeland, etc. It is long term process to give any clear cut information on floristic composition of an area, as it is liable to change with season, effect of biotic as well as abiotic factors. It is the net result of their interaction in the form of any community (Whitaker, 1970).

The species responds differently (photosociological performance) to environmental factors in the absence of competition from what it does under conditions of competition. The physiological approach indicates that the plant species show a greater degree of association than could be explained by superimposing independent response to simple gradient in the physical environment and have sociological interaction among

species which permit hierarchial graphing of plant communities (Menon and Balasubramanyan, 1985).

Within one altitude, the type of co-factors like topography slope aspects, slope inclination and soil type further affect the forest composition and vigour. This is evident from the studies of Wikum and Wali (1970) where they narrated that changes in site factors change microclimate and vegetation within short range.

Silas *et al.* (1987) analysed the pine-oak communities for structural changes and found the composition of vegetational cover at different altitudes in Pauri Garhwal which work markedly distinct and followed normal Raunkier's pattern of species distribution with slight variation in the species, but the number of species in different forest was different.

Gupta *et al.* (1990) explained that vegetation characteristics under selection and shelterwood system varies in fir spruce forest for dbh per tree, crown spread, top height, basal area and tree density which is higher in selection system. In selection system vegetation was significantly different from shelterwood system but the poor sites in two systems were insignificantly different.

Atul and Kapoor (1985) used two models to know the contribution of neighbours in performance of individuals both in pure and mixed stands to evaluate growing mixtures in different populations and measuring competitive ability of individuals of various populations, to know association effects, general dominance ability of a population changes in mixtures and they found that both annual and perennials were important to study neighbour interaction in plant populations.

Joshi *et al.* (1986) studied that various factors such as altitude, topography, climate and human interferences affect the vegetation, lower

altitude had greater diversity of species than that of higher between Kotdwara and Doggada in Garhwal region.

Chaturvedi (1994) mentioned that the tropical forests contain maximum number of species than the temperate forests due to more restricted climatic conditions and small growing season leading to the presence of fewer species. The biotic (human and livestock population) interference have tremendous influence on biodiversity which is directly linked with the reduction of population of both human and livestock.

Conservation of diversity means the preservation and protection of variability in organism in such a way that human interference and interests are ensured at an optimum level for indefinite period of time (Ambasht *et al.*, 1994).

Usually cold temperatures produce a more distinctive limit to tree growth than warm climates because of the transition phase at the freezing point of water. The binomial curve shows relationships between growth and temperature, there is increase in growth with increase in temperature upto an optimum level and then rapid decrease of growth at high temperatures. Low temperature limits for growth of various species tend to be much more well defined than the high temperature limits (Gates, 1981).

2.3 Biomass Production

The sampling technique used in forest inventory varies with the objective, kind of forest produce and geography of the forest. It is determined by the size of sampling unit, number of sampling units to be used, distribution of sampling units, type and methods of measurement and statistical procedures to be adopted. In hilly areas, quadrates located in selected sub-compartments or topographic sections along line are taken with random start.

Slight variation in line direction is not likely to involve appreciable bias in the result after plotting the map (Chacko, 1965).

Biomass productivity is the sum total of height, diameter and total dry weight of above ground biomass which is influenced by association, area coverage, age, site factors and growth characteristics (Zavitkovski, 1976; Singh, 1994).

Morris and Miller (1994) pointed out certain conditions that must be met to ensure that the evidence exists to document changes in site productivity :

a) differences in tree growth must be attributable to differences in site conditions rather than differences in resource allocation among target and non-target species or to differences in plant potential.

b) growth results must be available for a sufficient time so that the influence of ephemeral difference in initial site conditions has diminished and so that the capacity of the site to support tree growth is stressed.

c) adequate experimental control must exist.

Zavitkovski (1971) suggested that the first step in estimating biomass production of forest stands is to develop equations relating to some easily measurable variables viz. dbh and height with dry weight of whole tree and tree components. In a review of forest biomass studies by Zavitkovski *et al.* (1974), a positive relationship between the leaf biomass and net annual production of stem and branches for stands of numerous tree species have been reported.

Aboveground biomass, structure and productivity in a Zambezian woodland studied by Chidumayo (1990) attained leaf biomass per stem by multiplying number of twigs per stem with mean dry weight of leaves per twig.

Total organic matter production (green and dry) in any ecosystem depend upon its energy fixation potential. The estimation of biomass is a pre-requisite for determining the status and flux of biological materials and in understanding basic dynamics of ecosystem (Anderson, 1971). Thus the potential of forests for a variety of non-traditional products has prompted the workers to undertake biomass assessment at different stages of stand development particularly manmade forest ecosystem (Young and Carpenter 1967; Young, 1978; Young *et al.*, 1978)

Site, form, the expected height of a 2.5cm dbh over bark tree predicted from stand height - diameter relationship, is shown to be practical and useful measure of site productivity. Unlike site index, this measure is not based on age and thus has potential for site productivity assessment in stands of uneven age / unknown age (Vanclay and Henry, 1988).

Nieppola and Carleton (1991) studied the relation between understorey vegetation, site productivity and environmental factors in mature stands of *Pinus sylvestris* in Southern Finland and supported Cajander's forest type theory i.e. there exists a dominant relation between understorey vegetation and site productivity in boreal ecosystem.

Haase and Haase (1995) found that the above ground biomass from harvested specimens comprising grasslands and woodlands using regression analysis on dry weight of branch, leaf and total biomass versus basal area at breast height or ground level and verses leaf area and total plant height and all correlations were highly significant and better for woody

and total biomass than for leaf biomass. However, differences in regression curves between species depend upon growth habits or canopy structures and they gave that basal area derived from diameter at breast height or diameter at ground level was most suitable, simple and a predictor of woody and total biomass.

Adams (1982) obtained total biomass estimates using biomass conversion factor developed from the specific gravity and biomass distribution data. The preliminary equations of the data generated indicated that the approach should produce reasonable estimates of stand biomass in the region.

Scheer (1995) reported that growing stock was assessed by two phase sampling with regression using satellite data for 2200 hectare area in North Slovakia and results were compared with ground measurements of growing stock.

Singh and Negi (1997) studied the biomass prediction and distribution of organic matter in different components of *Cinnamomum camphora* tree species. Correlation coefficients and regression models were worked out separately for each biomass component and total above ground biomass. Among the predictor variables tried, D^2H was found to be the most reliable parameter for predicting biomass. The total standing above ground biomass of *C. camphora* stand is 104.0 tons/ha. Contributions of different tree components to the total above ground biomass is in the following order : bole > twigs + branches > Bark > Leaves > fruits.

Negi *et al.* (1984) reported that the above ground biomass (kg/ha) shows an increasing trend with age. The bulk of the biomass being concentrated in the bole ranging from 52-74 per cent of the total above ground biomass. Whereas, the per cent contribution in other components are

: bark (8-15%), twigs with branch (9-25%) and leaves (4-12%). It was calculated while studying distribution of organic matter in an age series of *Eucalyptus globulus* plantations in Tamil Nadu.

Rajvanshi and Gupta (1985) estimated above ground biomass of *Dalbergia sissoo* using allometric regression equations based on diameter and density averaged 56.41 ton/ha, out of which contribution of branch and bole biomass was 40 per cent and 60 per cent, respectively. Herbs contributed significantly in the biomass which averaged 1.33 ton/ha. The biomass production was more in branches (37%) and bole (32%) than the leaf components.

Negi *et al.* (1995) estimated the component size, dry matter and nutrient distribution of 10, 20 and 30 years old plantation of teak and linear regression analysis was carried out among the prediction variables. DBH alone was found to give reasonably precise values of biomass. The total standing biomass increased with age and diameter from 74.5 ton/ha (10 years) to 164.1 tons/ha (30 years).

Singh and Puri (1990) observed that biomass increased with an increase in diameter for different components and increase with spacing. Stem wood contributes maximum 64-73 per cent due to straightness of bole but the per cent contribution of bark and leaves decreased with increase in diameter in *Populus deltoidés*. The total biomass per unit area increases with decrease in spacing which depends upon density.

Rana *et al.* (1993) used two allometric equations viz. $y=a+bd$ and $y=a+bD^2H$, whereas "D" (dbh) is independent variable and D^2H (Diameter square x Height) to investigate *Populus deltoides* biomass in Tarai for 4 to 10 years plants and they found that the mean per cent variation of biomass of different components for three ages is within permissible limits of

±5 per cent and inferred that use of regression equation gives reasonably reliable estimates of tree biomass, moreover, recording of diameter at breast height "D" in the field is easier, precise and practicable than recording both diameter and total height of all standing trees.

Gupta and Bhardwaj (1993) found the seasonal variation in above ground biomass being highest during rainy season corresponding to the major growth period of the plants, the standing dead biomass was maximum during November - December in Shivalik forest but it depends upon the basal area of the trees and site conditions. Maximum tree biomass is contributed by bole in chir and almost equal by branches and bole in case of scrub forests using allometric regression equations.

The ability of forest stands to restrain increasing amounts of foliar biomass is related positively to both above ground woody biomass and to site productivity. The magnitude of increase depends on the relative value of the self thinning component compared to the exponent of allometric equation (Blake *et al.*, 1991).

Dash *et al.* (1991) predicted above ground biomass for *Casuarina equisetifolia* from data on height, basal diameter, dbh, number of main branches and combination of these parameters by using multiple linear regression and allometric relation. They found that multiple linear regression model gave best fit.

Gotze (1964) studied the specific gravity in poplar wood of 15 stems of each of nine variously aged 19-46 years. The oven dry density increased with increasing height in the stem and with distance from pith, built it was neither strong nor universal. There were close correlations between density of wood laid down early and wood formed later. In another study Farmer and Wilcox (1966) reported that statistical analysis of phenotypic

differences in *Populus deltoides* that most of the variation in specific gravity (0.32 - 0.46) was between trees.

Seth and Aggarwal (1983) suggested while studying the relationship between growth rings and volume in blue pine that maximum number of directions are required among the trees depending upon the magnitude of circumferential difference that exist at any sampling height in the tree boles which change its specific gravity.

Broad (1998) developed theory of multivariate allometry. He further showed bivariate and multivariate allometry to be compatible, the defining differential equations being analysis of each other and invariant under analogous allometric transforms. He examined the relevance of allometric equations to growth modelling, commonly used growth models that are invariant under allometric transforms are capable of being formulated in terms of allometric growth differential equations.

Tasissa and Burkhart (1998), while studying the effects of thinning on ring specific gravity in loblolly pines indicated that most variation in specific gravity values is due to within tree factors such as ring position with respect to vertical axis and physiological age and late wood proportion. External factors such as stand density thinning treatment, site factors had minor influences.

Gonzalez *et al.* (1998) while studying on production pattern of understorey layers in several Galician woodlands found a significant negative correlation between understorey biomass and tree canopy cover. However, stand tree density and basal area were not significantly correlated with understorey. Herbs were the major contributors to seasonal fluctuation in production. However, productivity differed among stands but not the seasonal pattern of production. Production was higher in the warmer

seasons for all sites. This higher productivity was correlated with plant species richness. The renewal rates of the understorey biomass were dependent on the herbaceous and woody plant ratio. Different responses were found in productivity of shrubs, herbs, forbs, ferns and grasses after cutting understorey biomass. These dissimilarities were also conditioned to forest type.

2.4 Soil profile and drainage pattern

Samanna *et al.* (1967) studied the morphological and physical characteristics of some soils of Himachal Pradesh. Their study revealed that parent material has a dominant influence on the development of morphological and physical properties of the soils.

Geis *et al.* (1970) found that soil colour and structure developed in A2 horizon was more pronounced under forest vegetation where in the podzolisation process of soil formation has played an important role.

Verma *et al.* (1976) studied some soil profiles in the toposequence in Kangra district of Himachal Pradesh. They reported that matrix colour of B horizon changed gradually downslope from reddish brown (5YR 4/3) to dark greyish brown (10 YR 4/2). Verma (1979) while undertaking some detailed pedological studies on the soils of Himachal Pradesh found a significant relationship existing between soil formation and vegetation but inter-dependent on climate.

In a comparative study conducted by Dolui *et al.* (1985) in Jhargram Forest Division, West Bengal concluded that the soils developed at ridge top, steep slopes and foot slopes were shallow and dark brown, deeper brownish yellow and deep reddish yellow in colour, respectively.

Minhas (1986) noticed that the surface horizons of forest soils were darker in colour as compared to the cultivated soils. This trend was attributed to higher amounts of organic matter accumulated over the forest floor which subsequently admixed with soil in surface horizons of the profiles.

Verma *et al.* (1987) studied the effect of climate and parent material on the nature and properties of hill soils of Himachal Pradesh. They further concluded that climatic factors were decisive in characterising the soils through their pronounced effect on intensity of soil development.

Rahman *et al.* (1997) have indicated that transecting and GIS based mapping is effective technique for producing general soil maps, and can aid in placing soil boundaries for detailed soil maps.

Grant *et al.* (1994) reported that comprehensive information on the properties and distribution of soils is important for making forest management decisions. Soil mapping through aerial photography and GIS form an important information tool.

Kaistha and Gupta (1994), while studying four Entisols and Inceptisols from cultivated and uncultivated areas in Himachal Pradesh, observed similar characteristics and profile development. All soils had marked similarities in sand, silt and clay minerology, thereby, suggesting overall minimal weathering occurred in these soils.

According to Schmid *et al.* (1993) soils were stratified on the basis of aspect and altitude, soil type, forest type and management and strata were compared to determine the influence of site factors on forest soil fertility. Soil fertility level was greater on sites which had been protected from biomass removal for alteast 15 years related to sites which had come under protection in the past seven years.

Hairston and Grigal (1994) studied the topographic variation in soil water and nitrogen for two forested land forms in Minnesota, USA. Three sloping positions (upper, middle and lower), four aspects (North east, South east, South west and North west) and concave and convex plan (across slope) curvature were compared in *Populus tremuloides* stand. In the outwash plain organic matter and nitrogen of the upper soil horizons were related to slope position while organic matter and nitrogen of the upper soil horizons were related to slope position while organic matter and total nitrogen in the forest floor and anaerobically released nitrogen in the upper soil horizon were related more strongly to aspect.

Das *et al.* (1997) studied seven profiles one each under horticulture, agroforestry and dairy farming and two each from maize / vegetable and adjacent fallow / pasture in East Khassi Hills District of Meghalaya and reported that soils were comparatively deeper (1 to 1.5m) under agriculture, agroforestry, horticulture and dairy farming. Red to reddish brown colour was prominent in agriculture and fallow / pasture whereas, dark to dark brown colour was distinct in dairy farming, horticulture and agroforestry land uses. Horizon differentiation was not so distinct under agriculture, fallow / pasture systems. Actually, the fallow or pasture was the ultimate result of continuous practice of shifting cultivation year after year.

Contractor and Badanur (1996) studied the effect of forest plantation on the physical properties of the soils and showed that soils under Eucalyptus had the highest water stable aggregates (51.3%) followed by teak (49.8%). Increase in aggregates may be due to high organic matter content of the soils.

Walia and Chamuah (1992) reported that under forests, soil solum is much deeper due to thicker A and B horizons than that under shifting cultivation. This may be attributed to differential weathering and

degree of erosion. Soils of jhum land are more prone to erosion and runoff than non jhum and forest land.

Baruah *et al.* (1992) while studying variability in surface soil properties related to geomorphology in North east India reported that soils belonging to same map unit based on geomorphic analysis may not be homogenous with respect to surface soil texture. It also indicated that high degree of variability exists between and within soils of different geomorphic units with regard to particle size differences.

Drainage basin can be considered as the laboratory of the hydrologic cycle. With the only exception of the atmospheric aspects of precipitation, that is where the hydrological processes occur and where these processes leave permanent imprints of their effects on the drainage basin itself. The evidence of these imprints is displayed in the surficial topography and exhibited in the stream channels themselves by their size, number and dimension (Singh, 1994).

The drainage pattern and texture seen on aerial photographs are indicators of land form and bedrock type and also suggest soil characteristics and site drainage conditions (Lillesand and Kiefer, 1994).

Economic production of different landuses

Negi *et al.* (1994) estimated financial feasibility of different forest tree species with the help of various measures of economic worth, such as net present worth (NPW), benefit -cost ratio (BCR), interval rate of return (IRR) and the annuity value. These measures were used by calculating economic worth of tree plantation at a discount rate of 12 per cent. This analysis showed that eucalyptus plantation was the best form

forestry option as NPW (Rs. 87,619/-), BCR (9.71) and IRR (50.50%) and annuity value (Rs. 15,507/-) were all favourable.

Subrahmanyam (1990) in his study emphasized on the need and requirements of marketing finance for horticultural crops. This study : i) estimated the capital requirement for production and marketing of important horticultural crops and examined the need for marketing credit, ii) analyzed different marketing costs and identified items to be considered for advancing marketing credit, and iii) estimated the additional credit requirement for marketing purposes. The sample considered of 382 vegetable cultivators from Kolar district, Karnatka, growing tomatoes, aubergines, cabbages, french beans, etc. 120 fruit growers and 170 flower cultivators growing Jasmine, Chrysanthemum, Marigolds and Roses in Kolar and Bangalore districts. The data pertained to the period of 1979-88. The expenditure incurred for marketing of horticultural crops is substantial and constituted 48 to 75 per cent of production costs. Among the cost items to be considered for credit purposes, transport is major item. The additional credit required for marketing ranged from 21 to 41 per cent above that required for production.

Chandel (1987) conducted a study in Kangra district of Himachal Pradesh. He suggested that the introduction of comparatively stable supplementary enterprises like dairy, horticulture and apiculture in existing product - mix, balanced use of fertilizer nutrients and better management of vegetable crops would also minimize the extent of fluctuations in yield and farm income.

Sharma *et al.* (1990) studied the risk and profitability in diversified farming in Kangra district of Himachal Pradesh. The study brought out that the cultivation of vegetables was highly risky though the profit was also the highest. The cereals were found to be less remunerative but at the

same time their cultivation was less risky. The cultivation of pulses involved more risk as compared to cereals.

Subrahmanyam (1982) while studying the efficiency of different channels in marketing of carrot, cabbage and cauliflower in Madurai district of Tamil Nadu revealed that selling to pre-harvest contractors was the least desirable channel of marketing. It was concluded that selling the produce in the market did not necessarily result higher returns to cultivators.

Najafi (1986) conducted the study in Shiraz and gave the wholesale market model for fresh fruits and vegetables. According to him the market merchants were the main inter-mediaries between the producers and the consumers and supplier of credit and farm input to farmers. The flow of farm products was completely controlled by market merchants and enjoyed the monopoly. He recommended an increasing competition in the markets through the establishment of marketing cooperatives.

Chapter-3
MATERIALS AND METHODS

MATERIALS AND METHODS 3

The present investigations on **Assessment of land uses and their productivity status in Parmar University, Nauni,** were carried out in the year 2000-2001. The details of the experimental site, materials used and methodology adopted for this study are discussed in this Chapter.

Experimental Site

The study area lies in the mid hill zone of Himachal Pradesh, with an elevation of 900-1300m above mean sea level. The area lies about 13 kilometers from Solan on Solan - Rajgarh State Highway between latitude $30^{o}50'30"$ to $30^{o}52'0"$N and the longitude $77^{o}8'30"$ and $77^{o}11'30"$E (Survey of India Toposheet No. 53F/1) It covers an area of 538.04 ha. Most of the area under the University forms a part of Solan district, with a small portion in Sirmour district of the State.

General description of the study area

The area is a transitional zone between sub-tropical to moist sub-temperate. There is a considerable variation in seasonal and diurnal temperature of the area. In general, May and June are the hottest months and December and January the coldest ones with severe frost. The minimum and maximum temperature varies from $3^{o}C$ during winter (January) to $33^{o}C$ during summer (June)

On an average the annual rainfall varies from 1000mm to 1400mm, major amount of which is being received during monsoon i.e. 15th June to 15th September with a few pre-monsoon showers. Winter showers are also common but the quantum of precipitation is usually low. The physiography of the area is marked by undulating topography. The whole area drains into Kawal Khud flowing along the south western boundry of the University area. However, before establishing the campus (before 1975) most of the area was under grassland with reasonable part under agricultural cultivation.

Natural vegetation

The forest vegetation in uncultivated area is luxuriant in plant growth but the lands with shallow soils support only shrubs and grasses. Important flora constitutes of *Acacia catechu, Pinus roxburghii, Ficus roxburghii, Citrus spp., Dalbergia sissoo, Ficus palmata, Grewia optiva, Pistacia integerrima, Zizyphus jujuba, Pyrus pashia, Bombax ceiba, Toona ciliata, Berberis lycium, Carissa carandus, Justacea adhatoda*, etc. Common grasses growing in the area are *Heteropogon contortus, Chrysopogon montanus, Cynodon dactylon, Themeda anathera*, etc.

Land use types

On the map reduced to the scale of 1:5000 with the help of pentagraph the land was classified (as per the classification of Directorate of Economics and Statistics) into five types viz. forest, grassland, horticulture, cultivated land and miscellaneous landuse types as per the use and ease in mapping according to spatial resolution.

Further, the area under each land use type was calculated with the help of Planimeter.

Phytosociological Study

Following phytosociological parameters were studied usi different formulae (Raunkiaer, 1934; Misra, 1968; Menon and Balasubramanya 1985).

Density (D)

It represents the numerical strength of species in a community calculated as :

$$\text{Density} = \frac{\text{Total number of individuals}}{\text{Total number of quadrates studied}}$$

Frequency (F) :

It is the indicator of number of samples in which the given species occurs, thus expresses the distribution of various species in a community.

$$\text{Frequency} = \frac{\text{No. of quadrates of occurrence}}{\text{Number of quadrates studied}}$$

Abundance (Ab)

It represents how abundantly the species occurs in the area and in community.

$$\text{Abundance} = \frac{\text{Total number of individuals}}{\text{No. of quadrates of occurrence}}$$

Relative basal area, density and frequency :

Relative basal area, relative density and relative frequency were calculated from the basic data as adopted by Phillips (1959).

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

$$\text{Relative Density (RD)} = \frac{\text{No. of individuals of the species in a quadrate}}{\text{No. of individuals of all species in all quadrates}} \times 100$$

$$\text{Relative frequency (RF)} = \frac{\text{No. of occurrence of the species}}{\text{Total no. of quadrates of occurrence of all species}} \times 100$$

Importance Value Index (IVI)

It is the combination of relative frequency, relative density and relative basal area.

IVI = Relative basal area + Relative density + Relative frequency

Similarity Index (SI) (Sorenson, 1948)

It expresses the ratio of common species to all species found in the vegetation.

$$\text{SI} = \frac{\text{No. of common species in two relives}}{\text{½ (Total number of species in stand A + stand B)}} \times 100$$

Growing stock estimation

a) Sampling Technique

The estimation was done using simple random sampling.

Two to three quadrates (in proportion to the area of compartment) of size 0.1 ha (trees), 5x5m (shrubs) and 0.5 x 0.5m (grasses) were laid out in each compartment.

Above ground biomass estimation by non-destructive method

Stem biomass

Trees falling in each quadrate were enumerated to determine the stand density as number of plants per quadrate or hectare. The diameter at breast height (dbh) was measured to classify them into different diameter classes. Height was measured with Ravi multimeter, form factor was calculated with Speigel Relaskope to find out their timber volume using the formula given by Pressler (1865) and Bitterlich (1984).

$$f = \frac{2h_1}{3h}$$

Where,

f = form factor

h_1 = height at which diameter is half of dbh

h = total height

and volume is calculated by Pressler formula (1865) i.e.

$V = f \times h \times g.$

Where,

V = volume

f = form factor

h = total height

g = basal area

The stem core was taken to find out specific gravity which was further used to determine the biomass of the stem timber using maximum moisture method (Smith, 1954).

$$Gf = \frac{1}{(M_n - M_0)/M_0 + (1/GS_0)}$$

Where,

Gf = Specific gravity based on green volume

M_n = Weight of saturated volume samples

M_0 = Weight of oven dried sample

GS_0 = Average density of wood substance = 1.53 (constant)

Thus the weight of the wood was estimated using density formula i.e. mass per unit volume

Mass = Average specific gravity of stem wood x volume

Branch biomass

Three trees of each species from different diameter classes (10cm interval) were taken for non-destructive estimation of biomass. Different sized trees within different class formation were sampled by taking three branches at different heights of each tree. The total branch biomass (branchwood + twigs) per tree was calculated by multiplying average (green and dry) weight per branch with number of branches per tree as per the method given by Chidumayo (1990). Similar method was employed for shrubs too

Leaf Biomass

Leaves from above mentioned branches were removed and weighed. Samples were separately oven dried to a constant weight at 80+5^{o}C (Chidumayo, 1990).

Biomass estimation of herbage

The herbage samples brought to the laboratory for phytosociological study were sorted out species wise and washed properly with fresh running water and stored in different paper bags. They were oven dried to a constant weight at 80±5°C, thereafter each sample was weighed for finding out the dry biomass.

For estimation of below ground biomass, the roots from each monolith of size 25 x 25cm were brought to the laboratory. These were separated out species wise and washed with tap water. Roots of different grasses were kept in separate bags and oven dried to constant weight at 80±5°C and weighed for further analysis. Thereafter, the aboveground and belowground biomass was collectively counted for each landuse.

Biomass of branches / leaves

It was obtained by drying small samples of branch and leaves at 80±5°C in oven till constant weight was achieved , using formula :

$$\text{Biomass of branches/leaves} = \frac{\text{Dry weight of sample}}{\text{Fresh weight of sample}} \times \text{Total fresh weight of branch leaves}$$

This sample data was taken for estimating the biomass.

Soil profile study

Profile study of each land use type was studied by digging pits at five different land uses (forest, grassland, miscellaneous, cultivated land and horticulture). The information regarding the presence or absence of horizons

alongwith their depth, soil colour, texture, structure and root characteristics were recorded.

Methods for analysis of different soil parameters

Soil colour (moist)	Munsel Soil colour chart.
Soil texture	International Pippet Method (Black, 1965).
Soil structure	Undisturbed soil samples were collected in the field and aggregate size distribution was determined employing net sieving method of Yodder (1936).

Drainage pattern was studied from the map of scale 1:5000 and length of each perennial source was measured with the scale.

Economic production of different land uses

Data for the last three years were collected from different departments of the University to calculate the income generated during the period.

Chapter-4
EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS 4

The results of the present investigations entitled **"Assessment of land uses and their productivity status in Parmar University, Nauni"**, are presented in this chapter under the following heads :

4.1 Land use types

4.2 Phytosiological study

4.3 Biomass production

4.4 Soil physical status and drainage pattern

4.5 Economic production of different land uses

4.1 Land Use Types

University area is divided into 43 compartments measuring 538.04 hectares. Presently, the area is under various uses. In the present study, nine types of land use given as per the classification of Directorate of Economics and Statistics were regrouped into five important land use types so as to delineate the whole study area. The five land use types considered in this study are tabulated in Table 1. The data reveals that 323.04 ha (60.04%) is under miscellaneous land use. Forest, horticulture and cultivated land uses cover an area of 110.10 (20.46%), 56.7 (10.54%) and 47.50 ha (8.83%), respectively. The pure grassland has merely a coverage of 0.70 ha

Table 1. Area under different land use types in Nauni Campus.

Class	Area (hectare)	Per cent Area
Miscellaneous (Covering constructed areas, nallah, roads, rivers, scrub, open scrub and sparse vegetation)	323.04	60.04
Forest (Natural + Plantations)	110.10	20.46
Horticulture	56.70	10.54
Cultivated (Nurseries + SPS + Experimental fields)	47.50	8.83
Grass land	10.70	0.13
Total	**538.04**	**100**

(0.13%). The area was calculated by using planimeter on reduced map of 1:5000 scale from Survey of India maps of scale 1:1000. The spatial distribution of each land use type is indicated in Fig. 1.

4.1.1 Floristic composition of various land uses

In the whole study area, nearly 94 species are existing out of which 42, 27 and 16 species are of trees, shrubs and grasses, respectively (Table 2). Amongst trees, the most prevalent and naturally growing species include *Celtis australis, Toona ciliata, Grewia optiva, Ficus palmata, Punica nana, Melia azadarach, Pyrus pashia, Pistacia integerrima and Albizia chinensis*. Many species are the planted ones like *Pinus roxburghii, Alnus nitida, Acacia catechu, Acer oblongum, Quercus spp., Populus spp., Eucalyptus sp., Acacia mollissima, Acrocarpus fraxinifolius*, etc. Though trees are common in forest and miscellaneous land use, in horticulture and

Table 2. Floristic composition of different land use types.

Species	Forest	Horticulture	Cultivated land	Miscella-neous	Grass-land
	I	II	III	IV	V
Trees					
Acacia mollissima	+	-	-	+	-
Acrocarpus fraxinifolius	+	-	-	+	-
Grewia optiva	+	-	+	+	-
Cupressus torulosa	+	-	-	+	-
Ulmus villosa	+	-	-	-	-
Ficus palmata	+	-	+	+	-
Punica nana	+	-	+	+	-
Morus alba	+	-	-	+	-
Acer oblongum	+	-	-	-	-
Toona cilita	+	+	-	+	-
Robinia pseudoacacia	+	-	-	+	-
Quercus leucotricophora	+	-	-	+	-
Pistacia integerrima	+	+	+	+	-
Sapium sebiferrum	+	-	-	-	-
Bauhinia variegata	+	-	-	+	-
Melia azedarach	+	-	+	+	-
Grevillea robusta	+	-	-	+	-
Jacaranda mimosaefolia	+	-	-	+	-
Celtis australis	+	+	+	+	-
Albizia lebbek	+	-	-	+	-
Pyrus pashia	+	-	+	+	-
Salix alba	+	-	-	+	-
Aesculus indica	-	-	-	+	-
Alnus nitida	+	-	-	-	-
Cedrus deodara	-	-	-	+	-
Citrus jhambhiri	-	-	-	+	-
Callistemon lanceolatus	-	-	-	+	-
Ougenia oojeinensis	-	-	-	+	-
Mallotus phillipinensis	-	-	-	+	-
Litsea chinensis	-	-	-	+	-

Butea monosperma	-	-	-	+	-
Prunus padus	-	-	-	+	-
Myrica esculenta	-	-	-	+	-
Quercus glauca	-	-	-	+	-
Albizia chinensis	+	-	+	+	-
Populus sp.	+	-	-	+	-
Acacia catechu	+	-	-	+	-
Dalbergia sissoo	+	-	-	+	-
Eucalyptus sp.	+	-	-	+	-
Pinus sp.	+	-	-	+	-
Bombax ceiba	+	-	-	+	-
Leucaena leucocephala	+	-	+	-	-
Shrubs					
Prinsepia utilis	+	-	+	+	+
Berberis lycium	+	+	+	+	+
Coriaria nepalensis	+	-	-	+	-
Carissa carandus	+	+	+	+	+
Woodfordia fruticosa	+	+	-	+	+
Oryris arborea	+	-	-	+	-
Mimosa himalayana	+	-	-	+	-
Rhamnus triquetra	+	-	-	+	-
Rubus ellipticus	+	+	-	+	-
Adhatoda vasica	+	-	-	+	-
Debregeasia hypoleuca	+	+	-	+	-
Murraya koenogii	+	-	+	-	-
Meriandra strobilifera	+	-	-	+	-
Hypericum cernuum	+	-	-	-	-
Verbena bonariensis	+	-	-	-	-
Elaegnus umbellata	+	-	-	+	-
Indigofera pulchella	+	-	-	-	-
Zanthoxylum alatum	+	-	-	+	-
Myrsine africana	+	-	+	+	-
Lantana camara	+	-	+	+	+
Zizyphus oxyphylla	+	-	-	+	-

Rhamnus virgata	+	-	-	+	-
Rhus cotinus	+	-	-	+	-
Artemesia vulgaris	+	-	-	+	-
Rhus parviflora	+	-	-	+	-
Zizyphus numularia	+	-	-	+	-
Leptodermis lanceolatus	+	-	-	+	-
Herbs					
Chrysopogon montanus	+	+	+	+	+
Heteropogon contortus	+	-	+	+	+
Themeda anathera	+	+	+	+	+
Panicum maximum	+	+	+	+	+
Apluda mutica	+	+	+	+	-
Urochloa panicoides	+	+	+	+	+
Chrysopogon gryllus	+	+	+	+	+
Cymbopogon martinii	+	+	+	+	-
Saccharum spontaneum	+	-	-	+	-
Cyprus rotundus	+	+	+	-	-
Eulaliopsis binata	+	+	+	-	-
Lathyrus aphaca	+	+	-	+	-
Cynodon dactylon	+	+	+	+	-
Ageratum conizoides	+	-	+	+	-
Euphorbia sp.	+	-	+	-	-
Forbs	+	+	+	+	+

+ Present
- Absent

cultivated land, they have come up sporadically in small numbers on bunds and in between the fields. The lands are otherwise under cultivation of specified fruit, agriculture and forestry crops. Pure grasslands are devoid of trees.

Similarly, shrubs mainly occupy forest and miscellaneous land use, but some of them like *Prinsepia utilis, Berberis lycium, Carissa carandus, Murraya koenigii, Myrsine africana, Lantana camara and Artemesia vulgaris* have been recorded in cultivated lands too. Of all the grass species, *Chrysopogon montanus, Themeda anathera, Panicum maximum, Urochloa panicoides and Chrysopogon gryllus* are common in all land use types. In forests in all 74 plant species were recorded. *Aesculus indica, Cedrus deodara, Citrus jhambhiri, Callistemon lanceolatus, Oogenia oogeinensis, Mallotus philippinensis, Litsea chinensis, Butea monosperma, Prunus cerasoides, Myrica esculenta and Quercus glauca* have not shown up their presence being present along river, nallah and road side. Whereas, all the species of shrubs (27) as well as grasses (16) are present sporadically in forest land use.

In horticulture land besides various fruit species, 20 other species are recorded. Few trees have come up naturally like *Toona ciliata, Pistacia integerrima* and *Celtis australis*. Shrubs are sparsely present. While all herbaceous species, except *Heteropogon contortus, Saccharum spontaneum* and *Ageratum conizoides* are present.

In cultivated land, in all, 29 plant species are recorded out of which 9 species of trees i.e. *Grewia optiva, Ficus palmata, Punica nana, Pistacia integerrima, Melia azaderach, Celtis australis, Pyrus pashia, Albizzia chinensis* and *Leucaena leucocephala* have been recorded. Six shrubs encountered have come sparsely. It includes *Prinsepia utilis, Berberis lycium, Carissa carandus, Murraya koenogi, Myrsine africana, Lantana camara* and

Artemesia vulgaris. Among herbs only *Saccharum spontaneum* and *Lathyrus aphaca* are absent compared to other land uses.

The data presented in Table 2 reveals that maximum species of trees are growing in miscellaneous land use type. Out of the total 73 species amongst trees *Ulmus villosa, Acer oblongum, Sepium sebiferrum, Alnus nitida* and *Leucaena leucocephala* are present in plantations. Similar trend is observed in shrubs with only four species forming exception *Murraya koenigii, Hypericum cernuum, Verbaena bonariensis and Indigofera pulchella*. Among herbs, other than *Cyperus rotundus, Eulaliopsis binata* and *Euphorbia* spp. all species are commonly found.

In pure grasslands, trees and shrubs are absent. Seven grass species are recorded apart from 5 sparsely distributed shrub species. The grasses like, *Chrysopogon montanus, Heteropogon contortus, Themeda anathera, Panicum maximum, Urochloa panicoides* and *Chrysopogon gryllus* are common. Among shrubs, sparse distribution of *Woodfordia fruticosa, Berberis lycium, Carissa carandus, Prinsepia utilis* and *Lantana camara* is also recorded. However, further phytosiociological and biomass studies of these shrubs is not undertaken in grasslands.

4.2 Phytosociological study

The phytosociological parameters such as density, basal area, frequency, relative density, relative basal area, relative frequency, and importance value index (IVI) have been tabulated in Tables 3.1 to 3.5.

An overview of the Tables 3.1 to 3.5 reveals that out of the total tree species *Acacia catechu* has the maximum average density as 124.66 number of trees per 0.1 ha of quadrate size followed by 108, 96 and 84 for *Eucalyptus* spp. *Pinus roxburghii and Populus* spp. respectively.

Minimum density (trees/quad.) is of *Ficus palmata* (0.62). Highest IVI is of *Morus alba* and *Robinia pseudoacacia* i.e. 300 each followed by *Populus* sp. (256.75) and *Acacia catechu* (247.57) whereas, lowest is of *Largerstroemia* sp. (4.58) and *Acer oblongum* (4.71).

In case of shrubs the most common species in all the land uses are *Carissa carandus, Berberis lycium, Osyris arborea, Lantana camara, Coraria nepalensis, Woodfordia fruticosa* and *Prinsepia utilis*.

In grasses, *Chrysopogon montanus, Heteropogon contortus, Themeda anathera, Apluda mutica* and *Chrysopogon gryllus* are the main and commonly occuring species in all land uses.

Forest

Since natural forests accounts for a meagre area out of the total forest area, plantations are of paramount importance. A perusal of Table 3.1 reveal that under plantations, *Pinus roxburghii* covers maximum area (36.61 ha) followed by *Eucalyptus* sp. (16.72 ha), *Robinia pseudoacacia* (7.22ha), *Populus* sp. (6.91 ha), *Acacia catechu* (5.32 ha), *Quercus* sp. (3.91ha), *Dalbergia sissoo* (2.21 ha), *Morus* spp. (2.05 ha) and *Toona ciliata* (1.85 ha) as pure and/or mixed. Rest of the speices are covered in miscellaneous forests (26.63 ha).

Pinus roxburghii is found associated with many trees, shrubs and grass species (Table 3.1.1). Under pines, *Acrocarpus fraxinifolius* is having highest IVI and basal area value of 22.00 and 18.70 x $10^3 cm^2$/ha, respectively which is followed by *Cedrus deodara* with IVI as 11.41 and basal area as 2.274 x $10^3 cm^2$/ha. Among shrubs *Lantana camara* is the most common shrub with IVI 49.52 and basal area value of 3.08 x $10^3 cm^2$/ha followed by *Berberis lycium* (main associate) (49.14) *Leptodermis*

lanceolatus (48.48), *Myrsine africana* and *Woodfordia fruticosa* with IVI values of 49.14, 48.48, 38.76 and 38.09, respectively.

Maximum basal area value of 13.45 x $10^3 cm^2$/ha is of *Leptodermis lanceolatus* followed by *Woodfordia fruticosa* (8.81 x $10^3 cm^2$/ha). As far as herbaceous cover is concerned, under *Pinus roxburghii*, grasses like, *Themeda anathera*, *Chrysopogon gryllus* and *Chrysopogon montanus* are common with IVI value of 66.61, 49.58 and 42.91, respectively, and basal area value of 28.28×10^4, 33.23×10^4 and 24.29 x 10^4 cm^2/ha), respectively. Minimum association is with *Apluda mutica* having IVI as (17.31) and basal area as $5.03 \times 10^4 cm^2$/ha) and *Urochloa panicoides* with IVI value of 18.66 and basal area value of $6.94 \times 10^4 cm^2$/ha.

In *Eucalyptus* plantations, the most related specie is *Populus* spp. (Table 3.1.2) with IVI value of 30.46 and basal area of $46.55 \times 10^3 cm^2$/ha preceeded by *Pinus roxburghii* and *Albizzia chinensis* with IVI values as 28.07 and 18.67, respectively, and basal area 13.53×10^3 and $25.37 \times 10^3 cm^2$/ha, respectively.

Amongst shrubs, *Elaegnus umbellata* is having highest IVI and basal area (80.90 and $15.118 \times 10^3 cm^2$/ha, respectively, followed by *Carissa carandus* and *Berberis lycium* with the values of IVI and basal area as 73.9 and $9.15 \times 10^3 cm^2$/ha and 70.93 and $15.12 \times 10^3 cm^2$/ha, respectively. Least occurring one is *Artemesia vulgaris* (19.13 IVI and $0.49 \times 10^3 cm^2$/ha basal area).

Grasses are more common beneath this species. *Chrysopogon montanus* is having highest IVI and basal area i.e. 105.36 and

Table 3. Phytosociological studies of different land use types.
FOREST (LAND USE I)

Table 3.1.1 *Pinus roxburghii*

Species	Average density (No./quad.) (D)	Basal area (cm^2/ha)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
Trees							
Pinus roxburghii	96	$577x10^3$	100	89.17	37.50	94.96	221.63
Cedrus deodara	1.33	$2.274x10^3$	33.33	1.241	12.50	0.37	14.11
Populus sp.	0.66	$5.789 x10^3$	33.33	0.62	12.50	0.95	14.07
Jacaranda mimosaefolia	1.00	$3.061 x10^3$	33.33	0.931	12.50	0.50	13.93
Acrocarpus fraxinifolius	8.00	$18.70 x10^3$	33.33	4.43	12.50	3.07	22.00
Eucalyptus sp.	0.66	$0.760 x10^3$	33.33	0.621	12.50	0.12	13.24
Total	107.65	$607.58 x10^3$	266.65				
Shrubs							
Carissa carandus	6.00	$1.95 x10^3$	66.66	6.29	12.49	4.65	23.44
Berberis lycium	17.33	$7.74 x10^3$	66.67	18.17	12.5	18.47	49.14
Woodfordia fruticosa	10.33	$8.81 x10^3$	33.33	10.83	6.24	21.02	38.09
Lantana camara	22.33	$3.08 x10^3$	100	23.42	18.75	7.35	49.52
Osyris arborea	2.00	$0.71 x10^3$	66.67	2.09	12.5	1.71	16.3
Myrsine africana	18.67	$0.18 x10^3$	100	19.50	18.75	0.43	38.76

Rosa moschata	2.67	1.14 x10^3	33.33	2.8	6.24	2.72	11.76
Leptodermis lanceolatus	9.67	13.45 x10^3	33.33	10.14	6.24	32.10	48.48
Rubus ellipticus	6.33	4.81 x10^3	33.33	6.64	6.24	11.49	24.37
Total		41.89 x10^3	533.32				
Herbs							
Chrysopogon montanus	32.33	24.29x10^4	66.67	14.28	12.50	16.13	42.91
Themeda anathera	65.00	28.82 x10^4	100	28.72	18.75	19.14	66.61
Panicum maximum	18.33	23.85 x10^4	66.67	8.10	12.50	15.83	36.43
Apluda mutica	3.33	5.03 x10^4	66.67	1.47	12.50	3.34	17.31
Heteropogon contortus	25.67	9.27 x10^4	66.6	11.34	12.50	6.15	29.99
Urochloa panicoides	17.67	6.94 x10^4	33.33	7.81	6.25	4.60	18.66
Chrysopogon gryllus	34.00	33.23 x10^4	66.67	15.02	12.50	22.06	49.58
Cymbopogon martinii	30	19.14 x x10^4	66.67	13.25	12.50	12.71	38.46
Total		150.57 x10^4	533.35				

Table 3.1.2. Eucalyptus species

Species	Average density (No./quad.) (D)	Basal area (cm^2/ha)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
Trees							
Eucalyptus sp.	108	308.43×10^3	100	87.57	33.33	78.11	199.01
Pinus roxburghii	3	13.53×10^3	66.67	2.43	22.22	3.42	28.07
Bauhinia variegata	0.33	0.14×10^3	33.33	1.08	11.11	0.04	11.42
Grevillea robusta	1.33	0.79×10^3	33.33	1.08	11.11	0.20	12.39
Populus sp.	9.33	46.55×10^3	33.33	4.57	11.11	11.78	30.46
Albizia chinensis	1.33	25.37×10^3	33.33	1.08	11.11	6.42	18.61
Total		394.82×10^3	299.99				
Shrubs							
Carissa carandus	6.67	9.15×10^3	100	2353	24.99	25.38	73.9
Zizyphus oxyphylla	3.00	2.02×10^3	66.67	10.59	16.66	5.61	32.86
Berberis lycium	7.00	7.66×10^3	100	24.70	24.99	(21,24)	70.93
Elaegnus umbellata	6.33	15.11×10^3	66.67	22.33	16.66	41.91	80.90
Artemesia vulgaris	2.67	0.49×10^3	33.33	9.42	8.33	11.38	19.13
Woodfordia fruticosa	2.67	1.612×10^3	33.33	9.42	8.33	4.47	22.22
Total		36.07×10^3	400.01				
Herbs							
Chrysopogon montanus	78.33	66.62×10^4	100	37.84	21.42	46.10	105.36
Heteropogon cortortus	12.33	4.62×10^4	66.67	5.96	14.29	3.19	23.44
Themeda anathera	45.00	23.23×10^4	66.67	21.74	14.29	16.07	52.1
Panicum maximum	31.67	30.59×10^4	100	15.30	21.42	21.17	57.89
Urochloa panicoides	13.67	4.07×10^4	33.33	6.60	7.14	2.81	16.55
Chrysopogon gryllus	4.67	0.85×10^4	33.33	2.25	7.14	0.59	12.2
Cyprus rotundus	18.00	8.81×10^4	33.33	8.70	7.14	6.09	21.93
Indigofera pulchella	17	5.67×10^4	33.33	0.08	7.14	3.92	11.14
Total		144.49×10^4	466.66				

66.62x$10^4$$cm^2$/ha, respectively, pursued by *Panicum maximum* with vlaues of IVI and basal area as 57.89 and 30.59x$10^4$$cm^2$/ha, respectively, and *Themeda anathera* (52.1 IVI and 23.23x$10^4$$cm^2$/ha basal area). Minimum values 11.14 (IVI) and 5.67x$10^4$$cm^2$/ha (basal area) are of *Indigofera pulchella*.

A perusal of Table 3.1.3 for phytosociological attributes of *Robinia pseudoacacia* plantations reveal that these are nearly pure with no trees associated with them. Only shrubs and herbs are common underneath. *Carissa carandus* is having highest IVI of 61.77 followed by *Osyris arborea* with IVI value of 51.72. However, basal area value follows the reverse order being highest for *Oryris arborea* (97.531x$10^3$$cm^2$/ha) and followed by *Carissa carandus* (88.61x$10^3$$cm^2$/ha). *Coriaria nepalensis* is having minimum IVI value 12.34 and *Zizyphus numullaria* is having least basal area (1.141x$10^3$$cm^2$/ha). Amongst the grasses, *Panicum maximum* is the leading associate preceded by *Chrysopogon montanus* with IVI as 89.19, 66.92 and basal area as 58.10x10^4 and 41.50x10$cm^4$$cm^2$/ha, respectively. The least associated is *Urochloa panicoides* with the value as 22.24 and basal area as 3.66x$10^4$$cm^2$/ha.

Populus spp. has close association with *Celtis australis* and *Pistacia integerrima* with IVI and basal area values of 21.93 and 7.746x$10^3$$cm^2$/ha and 21.31 and 4.677x$10^3$$cm^2$/ha, respectively (Table 3.1.4).

Elaegnus umbellata with 111.74 IVI and 19.765x$10^3$$cm^2$/ha basal area is the major shrub followed by *Berberis lycium* with 69.64 IVI and 6.011x$10^3$$cm^2$/ha basal area. *Cymbopogon martinii* is at

the top in grasses with IVI 74.20 $22.29x10^4cm^2/ha$ proceeded by *Chrysopogon montanus* (69.67 IVI) and basal area as $69.67x10^4cm^2/ha$ Minimum values (13.53 IVI and $3.30x10^4cm^2/ha$ basal area is of *Saccharum spontaneum*

In case of *Acacia catechu* plantations (Table 3.1.5) *Dalbergia sissoo* and *Bauhinia variegata* are the two associated species with IVI values as 23.11 and 24.47, respectively, and basal area equivalent to $8.534x10^3cm^2/ha$ and $4.243x10^3cm^2/ha$, respectively. In shrubs, maximum IVI value (70.74) is of *Berberis lycium* pursued by *Prinsepia utilis* (54.75) and *Rhamnus virgata* (36.77). The basal area values for the above species ranged between $5.233x10^3cm^2/ha$ and $9.57x10^3cm^2/ha$.

In case of grasses, out of the total 5 species observed *Chrysopogon montanus* is dominant followed by *Apluda mutica* and *Heteropogon contortus* with IVI values of 79.60, 68.35 and 64.50, respectively.

As regards phytosociological studies of *Quercus* plantations (Table 3.1.6) *Aesculus indica* is the major associate with IVI at 58.07 and basal area at $192.5^3cm^2/ha$. In shrubs, the most related species are *Berberis lycium*, *Rubus elipticus* and *Rosa moschata* with IVI and basal area values of 73.03, 52.08 and 46.25, and $97.13x10^2cm^2/ha$, $80.20x10^2cm^2/ha$ and $104.4x10^3cm^2/ha$, respectively. The minimal value of IVI and basal area (6.32 and $0.286x10^2cm^2/ha$, respectively) is of *Indigofera pulchella*. Referring to grasses, only five species are observed to be associated with *Quercus* and out of these, *Chrysopogon montanus* and *Apluda mutica* are the dominant with 127.48 IVI and $36.64x10^2cm^2/ha$ basal area and 78.11 IVI and $7.943x10^2cm^2/ha$ basal area, respectively.

Table 3.1.3. *Robinia pseudoacacia*

Species	Average density (No./quad.) (D)	Basal area (cm^2/ha)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
Trees							
Robinia pseudoacacia	28.1	12.54×10^3	100	100	100	100	300
Shrubs							
Woodfordia fruticosa	7.67	3.07×10^3	66.67	17.42	15.38	1.26	34.06
Osyris arborea	1.67	97.53×10^3	33.33	3.79	7.69	40.24	51.72
Berberis lyciun	7.67	9.44×10^3	100	17.42	23.07	3.89	44.38
Coriaria nepalensis	1.33	5.14×10^3	33.33	3.02	7.69	2.23	12.94
Carissa carandus	4.33	88.61×10^3	66.67	9.83	15.38	36.56	61.77
Leptodermis lanceolatus	5.67	3.84×10^3	33.33	12.88	7.69	1.58	22.15
Zizyphus numullaria	7	1.14×10^3	33.33	15.90	7.69	0.47	24.06
Mimosa himalayana	3.67	29.37×10^3	33.33	8.34	7.69	12.12	28.15
Rhamnus triquetra	5	3.90×10^3	33.33	11.36	7.69	1.61	20.66
		242.31×10^3	433.33				
Herbs							
Chrysopogon montanus	55.52	41.50×10^4	100	13.84	17.65	35.43	66.92
Heteropogon contortus	52.67	1.53×10^4	100	13.17	17.65	1.31	32.13
Themeda anathera	76.67	1.57×10^4	66.67	19.18	11.77	1.34	32.29
Panicum maximum	87.67	58.10×10^4	100	21.93	17.65	49.61	89.19
Urochloa panicoides	29.23	3.66×10^4	66.67	7.34	11.77	3.13	22.24
Apluda mutica	68	7.67×10^4	66.67	17.01	11.77	6.55	35.33
Cynbopogon martinii	30.00	3.07×10^4	66.67	7.50	11.77	2.62	21.89
Total		117.1×10^4	566.68				

Table 3.1.4. *Populus spp.*

Species	Average density (No./quad.) (D)	Basal area (cm^2/ha)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
Trees							
Populus sp.	84	482.44×10^3	100	99.22	60	97.48	256.75
Pistacia integerrima	0.33	4.67×10^3	33.33	0.39	19.99	0.94	21.31
Celtis australis	0.33	7.75×10^3	33.33	0.39	19.99	1.56	21.93
Total		494.86×10^3	166.66				
Shrubs							
Elaegnus umbellata	23	19.77×10^3	66.66	36.84	20.00	54.90	111.74
Berberis lycium	14.33	6.01×10^3	100	22.95	30	16.69	69.64
Prinsepia utilis	5.33	3.41×10^3	66.66	8.53	20	9.49	38.02
Rhamnus virgata	6.33	1.71×10^3	66.66	10.14	20	4.75	34.89
Osyris arborea	13.45	5.09×10^3	33.33	21.55	10	14.15	45.70
Total		35.99×10^3	333.31				
Herbs							
Chrysopogon montanus	75.67	37.67×10^4	66.66	24.78	16.67	28.22	69.67
Heteropogon contortus	37.66	11.54×10^4	66.66	12.33	16.67	8.64	37.64
Panicum maximum	20.33	36.00×10^4	33.33	6.66	8.33	26.97	41.96
Apluda mutica	37.33	8.03×10^4	66.66	12.23	16.67	6.02	34.92
Chrysopogon gryllus	17.33	7.65×10^4	66.66	5.68	16.67	5.73	28.08
Cymbopogon martinii	108.67	29.29×10^4	66.66	35.59	16.67	21.94	74.20
Saccharum spontaneum	8.33	3.30×10^4	33.33	2.73	8.33	2.47	13.53
Total		133.48×10^4	399.96				

Table 3.1.5. *Acacia catechu*

Species	Average density (No./quad.) (D)	Basal area (cm^2/ha)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
Trees							
Acacia catechu	124.66	265.39×10^3	100	92.11	60	95.40	247.51
Bauhinia variegata	4	4.24×10^3	33.33	2.95	20	1.52	24.47
Dalbergia sissoo	6.67	8.53×10^3	33.33	0.05	20	3.06	23.11
Total		278.167×10^3	166.66				
Shrubs							
Artemesia vulgaris	14	0.36×10^3	33.33	8.57	5.88	0.97	15.42
Berberis lycium	44.33	9.57×10^3	100	27.14	17.64	25.96	70.74
Mimosa himalayana	4.67	0.05×10^3	33.33	2.86	5.88	0.13	8.87
Rhamnus virgata	17.67	5.23×10^3	66.66	10.82	11.76	14.19	36.77
Prinsepia utilis	26.67	7.67×10^3	100	16.33	17.64	20.78	54.75
Lantana camara	18.67	1.61×10^3	33.33	11.43	5.88	4.37	21.68
Rosa moschata	18.33	4.1×10^3	66.66	11.22	11.76	11.12	34.10
Carissa carandus	9.33	0.89×10^3	66.66	5.71	11.76	2.42	19.89
Meriandra strobilifera	7	4.97×10^3	33.33	4.28	5.88	13.48	23.64
Woodfordia fruticosa	2.67	2.41×10^3	33.33	1.63	5.88	6.51	14.02
Total		36.866×10^3	566.63				
Herbs							
Chrysopogon montanus	67.37	43.13×10^4	100	21.10	23.07	35.43	79.60
Heteropogon contortus	73.27	31.86×10^4	66.66	22.95	15.38	26.17	64.50
Themeda anathera	54.32	21.44×10^4	100	17.01	23.07	17.61	57.69
Panicum maximum	36.62	3.59×10^4	66.66	11.47	15.38	2.95	29.80
Apluda mutica	87.67	21.69×10^4	100	27.46	23.07	17.82	68.35
Total		121.72×10^4	433.32				

Table 3.1.6. *Quercus spp.*

Species	Average density (No./quad.) (D)	Basal area (cm^2/ha)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
Trees							
Quercus sp.	80	482.5×10^3	100	78.31	60	71.11	209.42
Morus alba	12.15	3.5×10^3	33.33	11.8	20	0.51	32.31
Aesculus indica	10	192.5×10^3	33.33	9.70	20	28.37	58.07
Total		678.5×10^3	166.66				
Shrubs							
Rubus ellipticus	18.33	80.20×10^2	66.66	20.37	11.76	19.95	52.08
Rosa moschata	7.67	104.4×10^2	66.66	8.52	11.76	25.97	46.25
Berberis lycium	29	97.13×10^2	100	32.23	17.64	24.16	74.03
Leptodermis lanceolatus	1.33	3.18×10^2	33.33	1.47	5.88	0.79	8.14
Rhus parviflora	1	1.79×10^2	33.33	1.11	5.88	0.44	7.33
Indigofera pulchella	0.33	0.29×10^2	33.33	0.37	5.88	0.07	6.32
Artemesia vulgaris	11.33	19.90×10^2	33.33	12.59	5.88	4.96	23.43
Carissa carandus	6.33	49.56×10^2	66.66	7.03	11.76	12.33	31.12
Myrsine africana	10	15.92×10^2	66.66	11.11	11.76	3.96	25.83
Zizyphus oxyphylla	0.66	0.79×10^2	33.33	0.73	5.80	0.19	6.72
Rhamnus virgata	4	28.66×10^2	33.33	4.45	5.88	7.13	17.46
Total		401.87×10^2	566.62				
Herbs							
Chrysopogon montanus	82.33	51.89×10^4	66.66	38.17	20	69.31	127.48
Themeda anathera	25.33	2.56×10^4	66.66	11.74	20	3.42	35.16
Panicum maximum	9.33	0.66×10^4	66.66	4.33	20	0.88	25.21
Apluda mutica	71.33	11.25×10^4	100	33.08	30	15.03	78.11
Cyprus rotundus	27.33	8.50×10^4	33.33	12.67	10	11.35	34.02
Total		74.87×10^4	333.31				

Table 3.1.7 for *Dalbergia sissoo* reveals that it has a density of 69 trees per 0.1 ha. *Populus sp. Pyrus pashia, Prunus cersoides* are the dominant associates with IVI and basal area values at 86.69, 36.90 and 22.70, and 101.37×10^3, 10.92×10^3, and $5.205 \times 10^3 cm^2$/ha, respectively. Among the shrub species associated with *Dalbergia sissoo* the maximum dominance is of *Elaegnus umbellata* (102.22 IVI and $155.45 \times 10^2 cm^2$/ha basal area) and *Carissa carandus* and *Leptodermis lanceolatus* showed almost equal dominance with IVI values as 69.11 and 63.96, and basal area values as $35.834 \times 10^2 cm^2$/ha and $56.92 \times 10^2 cm^2$/ha, respectively. As regards grasses, again *Panicum maximum* showed maximum dominance (61.69 IVI and $18.55 \times 10^4 cm^2$/ha basal area) followed by *Chrysopogon montanus, Themeda anathera* and *Apluda mutica* showed similar dominance with respective values of IVI as 57.66, 56.29 and 52.05. However, basal area values of these species ranged between 11.38×10^4 to $61.17 \times 10^4 cm^2$.

The data presented in Table 3.1.8 for *Toona ciliata* reveals that *Acacia mollissima* and *Punica nana* are its major associates with IVI values of 61.79 and 24.98, respectively. *Rubus elipticus, Carissa carandus, Berberis lycium* and *Zizyphus oxyphylla* with IVI values as 81.38, 53.58, 38.29 and 36.38, respectively, and basal area as 201.03×10^2, 99.70×10^2, 32.64×10^2 and $11.54 \times 10^2 cm^2$, respectively are the most common and dominant shrubs.

Among the total nine main plantations (Table 3.1.9) *Morus alba* is found growing pure but there is profuse growth of shrubs in peak growing season. Dominant shrubs include *Rhamnus virgata, Prinsepia utilis* and *Carissa carandus* with IVI values of 75.53, 52.71 and 10.68, respectively. However basal area value are $49.95 \times 10^2 cm^2$/ha, $21.613 \times 10^2 cm^2$/ha and $1.791 \times 10^2 cm^2$/ha, respectively. Among the grasses

Chrysopogon montanus with 128.43 IVI and $94.55x10^4 cm^2$/ha basal area has dominant growth which is in close competition with *Themeda anathera*, *Panicum maximum* and *Heteropogon contortus* with IVI values of 50.72, 37 15 and 36.46, respectively, and basal area as $3.35x10^4$, $4.03x10^4$ and $36.46x10^4 cm^2$/ha, respectively.

Under the miscellaneous forests (Table 3.1.10), *Acacia mollissima* and *Sepium sebiferrum* have nearly equal density (trees/quad.) 11.61 and 11.00, respectively. Maximum IVI is of *Alnus nitida* (25.66) followed by *Albizia chinensis* (24.62) and *Acacia mollissima* (23.61) showing the dominance over other species. Minimum occurrence is of Lagerstroemia with 4.58 IVI, *Acer oblongum* 4.73 IVI and *Grevillea robusta* 4.85 IVI. Almost all shrub species are present in miscellaneous forests but the maximum dominance is of *Carissa carandus* (IVI 53.27) followed by *Rosa moschata* (IVI 31.51), *Berberis lycium* (IVI 24.08) and *Lantana camara* (IVI 24.00). The least found species is *Mimosa himalayana, Rhus cotinus* with the IVI values as 1.79 and 1.20, respectively, and basal area of $0.258x10^2 cm^2$/ha and $0.1791x10^2 cm^2$/ha, respectively. In grasses *Chrysopogon montanus* (IVI 81.39, basal area $29.93x10^4 cm^2$/ha) is most dominant followed by *Themeda anathera*, *Apluda mutica*, *Panicum maximum* and *Cymbopogon matinii* with IVI values as 34.89, 31.74, 28.59 and 25.29, respectively, and basal area as $6.28x10^4$, $5.39x10^4$, $5.37x10^4$ and $4.66x10^4 cm^2$/ha, respectively. The least common is *Cynodon dactylon* (1.839 IVI and $0.1044x10^2 cm^2$/ha basal area).

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In seed production *Themeda anathera*, *Panicum maximum* and *Chrysopogon montanus* are the dominant grass species with IVI value

Table 3.1.7 *Dalbergia sissoo*

Species	Average density (No./quad.) (D)	Basal area (cm^2/ha)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
Trees							
Dalbergia sissoo	69	36.8×10^3	100	86.97	42.86	23.86	153.69
Populus sp.	5.33	101.4×10^3	33.33	6.72	14.29	65.68	86.69
Pyrus pashia	1.00	10.9×10^3	66.66	1.26	28.57	7.07	36.90
Prunus cerasoides	4.00	5.2×10^3	33.33	5.04	14.29	3.37	22.70
Total		154.3×10^3	233.32				
Shrubs							
Carissa carandus	7.3	35.83×10^2	100	25.20	30	13.91	69.11
Elaegnus umbellata	6.33	155.45×10^2	66.66	21.86	20	60.36	102.22
Zizyphus oxyphylla	1.30	0.23×10^2	33.33	4.59	10	0.89	15.48
Prinsepia utilis	7.67	9.07×10^2	66.66	26.48	20	3.52	50
Leptodermis lanceolatus	6.33	56.92×10^2	66.66	21.86	20	22.10	23.96
Total		259.50×10^2	333.31				
Herbs							
Heteropogon contortus	59.67	7.13×10^4	100	18.33	16.66	13.12	48.11
Themeda anathera	62.67	11.36×10^4	100	19.25	16.66	20.38	56.29
Apluda mutica	79.17	6.17×10^4	100	24.32	16.66	11.07	52.05
Urochloa panicoides	4	0.18×10^4	33.33	1.23	5.55	0.32	7.10
Chrysopogon gryllus	15	0.58×10^4	66.66	4.61	11.11	1.04	16.76
Chrysopogon montenus	67	11.38×10^4	100	20.58	16.66	20.42	57.66
Panicum maximum	38	18.55×10^4	100	11.67	16.66	33.29	61.69
Total		55.72×10^4	599.91				

Table 3.1.8 *Morus alba*

Species	Average density (No./quad.) (D)	Basal area (cm^2/ha)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
Trees							
Morus alba	57.3	165.99×10^3	100	100	100	100	300
Shrubs							
Prinsepia utilis	11	21.61×10^2	66.67	19.53	16.67	16.51	52.71
Artemesia vulgaris	15	16.52×10^2	33.33	26.63	8.33	12.62	47.58
Rhamnus virgata	11.66	49.95×10^2	66.67	20.71	16.67	38.16	75.53
Berberis lycium	5.67	12×10^2	66.67	10.06	16.67	9.16	35.89
Coriaria nepalensis	4.33	1.57×10^2	33.33	7.69	8.33	1.19	17.21
Woodfordia fruticosa	2.33	10.32×10^2	33.33	4.14	8.33	7.85	20.32
Rosa moschata	2	4.98×10^2	33.33	3.55	8.33	3.80	15.68
Carissa carandus	0.66	1.79×10^2	33.33	1.17	8.33	1.36	10.86
Leptodermis lanceolatus	3.67	12.14×10^2	33.33	6.52	8.33	9.27	24.12
Total		130.87×10^2	399.99				
Herbs							
Chrysopogon montanus	85.66	94.55×10^4	100	17.88	25	85.55	128.43
Themeda anathera	108.66	3.35×10^4	100	22.69	25	3.03	50.72
Panicum maximum	80.67	4.03×10^4	66.67	16.84	16.67	3.64	37.15
Apluda mutica	85.66	3.24×10^4	33.33	17.88	8.33	2.93	29.14
Chrysopogon gryllus	35	2.68×10^4	33.33	7.30	8.33	2.42	18.05
Heteropogon contortus	83.33	2.66×10^4	66.67	17.39	16.67	2.40	36.46
Total		110.52×10^4	400				

Table 3.1.9 *Toona ciliata*

Species	Average density (No./quad.) (D)	Basal area (cm^2/ha)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
Trees							
Toona ciliata	62.67	145.0×10^3	100	75.17	60	77.73	212.90
Acacia mollissima	16.5	41.19×10^3	33.33	19.79	20	22.08	61.79
Punica nana	4	0.35×10^3	33.33	4.79	20	0.19	24.98
Total		186.54×10^3	166.66				
Shrubs							
Zizyphus oxyphylla	1.67	11.54×10^2	33.33	5.16	6.67	24.55	36.38
Osyris arborea	5.67	54.68×10^2	66.66	17.53	13.33	11.63	42.49
Carissa carandus	4	99.70×10^2	100	12.37	20	21.21	53.58
Berberis lycium	3.67	32.64×10^2	100	11.35	20	6.94	38.29
Rosa moschata	3	33.63×10^2	33.33	9.28	6.67	7.15	23.10
Rubus ellipticus	10.33	201.03×10^2	33.33	31.94	6.67	42.77	81.38
Eleagnus umbellata	4	36.82×10^2	33.33	12.37	6.67	7.83	26.87
Total		470.04×10^2	499.96				
Herbs							
Chrysopogon montanus	81.67	86.68×10^4	100	39.07	30	59.16	128.23
Heteropogon contortus	18.67	7.32×10^4	33.33	8.93	10	5.0	23.93
Themeda anathera	36.67	20.78×10^4	66.67	17.54	20	14.18	51.72
Apluda mutica	21.33	16.79×10^4	33.33	10.20	10	11.46	31.66
Chrysotogon gryllus	5	7.56×10^4	66.67	2.39	20	5.16	27.55
Cymbopogon martinii	45.67	7.36×10^4	33.33	21.85	10	5.03	36.88
Total		146.51×10^4	333.31				

Table 3.1.10 Miscellaneous forests

Species	Average density (No./ quad.) (D)	Basal area (cm^2/ha) (BA)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
Trees							
Acacia mollissima	11.61	221.1×10^3	19.23	10.24	7.93	5.44	23.61
Acrocarpus fraxinifolius	5.69	149.6×10^3	11.53	5.01	4.76	3.68	13.45
Ulmus villosa	7.15	114.9×10^3	7.69	6.30	3.17	2.83	12.30
Ficus palmata	0.62	23.6×10^3	11.53	0.54	4.76	0.58	5.88
Pyrus pashia	3.11	42.3×10^3	19.23	2.75	7.93	1.04	11.72
Punica nana	3.26	53.9×10^3	19.23	2.87	7.93	1.32	12.12
Pistacia integerrima	4.30	383.4×10^3	7.69	3.79	3.17	9.44	16.40
Bombax ceiba	0.88	63.0×10^3	15.38	0.77	6.34	1.55	8.66
Jacaranda mimosaefolia	8	204.3×10^3	7.69	7.05	3.17	5.03	15.25
Celtis australis	2.15	105.2×10^3	19.23	1.89	7.93	2.59	12.41
Grewia optiva	0.96	49.6×10^3	11.53	0.84	4.76	1.22	6.82
Acer oblongum	2.92	23.4×10^3	3.85	2.57	1.58	0.58	4.73
Cupressus torulosa	1.92	194.2×10^3	3.85	1.69	1.58	4.78	8.05
Bauhinia variegata	4.08	260.0×10^3	23.07	3.59	9.52	6.40	19.51
Sapium sebiferrum	11	248.7×10^3	3.85	9.70	1.58	6.12	17.40
Lagerstroemia parviflora	3.19	18.1×10^3	3.85	2.81	1.58	0.19	4.58
Melia azedarach	7	266.5×10^3	3.85	6.17	1.58	6.56	14.31
Leucaena leucocephala	4.80	30.3×10^3	3.85	4.23	1.58	0.74	6.55
Aesculus indica	1.54	282.8×10^3	3.85	1.36	1.58	6.96	9.90
Albizia chinensis	5.76	342.5×10^3	26.92	5.08	11.11	8.43	24.62
Alnus nitida	12.5	530.4×10^3	3.85	11.02	1.58	13.06	25.66
Grevellia robusta	1.31	21.8×10^3	7.69	1.15	3.17	0.53	4.85
Salix alba	9.60	441.0×10^3	3.85	8.46	1.58	10.86	20.96
Total		4060.7×10^3	242.29				

Shrubs							
Coriaria nepalensis	0.38	2.96×10^3	19.23	1.10	3.10	0.53	4.73
Carissa carandus	1.46	223.01×10^3	50	4.24	8.07	40.06	53.27
Berberis lycium	1.54	58.46×10^3	57.69	4.47	9.31	10.50	24.28
Osyris arboea	0.92	16.52×10^3	26.92	2.67	4.34	2.97	9.98
Rhus cotinus	0.19	0.17×10^3	3.85	0.55	0.62	0.03	1.20
Rosa moschata	2.19	105.48×10^3	38.46	6.36	6.21	18.94	31.51
Leptodermis lanceolatus	0.81	5.33×10^3	11.54	2.35	1.86	0.95	5.16
Zizyphus oxyphylla	0.35	4.69×10^3	23.07	1.02	3.72	0.84	5.58
Debregeasia hypoleuca	1.04	4.43×10^3	11.54	3.02	1.86	0.86	5.68
Lantana camara	6	5.45×10^3	34.62	17.43	5.59	0.98	24
Artemesia vulgaris	3.42	1.12×10^3	34.62	9.93	5.59	0.20	15.72
Rhamnus virgata	0.92	3.59×10^3	50	2.67	8.07	0.64	11.38
Prinsepia utilis	1.65	3.21×10^3	43.21	4.80	0.83	0.57	6.20
Zizyphus numullaria	1.15	1.06×10^3	15.38	3.34	2.48	0.19	6.01
Rubus ellipticus	1.15	3.81×10^3	30.77	3.34	4.97	0.68	8.99
Rhus parviflora	0.38	8.81×10^3	3.85	1.10	0.62	1.58	3.30
Meriandra strobilifera	0.5	7.52×10^3	26.92	1.45	4.34	1.35	7.14
Zanthoxylum alatum	0.23	6.93×10^3	15.38	0.67	2.48	1.24	4.39
Murraya koenogii	0.42	0.67×10^3	3.85	1.22	0.62	0.12	1.96
Rhamnus triquetra	0.58	4.96×10^3	11.54	1.68	1.86	0.89	4.43
Woodfordia fruticosa	1.5	15.82×10^3	23.07	4.35	3.72	2.84	10.99
Verbena bonariensis	1.42	39.87×10^3	19.23	4.12	3.10	7.16	14.38
Justacia adhatoda	1.15	3.48×10^3	11.54	3.34	1.86	0.62	5.82
Myrsine africana	2.23	2.26×10^3	19.23	6.48	3.10	0.40	9.98
Eleagnus umbellata	1	20.92×10^3	23.07	2.90	3.72	3.75	10.37
Indigofera pulchella	1.44	5.88×10^3	7.69	4.18	1.24	1.05	6.47
Mimosa himalayana	0.39	0.26×10^3	3.85	1.13	0.62	0.04	1.79
Total		556.76×10^3	619.22				

Herbs							
Chrysopogon montanus	33.54	29.93×10^4	88.46	21.37	13.29	46.73	81.39
Heteropogon contortus	14.69	4.35×10^4	53.84	9.36	8.09	6.86	24.25
Themeda anathera	18.53	6.28×10^4	88.46	11.80	13.29	9.80	34.89
Panicum maximum	10.88	5.37×10^4	88.46	6.93	13.29	8.36	28.59
Apluda mutica	16.61	5.39×10^4	84.62	10.59	12.71	8.41	31.74
Urochloa panicoides	5.15	0.56×10^4	30.76	3.28	4.62	0.87	8.77
Chrysopogon gryllus	9.73	2.54×10^4	57.69	6.20	8.67	3.96	18.83
Cymbopogon martinii	18.31	4.66×10^4	42.31	11.67	6.35	7.27	25.29
Saccharum spontaneum	4.65	0.97×10^4	19.23	2.96	2.89	1.51	7.36
Cyprus rotundus	1.62	0.96×10^4	7.69	1.03	1.15	0.25	2.43
Mimosa species	2.65	0.12×10^4	7.69	1.69	1.15	0.17	3.01
Ageratum conizoides	1.30	0.28×10^4	7.69	0.82	1.15	0.44	2.41
Cynodon dactylom	1.34	0.13×10^4	11.54	0.85	1.73	0.20	1.84
Forbs	8.72	2.47×10^4	57.69	5.55	8.67	3.83	18.07
Eulaliopsis binata	9.2	0.82×10^4	19.23	5.86	2.89	1.28	10.03
Total		64.04×10^4	665.36				

as 59.70, 51.01 and 42.54, respectively. *Cynodon dactylon* is least prevalent with IVI value as 11.20 among seven grass species present in this type (Table 3.2).

Nurseries have dominance of *Apluda mutica* (90.34 IVI, $23.57x10^4$ basal area) followed by *Heteropogon contortus* (43.04 IVI, $10.49x10^4$ basal area), *Cymbopogon martinii* (34.04 IVI, $3.45x10^4$ basal area) and *Chrysopogon gryllus* (30.54 IVI, $3.34x10^4 cm^2/ha$ basal area) among 11 grass species encountered.

As regards animal science fields *Chrysopogon montanus*, *Apluda mutica* and *Heteropogon contortus* are the dominant species with IVI values 64.94, 55.70 and 54.94, respectively, and basal area as $10.04x10^4$ and $23.34x10^4$ and $10.35 x10^4$ cm^2/ha, respectively. *Chrysopogon gryllus* has minimum IVI of 15.34 and basal area value of $0.45x10^4 cm^2/ha$.

In soil science fields *Apluda mutica* is at the top and *Themeda anathera* at the modicum with IVI values as 153.45 and 38.56, respectively, out of total four grass species present.

Horticulture

In this land use, the study was done as per the type of fruit crop grown. Table 3.3 reveals that as a whole under olive plants, the dominant grass species is *Panicum maximum* (71.66 IVI, $46.91x10^4/cm^2/ha$ basal area) and least dominance is of *Themeda anathera* (20.51, $3.12x10^4 cm^2/ha$).

Underneath plum orchard, *Apluda mutica* (75.45 IVI and $64.68 \times 10^4 cm^2$/ha basal area) is the most commonly found species with *Chrysopogon montanus* (59.56 IVI and $26.88 \times 10^4 cm^2$/ha basal area), the next one to follow *Cyprus rotundus* (15.08 IVI and $0.51 \times 10^4 cm^2$/ha basal area) is of least dominance.

Below Peach, Walnut, Pecanut and Persimmon orchards *Chrysopogon gryllus* is maximum with IVI as 82.72 pursued by *Apluda mutica* with IVI value of 56.1 and minimum value is of *Cyprus rotundus* (31.03). The basal area values ranged between 40.47×10^4 to $15.35 \times 10^4 cm^2$/ha.

Beneath Pomegranate maximum IVI is of *Apluda mutica* (56.78) followed by *Panicum maximum* (55.22) among the total 6 grass species. Similarly, *Apluda mutica* (122.58 IVI and $56 \times 10^4 cm^2$/ha basal area) is the major grass component in Pear orchard. In mixed orchards, *Themeda anathera* is the major species (61.68 IVI and $37.80 \times 10^4 cm^2$/ha basal area) followed by forbs (47.7 IVI and $20.89 \times 10^4 cm^2$/ha basal area).

Miscellaneous land use

This landuse type covers scrub, open scrub, riverside, nallahs, roadsides, constructed areas, etc. Vegetation recorded in this type is sparse and sporadic with more of shrubs and grasses with trees interspersed in between. Table 3.4 reveal that the maximum density is of *Pinus roxburghii* (18.17) pursued by Acacia mollissima (15.5) and *Robinia pseudoacacia* (5.67). In terms of IVI values it followed the order : *Acacia mollissima* (39.74) followed by *Pinus roxburghii* (33.83), *Celtis australis* (33.18), *Populus* spp. (13.19) and *Eucalyptus* spp. (3.89).

Table 3.2 HORTICULTURE (LAND USE II)

Species	Average density (No./quad.) (D)	Basal area (cm^2/ha)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
			GRASSES				
Olive							
Apluda mutica	13.5	7.67×10^4	50	12.07	22.22	4.78	39.07
Chrysopogon montanus	28	43.34×10^4	25	25.04	11.11	27.03	63.18
Themeda anathera	8.33	3.12×10^4	25	7.45	11.11	1.95	20.51
Panicum maximum	35	46.91×10^4	25	31.29	11.11	29.26	71.66
Chrysopogon gryllus	10	1.02×10^4	50	8.94	22.22	0.64	31.80
Forbs	17	58.24×10^4	50	15.20	22.22	36.33	73.75
Total		160.3×10^4	225				
Plum							
Chrysopogon montanus	60	26.88×10^4	50	29.33	11.11	19.12	59.56
Themeda anathera	31	27.61×10^4	50	15.15	11.11	19.64	45.90
Panicum maximum	35	13.07×10^4	50	17.11	11.11	9.30	37.52
Apluda mutica	37.5	64.68×10^4	50	18.33	11.11	46.01	75.45
Sorghum halepense	9.5	1.32×10^4	50	4.64	11.11	0.94	16.69
Chrysopogon gryllus	7.5	1.77×10^4	100	3.66	22.22	1.26	27.14
Saccharum spontaneum	16.0	6.49×10^4	50	7.82	11.11	4.61	23.54
Cyprus rotundus	8.00	0.51×10^4	50	3.91	11.11	0.06	15.08
Total		140.55×10^4	450				
Peach / Walnut / Pecanut / Persimon							
Chrysopogon montanus	60	28.52×10^4	50	19.58	10	17.75	47.33
Apluda mutica	58.5	27.34×10^4	100	19.08	20	17.02	56.10
Chrysopogon gryllus	115	40.47×10^4	100	37.52	20	25.20	82.72
Saccharum spontaneum	16	15.35×10^4	50	54.22	10	9.56	24.78
Cyprus rotundus	19	7.91×10^4	100	6.10	20	4.93	31.03
Forbs	38	41.00×10^4	100	12.39	20	25.53	57.92
Total		160.59×10^4	500				

Pomegranate							
Panicum maximum	32	39.23 x10^4	50	18.99	12.50	23.73	55.22
Apluda mutica	43.5	9.87 x10^4	100	25.81	25.0	5.97	56.78
Urochloa panicoides	30	38.46 x10^4	50	17.80	12.5	23.26	53.56
Cymbopogon martini	27.5	25.76 x10^4	50	16.32	12.5	15.58	44.40
Forbs	35.5	51.99 x10^4	150	21.06	37.5	31.44	90.00
Total		165.31 x10^4	400				
Pear							
Apluda mutica	65	56.08 x10^4	50	52.20	33.33	37.05	122.58
Cyprus rotundus	21	30.69 x10^4	50	16.86	33.33	20.31	70.50
Forbs	38.5	64.36 x10^4	50	30.92	33.33	42.59	106.84
Total		151.13 x10^4	150				
Mixed Orchards							
Chrysopogon montanus	19.5	10.26 x10^4	50	6.7	10	7.08	23.78
Themeda anathera	74	37.80 x10^4	50	25.6	10	26.08	61.68
Panicum maximum	27.5	20.59 x10^4	50	9.5	10	14.21	33.71
Apluda mutica	27.5	5.13 x10^4	100	9.5	20	3.54	33.04
Cymbopogon martinii	72.5	35.95 x10^4	100	2.50	20	24.81	47.31
Urochloa panicoides	30	14.27 x10^4	50	10.3	10	9.84	30.14
Forbs	38.5	20.89 x10^4	100	13.29	20	14.41	47.70
Total		144.89 x10^4	500				

3.3 Cultivated land (LAND USE III)

Species	Average density (No./ quad.) (D)	Basal area (cm^2/ha) (BA)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
Seed Technology Centre							
Themeda anathera	38	24.36×10^4	100	21.68	20.00	18.02	59.70
Panicum maximum	29.75	18.96×10^4	100	16.98	20.00	14.03	51.01
Urochloa panicoides	13.25	7.34×10^4	50	7.56	10	5.43	22.99
Saccharum spontaneum	9.25	5.75×10^4	25	5.28	5	4.25	14.53
Cymbopogon martinii	25.75	17.37×10^4	75	14.69	15	12.85	42.54
Chrysopogon gryllus	12.75	6.01×10^4	25	7.28	5	4.45	16.73
Eulaliopsis binata	4.25	1.99×10^4	25	2.42	5	1.47	8.89
Forbs	24.5	31.72×10^4	50	13.98	10	23.47	47.45
Ageratum conizoides	8.5	20.38×10^4	25	4.85	5	15.08	24.93
Cynodon dactylon	9.25	1.27×10^4	25	5.27	5	0.93	11.20
Total		135.15×10^4	500				
Nurseries							
Heteropogon contortus	66	10.49×10^4	33.33	18.16	6.24	18.64	43.04
Apluda mutica	108	23.57×10^4	100	29.72	18.75	41.87	90.34
Cymbopogon martinii	56	3.45×10^4	66.67	15.41	12.50	6.13	34.04
Saccharum spontaneum	8.3	2.05×10^4	100	2.28	18.75	3.65	24.68

Chrysopogon gryllus	60.3	4.34×10^4	33.33	16.59	6.24	7.71	30.54
Cynocon dactylon	31.67	1.21×10^4	100	8.71	18.75	2.15	29.61
Cyprus rotundus	3.67	0.14×10^4	66.67	1.01	12.5	0.24	13.75
Forbs	29.33	11.03×10^4	33.33	8.07	6.24	19.57	33.88
Total		56.28×10^4	533.33				
Animal Science Fields							
Chrysopogon montanus	32	10.08×10^4	66.67	29.26	18.18	17.50	64.94
Heteropogon contortus	10.67	10.35×10^4	100	9.75	27.27	17.97	54.99
Themeda anathera	8.33	7.86×10^4	33.33	7.61	9.09	13.13	29.83
Panicum maximum	45.67	5.81×10^4	100	41.77	27.27	10.08	79.12
Apluda mutica	6.66	23.34×10^4	33.33	6.09	9.09	40.52	55.70
Chrysopogon gryllus	6	0.54×10^4	33.33	5.48	9.09	0.77	15.34
Total		57.60×10^4	366.66				
Soil Science Fields							
Themeda anathera	1	10.19×10^4	100	1.1	25	12.46	38.56
Panicum maximum	2	17.17×10^4	100	2.2	25	21.00	48.20
Apluda mutica	75	37.32×10^4	100	82.8	25	45.65	153.45
Cynodon dactylon	12.5	17.07×10^4	100	13.8	25	20.88	59.68
Total		81.75×10^4	400				

Amongst 21 shrubs species, *Berberis lycium* is having maximum dominance with IVI and basal area values of 52.42 and $4192.36x10^2 cm^2/ha$, respectively, pursued by *Carissa carandus*, *Rubus elipticus* and *Lantana camara* with IVI values as 29.26, 27.32 and 25.72, respectively, and basal areas as $1728.26x10^2$, $1646.09x10^2$ and $529.93x10^2$.ha, respectively.

In forbs, *Chrysopogon montanus*, *Heteropogon contortus*, *Themeda anathera*, *Panicum maximum*, *Apluda mutica*, and *Chrysopogon gryllus* are the common species with IVI values as 55.63, 54.12, 35.5, 31.85, 22.84 and 19.68, respectively.

Grassland

Among 7 grass species in this land use type (Table 3.5), *Chrysopogon montanus* is the dominant species growing in close association with *Heteropogon contortus* and *Themeda anathera* with IVI values of 118.36, 48.75 and 31.5, respectively. Forbs attained the IVI value as 45.28.

Similarity Index

The data presented in Table 4 indicate that land use type I has maximum similarity (82.99%) of species with land use IV, however type II

Table 4. Similarity index

Land use type	I	II	III	IV	V
I		33.70	57.69	82.99	17.28
II			66.66	29.54	54.54
III				48.54	37.83
IV					17.5
V					

has high similarity (66.68%) with III. Land use III has 48.54 per cent species to type IV and type IV shows similarity in species to type V which is 17.5 per cent equivalent to similarity (17.28%) between type I and type IV being lowest among all combinations.

4.3 Biomass production

Ensemblage of different species of trees, shrubs and grasses in Table 5.1 reveal that *Populus spp.* has maximum biomass production to the tune of 3502.24 q/ha with exploitable biomass of 555.60 q/ha (trees above 30cm diameter dbh). It is closely followed by *Eucalyptus* spp. with total standing biomass of 3167.08 q/ha and exploitable biomass as 1093.63 q/ha. Least exploitable biomass is of *Pyrus pashia* i.e. 3.88 q/ha.

The maximum average number of trees per hectare is of *Acacia catechu* (1246) preceeded by *Eucalyptus spp.*, *Pinus roxburghii* and *Populus* spp. with density/ha as 1080, 960 and 840, respectively. The minimum value is of *Myrica esculenta* and *Albizia chinensis*, both having density as 18 trees per hectare and following them is *Butea monosperma* with density value as 15.66.

In case of stem biomass, the highest biomass is of *Populus* spp., followed by *Eucalyptus* spp., *Pinus roxburghii, Acacia catechu, Dalbergia sissoo* and *Pistacia integerrima* having standing biomass as 3129.47, 2728.13, 2338.09, 1348.52, 3801.17 and 248.62 q/ha, respectively. The least biomass value holds for *Punica nana* (7.33 q/ha) and *Pyrus pashia* (7.58 q/ha).

Regarding branch and twig biomass, *Pinus roxburghii*, *Eucalyptus* spp. and *Populus* spp. is having having biomass values as 449.89, 438.96 and 372.77 q/ha, respectively, while *Punica nana* has the lease biomass value of 1.65 q/ha.

Table 3.4. Miscellaneous (LAND USE IV).

Species	Average density (No./quad.) (D)	Basal area (cm^2/ha (BA)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
Trees							
Ficus palmata	3.67	10.29×10^3	16.67	5.05	3.33	1.55	9.93
Acrocarpus fraxinifolius	3.5	60.42×10^3	50	4.81	9.99	9.14	23.94
Toona ciliata	2.67	106.45×10^3	33.33	3.67	6.66	16.11	26.44
Prunus padus	0.67	13.27×10^3	16.67	0.92	3.33	20.08	6.33
Populus sp.	1.0	153.03×10^3	33.33	1.37	6.66	23.16	31.19
Pinus roxburghii	18.17	14.38×10^3	33.33	25.00	6.66	2.17	33.83
Albizia chinensis	0.83	26.07×10^3	16.67	1.13	3.33	3.94	8.4
Grewia optiva	2.83	35.64×10^3	33.33	3.89	6.66	5.39	15.94
Celtis australis	8.33	77.52×10^3	50	11.46	9.99	11.73	33.18
Acacia mollissima	15.5	55.07×10^3	50	21.39	9.99	8.34	39.74
Punica nana	1.0	15.95×10^3	33.33	1.37	6.66	2.41	10.44
Eucalyptus spp.	0.33	0.76×10^3	16.67	0.45	3.33	0.11	3.89
Robinia pseudoacacia	5.67	14.75×10^3	16.67	7.80	3.33	2.23	13.36
Morus alba	1.33	4.45×10^3	16.67	1.83	3.33	0.67	5.83
Dalbergia sissoo	0.67	13.00×10^3	16.67	0.92	3.33	1.96	6.21
Pyrus pashia	1.0	7.57×10^3	16.67	1.37	3.33	1.15	5.85
Acacia catechu	4.17	42.65×10^3	33.33	5.73	6.66	6.45	18.84
Cedrus deodara	1.33	5.0×10^3	16.67	1.83	3.33	0.75	5.91
Total		660.67×10^3	500.01				
Shrubs							
Berberis lycium	18.5	4192.36×10^2	50	9.86	5.76	36.80	52.42
Myrsine africana	26.33	388.17×10^2	50	14.04	5.76	3.40	23.20
Rhamnus triquetra	0.83	7.96×10^2	33.33	0.44	3.84	0.07	4.35
Coriaia carandus	0.67	4.97×10^2	16.67	0.35	1.92	0.04	2.31
Leptodermis lanceolatus	8.33	296.56×10^2	16.67	4.44	1.92	2.60	8.96

Elaegnus umbellata	1.83	67.67 x10^2	33.33	0.97	3.84	0.59	5.4
Xanthoxylum alatum	16.17	91.63 x10^2	33.33	8.62	3.84	0.80	13.26
Justacea adhatoda	4.67	11.49 x10^2	16.67	2.49	1.92	0.10	4.51
Meriandra strobilifera	1.5	7.16 x10^2	16.67	0.8	1.92	0.06	2.78
Rhus cotinus	0.83	1.79 x10^2	16.67	0.44	1.92	0.01	2.37
Rhus parviflora	7	61.65 x10^2	16.67	3.73	1.92	0.54	6.19
Deberegeasia hypoleuca	5.33	293.79 x10^2	16.67	2.84	1.92	2.57	7.33
Lantena camara	21.5	529.93 x10^2	83.33	11.46	9.61	4.65	25.72
Artemesia variegata	7.0	42.17 x10^2	66.67	3.73	7.69	0.37	11.79
Rhamnus virgata	16.5	842.66 x10^2	83.33	8.80	9.61	7.40	25.81
Prinsepia utilis	8.67	442.58 x10^2	66.67	4.62	7.69.	3.89	16.2
Rubus ellipticus	13.33	1646.09 x10^2	50	7.11	5.76	14.45	27.32
Carissa carandus	12.00	1728.26 x10^2	66.67	6.40	7.69	15.17	29.26
Zizyphus numullaria	4.67	74.24 x10^2	33.33	2.49	3.84	0.65	6.98
Rosa moschata	10.17	586.37 x10^2	50	5.42	5.76	5.15	16.33
Zizyphus oxyphylla	1.67	74.84 x10^2	50	0.89	5.76	0.64	7.29
Total		11391.32 x10^2	866.67				
Herbs							
Chrysopogon montanus	74.17	23.91 x10^4	100	16.80	10.71	28.12	55.63
Heteropogon contortus	35.5	30.08 x10^4	100	8.04	10.71	35.37	54.12
Themeda anatherea	73.17	6.99 x10^4	100	16.57	10.71	8.22	35.50
Panicum maximum	47.83	8.77 x10^4	100	10.83	10.71	10.31	31.85
Apluda mutica	38	2.99 x10^4	100	8.61	10.71	3.52	22.84
Urochloa panicoides	16.83	0.99 x10^4	33.33	3.81	3.57	1.16	8.54
Chrysopogon gryllus	30.33	3.31 x10^4	83.33	6.87	8.92	3.89	19.68
Cymbopogon martiniii	10	1.29 x10^4	50	2.26	5.35	1.51	9.12
Saccharum spontaneum	17.83	2.13 x10^4	83.33	4.04	8.92	2.50	15.46
Eulaliopsis binata	14	2.40 x10^4	33.33	9.06	3.57	2.82	15.45
Ageratum conizoides	7.67	0.72 x10^4	16.67	1.73	1.78	0.84	4.35
Cynodon dactylon	7.83	0.04 x10^4	16.67	1.77	1.78	0.05	3.65
Forbs	42.17	5.74 x10^4	116.67	9.55	12.49	5.57	27.61
Total		85.04 x10^4	933.35				

Table 3.5 Grass land (LAND USE V)

Species	Average density (No./ quad.) (D)	Basal area (cm^2/ha) (BA)	Per cent frequency (% F)	Relative density (RD)	Relative frequency (RF)	Relative Basal Area (RBA)	IVI
Chrysopogon montanus	536	53.82 $x10^4$	100	59.66	29.41	29.29	118.36
Heteropogon contortus	148	26.90 $x10^4$	60	16.47	17.64	14.64	48.75
Themeda anathera	61.60	34.50 $x10^4$	20	6.85	5.88	18.77	31.50
Panicum maximum	40.80	26.90 $x10^4$	20	4.54	5.88	14.64	25.06
Urochloa panicoides	25.6	14.00 $x10^4$	20	2.85	5.88	7.62	16.35
Chrysopogon gryllus	15.20	13.00 $x10^4$	20	1.69	5.88	7.07	14.64
Forbs	71.20	14.60 $x10^4$	100	7.92	29.41	7.95	45.28
Total		183.72 $x10^4$	340				

Table 5.1 Tree component biomass on dry weight basis (q/ha)

Species	Average Number of trees/ha	Stem biomass (q/ha)	Branch + twig biomass (q/ha)	Total biomass (q/ha)	Exploitable biomass* (q/ha)
Acacia mollissima	116	33.92	14.51	48.43	8.09
Acrocarpus fraxinifolius	56.9	10.17	5.24	15.41	Ornamental
Grewia optiva	28.3	40.33	1.65	41.99	18.78
Cupressus torulosa	20	38.25	9.76	48.01	Ornamental
Ulmus villosa	72.3	69.26	13.59	82.86	-
Ficus palmata	36.7	24.35	4.07	28.43	-
Punica nana	32.6	7.33	1.88	9.21	-
Morus alba	573	55.30	25.22	80.53	65.44
Acer oblongum	86.6	77.25	12.11	89.37	17.15
Toona ciliata	76.7	195.51	35.43	230.93	151.45
Robinia pseudoacacia	281	53.42	37.23	90.65	20.66
Quercus leucotricophora	137.5	66.06	19.52	85.58	61.78
Pistacia integerrima	65.71	248.62	40.07	288.70	274.45
Sapium sebiferrum	110	20.25	8.08	28.33	-
Bauhinia variegata	45.8	107.82	7.19	115.02	97.45
Melia azaderach	70	100.47	8.61	109.09	81.63
Grevillea robusta	26.4	20.65	4.31	24.97	Ornamental
Jacaranda mimosaefolia	80	25.80	2.63	28.43	Ornamental
Celtis australis	52.4	205.38	37.19	242.56	190.37
Albizia lebbek	57.6	30.08	8.26	38.34	20.40
Pyrus pashia	32.2	7.58	3.08	10.67	3.88.
Aesculus indica	57	112.11	27.82	139.93	128.60
Salix alba	96	169.76	35.91	205.67	12.31
Alnus nitida	125	183.73	32.65	216.19	-

Cedrus deodara	26	22.35	22.16	44.52	-
Citrus jhambhiri	44 18	42.89	20.86	63.75	-
Callistemon lanceolatus	30	15.68	3.24	18.93	Ornamental
Ougenia oojeinensis	20	16.90	3.06	19.96	-
Mallotus philippinensis	21.66	32.16	9.69	41.86	-
Litsea chinensis	30	89.66	24.99	114.66	71.75
Butea monosperma	15.66	18.86	7.75	26.62	Ornamental
Prunus padus	20	26.05	5.38	31.44	-
Quercus glauca	25.66	31.31	5.57	36.89	10.08
Myrica esculenta	18	36.45	7.24	43.69	-
Albizia chinensis	18	68.26	17.06	85.32	68 53
Populus spp	840	3129.47	372.77	3502.24	555.60
Acacia catechu	1246	1348.52	274.19	1622.72	559.31
Dalbergia sissoo	690	380.11	168.02	548.14	365.59
Eucalyptus spp	1080	2728.12	438.95	3167.08	1093 63
Pinus roxburghii	960	2084.74	449.89	2534.64	459 22

- **Exploitable diameter not reached.**
- * **Total biomass of trees above 30cm dbh**

Table 5.2 Shrub component biomass on dry weight basis (kg/ha)

Species	Average dry weight		Total Biomass (Kg/ha)
	Leaves + Twig (Kg/ha)	Branch (Kg/ha)	
Prinsepia utilis	95.20	139.96	235.16
Berberis lycium	2598.80	3846.96	6445.76
Coriaria nepalensis	372.64	631.28	1003.92
Carissa carandus	256.72	363.84	620.56
Woodfordia fruticosa	1996.56	2130.76	4127.32
Osyris arborea	123.56	190.68	314.24
Mimosa himalayana	289.60	301.04	590.64
Rhamnus triquetra	783.84	1033.60	1817.44
Rubus ellipticus	130.84	647.28	778.12
Justacea adhatoda	65.48	158.406	223.88
Debregeasia hypoleuca	610.76	642.36	1253.12
Murraya koenogii	654.00	465.60	1119.60
Meriandra strobilifera	594.34	2173.86	2768.20
Hypericum cernuum	58.44	94.00	152.44
Verbena bonariensis	340.32	345.342	685.64
Elaegnus umbellata	227.04	258.32	485.36
Indigofera pulchella	124.20	496.702	620.902
Zanthoxylum alatum	64.52	121.638	186.158
Myrsine africana	28.56	41.389	69.949
Lantana camara	126.96	190.435	317.395
Zizyphus oxyphylla	296.28	384.991	681.271
Rhamnus virgata	390.26	540.892	931.152
Rhus cotinus	160.48	459.963	620.443
Artemesia vulgaris	271.48	276.36	547.840
Rhus parviflora	111.44	501.21	612.610
Zizyphus numularia	81.48	214.94	296.421

Similarly, aggregate of shrub species in Table 5.2 gives an account of maximum biomass in case of *Berberis lycium* (64.45kg/ha) followed by. *Woodfordia fruticosa* (41.27 kg/ha), *Meriandra strobilifera* (2768.20 kg/ha) and *Rhamnus triquetra* (1817.44 kg/ha). Minimum value goes for *Myrsine africana* (69.949 kg/ha) followed by *Hypericum cernuum* (152.44 kg/ha). Maximum branch weight is of *Berberis lycium* (3846.96kg/ha) and minimum is of *Hypericum cernuum* (94 kg/ha).

Among the total grass component (Table 5.3) in various land uses, maximum aboveground biomass is recorded for grassland 3955.546 kg/ha and minimum for horticulture 2979.44 kg/ha. The highest belowground biomass value is estimated in horticulture 871.89 kg/ha and lowest in forest 628.47 kg/ha.

Table 5.3. Herb component biomass (Belowground and Aboveground) on dry weight basis (Kg/ha)

Land use type	Belowground	Aboveground	Total
Forest	628.47	3148.67	3777.14
Grass land	850.44	3955.54	4805.99
Horticulture	871.18	2979.44	3850.63
Cultivated land	672.43	3100.20	3772.43
Miscellaneous	720.84	3084.48	3805.33

4.4 Soil physical status and drainage pattern

Present investigation reveals that all the pedons have a common hue of 10 YR, indicative of uniform conditions of drainage and aeration throughout the soil profile (Table 6) in all land use types. The value of matrix colour and chroma ranged from 3-5 and 3-4, respectively.

In forest land "B" horizon is absent but A1, A3, C1 and C2 horizons are observed upto 150 cm depth. Soil vary from gravely sandy loam to gravely loam in texture and moderate medium granular to granular in structure. Roots are present in all depths.

In horticulture land use, soil profile has four horizons A1, A3, B and C progressing from surface to 130cm depth. The soil is gravely silty loam in all layers in texture and granular to massive in structure. Roots are found in the deepest horizon upto 68cm depth (Table 6).

In cultivated land maximum five horizons (A1, A3, B, C1 and C2) are recorded upto 150cm depth of soil profile. The soil is gravely loam in surface horizon and gravelly silty loam in sub-surface horizons. The structure is granular to massive from top to bottom and roots are totally absent in (C_1 and C_2) deeper horizons.

The soil is shallow in miscellaneous land use. Only A1 horizon is found with bedrock just 11 cm below soil surface. The soil is gravely loam in texture and granular in structure with continuous coherent rock substratum.

Grassland soils has thicker "B" horizon (53cm), with soil granular to semiweathered gravely sandy clay loam in structure and texture. Roots are absent below "B" horizon after 85 cm from the ground.

Table 6. Soil profile status of different land use types.

Land	Horizon	Depth (cm)	Colour (moist)	Texture	Structure	Root distribution
Cultivated	A1	0-15	10 YR 4/4	GL	gr	Common fine
	A3	15-28	10 YR 3/4	GSiL	m_2 sbk	Few and fine
	B	28-43	10 YR 3/3	GSiCL	m_2 sbk to abk	Few and fine
	C1	43-68	10 YR 3/4	GSiL	massive	Absent
	C2	68-150	10 YR 3/4	GSiL	massive	Absent
Horticulture	A1	0-14	10 YR 4/3	GSiL	gr	Many coarse roots
	A3	14-30	10 YR 4/4	GSiL	gr to sbk	Common coarse and fine roots
	B	30-68	10 YR 5/4	GSiL	massive	Very few and fine
Grassland	A1	0-13	10 YR 4/3	GSCL	gr	Many roots
	A3	13-22	10 YR 4/3	GSCL	gr	Few roots
	B	32-85	10 YR 4/4	GSCL	gr to m_2 sbk	Scanty roots
	IIC	85 +	-	-	semi weathered	
Forest	A1	0-17	10 YR 4/3	GSL	m_2 gr	Plenty roots
	A3	17-32	10 YR 5/4	GSCL	gr to m_2 sbk	Plenty roots
	C1	32-85	10 YR 5/4	GL	massive	Few roots
	C2	85-150	10 YR 5/4	GL	massive	Few roots
Miscellaneous	A1	0-11	10 YR 4/3	GL	gr	Many roots
	R	11 +	-	Conti-nuous	Coherent rock	substratum

Texture
L = Loam
C = Clay
S = Sandy
Si = Silty
G = Gravely

Structure
gr – granular
abk- angular blocky
sbk – sub- angular blocky
m_2 - moderate medium
(Soil survey Manual, Soil survey staff 1951)

Drainage Pattern

Whole of the University area is having drainage of excess water directly or indirectly to Kawal Khud tributory of river Giri. Entire area is having drainage mainly from North towards South and South-east.

Overall pattern of drainage of the area is fan shaped but the drainage to each rivulet is fern shaped (Fig. 1). The major perennial rivulets feeding the Kawal Khud (4km long) are Cha-ki-khud (2.6 km), Raun-ki-khud (2.03 km), Gatol khud (3.25 km) and Sak-ka-nala (1.05 km).

The quantity of water is less throughout the year and the quantum further decreases during summer. However, flow of water is fast due to variation in elevation at the start and end of the rivulets.

4.5 Economic production of different land uses

The data with regard to economic production of different land uses has been given in Table 7. Cultivated land use covers the area under Seed Technology and Production Centre, nurseries of various department and experimental fields. Floriculture, various ornamental annuals and bulbous plants are grown. Sale is usually through plants / seedlings, seeds / bulbs, cuttings, loose flowers, bouquets and cut flowers. In the last three years, highest income was generated by the sale of plants / seedlings to the tune of Rs. 1,90,438.45.

Through poplar cuttings and plants, the economic production was of Rs. 50,410.00 in nurseries of the department of Tree improvement and Genetic Resources in last three years. In the area under Fruit Breeding and Genetic Resources, nursery seedlings of apple, pear, strawberry, apricot, plum, almond, peach, wanut and persimmon are grown for sale. The money generated is to the tune of Rs. 53,019.00 and grass

was auctioned to the tune of Rs. 77,010.00 in last three years. Forest Products department mainly sell seeds of *Solanum* spp., *Mentha*, spp., *Salvia* spp. *Cassia* spp., etc. The monetary gain assessed in last three years is Rs. 80,670.00.

Nurseries under Department of Silviculture and Agroforestry have tree seedlings *Robinia, Leucaena, Bauhinia, Morus, Grewia, Celtis, Populus, Acacia,* etc. and the sale generated equivalent to Rs. 79,452.00. Grass was auctioned for Rs. 2,00,875.00. The maximum benefit is from sale of milk, milk products, and auction of livestock, etc. which amounts to Rs. 31,06,989.70.

In Vegetable Crops department, various Rabi and Kharif season crops are grown. In Kharif, ginger, turmeric, bean, cucumber, capsicum, tomato and okra, and in Rabi, cauliflower, cabbage, peas, garlic and onion are the major ones. The sale was Kharif season crops yielded Rs. 2,37,238.62.

Similarly in Seed Technology and Production Centre, Kharif season crops include tomato, capsicum, bean, okra, brinjal, pumpkin, breeded seed, pulses, etc. and the economic gain was of Rs. 4,81,695.20. Rabi season crops include peas, radish, turnip, breeder seed of peas and radish, cabbage, etc. and sale was to the tune of Rs. 4,03,445.20 in last three years.

In forest land use, in 1998-99, 960 Popular plants were harvested to add Rs. 7,28,000.00 to the university economy.

In horticulture landuse, the net income generated by the sale of various fruit plants was to the tune of Rs. 23,70,613.25 and through fruits the financial gain was of Rs. 7,95,294.00 and through oil sale and grass auction, the monetary gain was of Rs. 1,54,530.10 in the last three years.

Table 7. Economic Production of different land use types.

Source	Year (Production in Rupees) 1998-99	1999-2000	2000-2001	Total
Floriculture (Over all income)				
Plants/Seedlings	141142.5	22548.75	26747.20	190438.45
Seeds/Bulbs	6857.00	7906.00	14085.00	28848.00
Cuttings	23120.50	20611.00	111277.50	155009.00
Loose Flowers/ Cut Flowers/Bouquets	8074.25	13585.00	19660.00	41319.25
Tree Improvement (Nursery)				
Popular (Cutting + Plants)	15080.00	17960.00	17370.00	50410.00
Bamboos	-	255.00	-	255.00
Grass Auctioned	19475.00	12550.00	18275.00	50300.00
Deodar	-	-	3000.00	3000.00
Fruit Breeding and Genetic resources (Nursery)				
Fruit Crops	14647.00	18077.00	20295.00	53019.00
Grass Auctioned	30310.00	22625.00	24075.00	77010.00
Auction of Wood of Dried Almond trees	-	900.00	-	900.00
Forest Products (Nursery)				
Seed	6169.50	9251.50	65249.00	80670.00
Silviculture (Overall income)				
Plants	35167.00	28925.00	15.360.00	79452.00
Grasses	63500.00	80950.00	56425.00	181125.00
Farm Products	20759.50	27965.00	7450.00	56174.5

Animal Science Products	1206151.75	1278865.95	621972.50	3106989.70

Year (Production in Rupees)

Vegetable Crops (Over all income)	**1997-98**	**1998-99**	**1999-2000**	**Total**
Kharif	77583.78	84406.95	75247.89	237238.62
Rabi	12781.35	15670.40	23956.10	52407.85

Seed Production (SPS) (Over all income)

Kharif	209898.08	126173.50	145623.62	481695.20
Rabi	132047.00	106276.00	165123.20	403445.20
Forest	-	728000.00	-	-

Horticulture (Overall income)

Plants	673948.009	700733.50	995931.75	2370613.25
Fruits	308795.00	311565.00	174934.00	795294.00
Miscellaneous	59963.00	40572.00	53995.10	154530.10

Chapter-5
DISCUSSIONS

DISCUSSIONS 5

With the change in conditions in relation to population explosion, improvement in living standard and higher demand for natural resources is continuously changing the land use and cover pattern. However, on the basis of productivity status of individual land use which is having more impact on their adoption for the new purpose. But in Indian conditions emphasis is given on the easy availability rather than capacity of the area to provide economic benefits for which the adoption is made. The work was conducted to overcome land use classification, study vegetal cover and productivity status under the different heads.

5.1 Land use type

5.2 Phytosociological study

5.3 Biomass production

5.4 Soil profile and drainage pattern

5.5 Economic production of different land uses

5.1 Land use type

The information of different land use types for Nauni campus is given in Table 1. The total area of the campus was calculated as 538.04 ha (Fig. 1) which is 0.1. ha less than the area reported by Singh *et al.* 1980. This

difference in area calculation can be attributed to cartography. Present status of land use revealed that the area under miscellaneous land use was 60.04 per cent. Cultivated land including horticulture covered 19.37 per cent, forest covered 20.46 per cent and grass land, a meager area of 0.13 per cent out of the total area of 538.04 ha. Delineation of land uses done in the present study is according to the area allocated to different types of land use on the basis of diverse physiography and past land use. Considerable area under natural grassland and marginal agriculture was used for forest plantations, which is included under forest land use in present study. Forest land use also covers the area under miscellaneous forests which is classified on the basis of small intermingled plantation of different species and sporadic natural vegetation. Such plantations are difficult to identify, map and quantify species wise due to low spatial resolution on the scale of map. Miscellaneous land use seems to cover higher area on account of large area presently under construction, roads, playground, scrubby vegetation and out cropped area. A wide difference in area under different land uses was recorded in study conducted by Singh, et. al. 1980 for identifying land uses in Nauni campus when compared with the present study. They had reported 45.34 per cent land under grass land/pastures. Presently the area under same land use was calculated as only 0.13 per cent. Thus, as described earlier during past two decades, massive plantation work was done by utilizing grassland for plantations, may be the reason for this difference. Similarly, they have reported 36.13 per cent area under cultivated land which include horticulture and agriculture. Presently the same land use covered 19.37 per cent which reveals that the large area considered under agriculture and horticulture by Singh, et. al. 1980 has been put under other land use types.

5.2 Phytosociological study

The phytosociology of different land uses in present study revealed that the site difference accounted for variations in the vegetational composition. Out of the tree species *G. optiva, T. ciliata, F. palmata, P. nana, P. integerrima , M. azadarach, C. australis, P. pashia and A. chinensis* were found growing amidst fields, horticulture and cultivated land apart from forest and miscellaneous land use. These are the natural species of the locality and have come up sporadically (Table 2). In plantations these species were sparsely distributed and could not be sampled out on account of their absence in the selected sample plots.

In forest land use, natural forest area was very less as compared to the plantations and so, they have been discussed under individual plantation having considerable area and miscellaneous forests.

P. roxburghii has maximum association with *A. fraxinifolius* amongst the other tree species due to high relative density and relative basal area however, relative frequency was equal (Table 3.1.1). In case of understorey vegetation dominant associate were : *B. lycium, L lanceolatus* and *M. africana* on the basis of relative density and relative basal area. The association of chir with these shrubs has also been indicated by Troup, (1921) and Singh *et. al.* (1991). In case of herbs 8 species were found in which *T. anathera* was the major associate followed by *C. gryllus* due to higher relative density and relative frequency. These results are in confirmation with studies conducted regarding grass cover of India (Dabadghao and Shankarnarayan, 1973). The other reason is attributed to the altitudinal zone of occurrence of chir is similar to that of Nauni.

In *Eucalyptus spp.*, though 5 species had been observed to be common but, *Populus* spp. was having the maximum association on the

basis of more value of relative density and relative basal area (Table 3.1.2). Amongst the underneath vegetational cover *E. umbellata* was most dominant followed by *C. carandus* and *B. lycium*, mainly accounted for relative density and relative basal area. Since, these species are common in the area of study (Sindhi, 1996). *E. umbellata* was found to be dominant while studying its association under *E. tereticornis* by Workneh, (1999) which is in accordance to this study. In herbaceous vegetation *C. montanus, P. maximum and T. anathera* were common due to higher relative density. This was due to the first rotation and initial stage of growth under *Eucalyptus*. These findings have congruence with the studies of Dabadghao and Shankarnaryan (1993) where they found these grass species growing common in this area. It is also evident from the studies of Woo and Lee (1989) who indicated that damaged vegetation if restored to original, the species composition can not immediately return to normal.

Regarding *R. pseudoacacia*, the plantations are nearly pure with no tree species growing with them. The major dominant shrubs found below this specie were *C. carandus, O. arborea* and *Woodfordia fruticosa, and among herbs C. montanus* and *Panicum maximum* were common mainly due to relative basal area (Table 3.1.3). The presence of these species is in accordance with the prescribed range of their distribution (Gupta, 1969). The reason may be ascribed to the altitudinal zonation i.e. 4000' to 6000' is of common occurrence with best growth on loamy soil (Troup, 1921). These both requirements are fulfilled at the place of study.

Populus spp. has association with *C. australis* and *P. integerrima* with almost equal IVI value due to higher relative frequency as indicated in table (3.1.4). The major shrubs and herb species covering the ground flora were *E. umbellata, B. lycium and C. martini and C. montanus* mainly due to higher values of relative density and relative basal area. It is in

accordance to natural occurrence of associated species to the area under *Populus* spp. plantations as reported by Sindhi (1996) .

Regarding, *A. catechu* plantations, it has maximum density of 124.6 trees per quadrat (Table 3.1.5). However, the associated species of almost equal dominance were *B. variegata* and *D. sissoo*. It is reasoned to the less spacing and more proportion of young crop and poor growth, since, highest distribution of this tree species is described upto 1200 meters above mean sea level (Ram Parkash, 1991). The main associated species include B. lycium and *P. utilis* among shrubs and *C. montanus* and *A. mutica* in herbs due to relative density and relative basal area.

Quercus spp. covers an area of 3.91 ha with *A. indica* the dominant associated species due to relative basal area (Table 3.1.6). The maximum number of trees were along khud side showing its affinity for shade and moisture which is in accordance to the study of Troup (1921). In the underneath association *B. lycium*, *R. elipticus* are the major among shrubs and *C. montanus* and *A. mutica* in the herb species due to higher values of relative density and relative basal area in both. The reason for shrubs and herbaceous growth may be that this plantation was comparatively young and the area before plantation was under grasses and scrubs. These observations are compatible with the studies conducted by Singh et. al. (1991) in Ban oak natural forest and found higher proportion of density and IVI value of *B. aristata*.

Populus spp., *P. pashia* and *P. puddum* were the major tree species in *D. sissoo* plantation (Table 3.1.7) . In shrubs, only 5 species and in herbs 7 species were observed. The dominant among shrubs was of *E. umbellate* due to higher relative basal area. In herbs *P. maximum*, *C. montanus* and *T. anathera* were having equal dominance influenced by

relative basal area. The natural existence of species had impact on the occurrence as indicated by Dabadghao and Shankarnaryan (1973).

M. alba was growing pure with only understorey vegetation of shrubs and herbs. The maximity was of *R. virgata* and *C. montanus* (Table 3.1.8) induced by relative basal area, indicating the characters of their distribution in the study zone.

In plantation of *T. ciliata* (Table 3.1.9) *A. mollissima* and *P. nana* were the only tree species associated. In shrubs *R. elipticus* was most dominant due to more relative density and relative basal area. Among herbs *C. montanus* was dominant due to more relative density , relative frequency and relative basal area.

In the miscellaneous forests (Table 3.1.10) is all 23 tree species were included which had marginal area coverage and were in mixture and thus taken under this sub heading. Moreover, the area under these forests was less than that under the plantations and is matched with departmental records. Regarding, shrubs (27) and herbaceous (15) vegetation though maximum number of species have been recorded but the values were less. The maximum dominance was of those tree species which had higher relative density and relative basal area. In case, of shrubs *C. carandus* and *R. moschata* were dominant due to higher relative basal area, since improvement operation were not carried out in the area. Among herbaceous vegetation C. montanus was very common with comparatively high value of IVI.

In horticulture land use, under various plantations the herbage component was high (Table 3.2). It was due to various cultural practices which led to improvement in soil status and reduction in competition with unwanted vegetation. The presence of *A. mutica* was maximum under pear

followed by plum plants, *T. anathera* under mixed and forbs under olive and pomegranate trees mainly due to relative basal area followed by relative density.

Similarly, in cultivated land, the number of herbs varied from 4 to 10 under different units (Table 3.3). Along agricultural fields *T. anathera* was common due to higher relative density and frequency. In nurseries *A. mutica* was more.

Miscellaneous land use included the area under scrubby vegetation, roads, nallahs, habitation and constructed area. The observed dominance was of *A. mollissima, P. roxburghii,* and *C. australis* in trees; B. *lycium and C. carandus* in shrubs whereas *C. montanus* and *H. contortus* in herbaceous vegetation (Table 3.4). It was due to relative density in trees, relative basal area in shrubs and relative density and relative basal area in herbs.

Grassland association was of 7 species (Table 3.5) dominated by *C. montanus* due to high relative density and relative basal area. However, its relative frequency was equal to forbs. It may be due to the fact that the area was free from biotic and abiotic disturbances.

5.3 Biomass production

The total aboveground biomass content of different species varied considerably from 9.22 q/ha to 3502.24 q/ha depending upon the plant density and area covered by the species in general (Table 5.1). However, the stem biomass content varied from 50.21 per cent to 96.05 per cent for the tree species present in the study area. Out of the total 40 species, 23 species were taken to find out the exploitable biomass on the basis of prescribed exploitable diameter of 30 cm and above as per the HP Forest

Department prescription. The exploitable biomass content varied from 3.88 to 1093.64 q/ha for different species.

On the basis of total area, average number of trees per hectare were found maximum in *A. catechu* followed by *Eucalyptus* spp. and *P. roxburghii*. The variations in tree density was due to the adoption of area at different stages for plantation purposes for experiments, arboretum, germplasm collection, seed orchards etc. as evident from the departmental records.

The average number of trees per hectare were found maximum in *A. catechu*. The stem and branch + twig biomass was maximum in *P. roxburghii* which can be attributed to the more number of trees in upper diameter classes. However, the least average number of trees per hectare were of *B. monosperma M. esculenta* and *A. chinensis* but, the least stem biomass was observed in *P. nana* followed by *P. pashia, A. fraxinifolius* and *C. lanceolatus*. Since, the trees of these species were in lower diameter classes and low in density per hectare.

The maximum branch + twig biomass was recorded in *P. roxburghii* closely followed by *Eucalyptus* spp. and then by *Populus* spp. however, in general, the percentage of branch and twig to the total biomass varied from 3.95 to 49.79 per cent (Appendix-I). It is due to the variation in plant growth characteristics of different species.

The allocation of oven dried biomass among the tree components was of the order stem wood > branch +twig in all tree species. The share of stem wood was recorded more than 50 per cent of total biomass of the trees. Such findings are in close proximity with those of Tandon *et al.* (1991), Raizada and Srivastva (1989), Pandey *et al.* (1986), Pandey *et al.* (1988) and Dey, (1996). The stem biomass was the major

contributor to the total above ground biomass and may be ascribed to the fact that with age, diameter growth increases resulting in more accumulation in stem wood. These results are in line with those of Kaul *et al.* (1983), Bhartari (1986) and Banerjee *et al.* (1993).

The maximum stem biomass percentage (96.05) was observed in *G. optiva* followed by *B. variegata* (93.74). Since, the trees of these species are lopped for leaf fodder which decreased the branch + twig biomass. However, the minimum stem biomass (50.21 %) and maximum branch + twig biomass (49.79 %) was recorded in *C. deodara* (Appendix-II). The higher biomass ratio of branch + twig in *C. deodara* was due to the young trees.

In shrub species maximum (83.19 %) contribution of branch biomass to total biomass was of *R. elipticus* followed by *R. parviflora* (81.81 %) whereas, the minimum biomass (41.59 %) was recorded in *M. koenigii* (Appendix-II). However, the maximum (6445.76) total biomass (kg\ha) was recorded in *B. lycium* followed by *W. fruticosa* whereas, the minimum (69.95) in *M. africana*. The variation in biomass of different shrubs is attributed to species difference with particular reference to tree component. This is in accordance with the studies conducted by Myongjong (1998) on above ground biomass of herbs and shrubs species who reported 4 to 39 and 0.5 to 6 q/ha biomass under 9-66 year old *P. koraiensis* plantation. It has also been reported by Temeche (1999), while conducting studies on biomass production and nutrient dynamics in *E. tereticornis* plantations, that the shrubs biomass decreased with the increase in tree density.

Maximum total biomass (kg/ha) was found in grass land (4805.99) followed by horticulture (3850.63) however, the minimum biomass (3772.43) was observed in cultivated land (Appendix 3). Reviewing the herbaceous biomass in different land uses in Table 5.3 revealed that above

ground biomass component was highest in grasslands and lowest in horticulture land use, whereas, below ground biomass was maximum in horticulture land use and minimum in cultivated land use. However, it was observed that the biomass of herbaceous vegetation did not vary much when different land uses were compared.

The low variations in biomass production under different land uses are attributed to almost similar conditions of growth and vegetational composition. The results are in confirmation with the findings of Singh *et al.* (1975), who reported the dry matter yield of grasslands of HP as 250 to 518 q/m^2. Similar result, have been reported by Malkania and Tandon (1983) while studying the biomass of grasslands in Western Temperate Himalayas.

5.4 Soil profile status and drainage pattern

The important soil morphometric characteristics namely colour, structure, thickness of solum, texture and soil depth of the studied pedons are indicators of soil profile development. The data (Table 6) revealed that all soil profile were characterized by 10 YR as the common hue for surface and sub-surface horizons. The dark matrix colour was observed in forest land use followed by horticulture in all horizons as compared to other land uses which was due to the presence of high organic matter content in these soils. The high colour values ranging from 3 to 5 suggested well drained nature of these soils. Similar observations regarding the colour of matrix in the soils of HP have earlier been reported by various workers (Dhir, 1967 ; Sehgal, 1973 ; Verma, 1979 and Singh 1987 ; Kaushal, 1992 and Sushil Kumar, 1999). The granular structure observed in surface horizons might be the consequence of mixture of organic matter with mineral soil.

A close scrutiny of horizonation showed that the presence of only A and C horizons in all land use types except horticulture and

miscellaneous land use was indicative of their being in the initial stage of development. The minimum profile development was visualized in miscellaneous land use, wherein the thickness of solum was only 11 cm which may be attributed to minimum cultural operations under taken and natural physiography of this land use.

The tree and grass roots exhibited the ubiquity through out the profile in all the land uses and were common from coarse to few and fine in their distribution and size, from top to lower horizons, respectively.

The overall drainage pattern of the area was fan shaped, however, the individual rivulet showed fern like shapes. Whole of the study area was well drained forming the part of Kawal Watershed. The total length of perennial rivulets feeding Kawal Khud was 8.93 kms.

5.5 Economic production of different land uses

The economic data for different land uses was collected from different departmental records for three consecutive financial years. Maximum economic production was recorded from animal science products under the Department of Silviculture and Agroforestry during the year 1999-2000 which was due to the auction of animals and sale of animal products.

In horticulture, maximum contribution was from sale of horticulture plants, however, the contribution of fruits was to the tune of 3,11,565.00 during the year 1998-99.

Chapter-6
SUMMARY AND CONCLUSIONS

SUMMARY & CONCLUSIONS 6

In order to fulfill the objectives of the study entitled **Assessment of different land uses and their productivity status in Parmar University, Nauni"** research was carried out at Nauni main Campus during the year 2001-02. The results of the investigation have been summarized as under :

6.1 Land use types

The total area of Dr. Y. S Parmar University of Horticulture and Forestry, main Campus, Nauni comprised of 538.04 ha which was 0.1 ha less than reported by Singh *et al.* (1980) and classified into five land use types viz. forest, horticulture, cultivated land, miscellaneous and grassland. The maximum area was under miscellaneous land use followed by forest, horticulture, cultivated land and grassland. Out of the total area only 19.37 per cent was under intensive cultivation (horticulture and cultivated land use). Besides forest, rest still needs to be brought under better use excluding the main infrastructure needed for the institution to run.

A review of floristic composition revealed that forest land use had 31 tree species, 27 shrubs and 16 herbs. Horticulture land use had 3 tree, 5 shrub and 12 herbaceous species in addition to fruit trees whereas, in cultivated land use 9, 6 and 14 tree, shrub, herb species were found. In miscellaneous land use maximum 37 tree, 23 shrub and 19

herb species were recorded. Grasslands had sparse growth of shrubs (5 species) which could not be encountered in sampling, and among herbaceous growth 7 species were recorded. In all the land uses common species were : *Pistacia integerrima and Toona cilitata* among trees (except grassland); *Berberis lycium and Carissa carandus* in shrubs; and *Themeda anathera, Panicum maximum, Apluda mutica, Urochloa panicoides, Chrysopogon gryllus and Cymbopogon martini* in grasses apart from forbs which were prevalent in all types.

6.2 Phytosociological study

According to phytosociological studies among trees *Acacia catechu* was having maximum average density of trees (124.66) per 0.1ha followed by *Eucalyptus* spp., *Pinus roxburghii* and *Populus* spp. in decreasing order. However, minimum density among trees per 0.1ha was of *Ficus palmata*.

Regarding the dominance of different tree species in individual forest, on overall basis, maximum IVI value of *Morus alba and Robinia pseudoacacia* was recorded. Under *Pinus roxburghii* trees, the shrub species *Berberis lycium, Leptodermis laneolatus* and *Myrsine africana* were dominant, whereas, in *Eucalyptus spp* and *Populus spp.*, *Elaegnus umbellate* was most dominant. Among different landuses, dominant shrub species were : *Carissa carandus, Berberis lycium, Woodfordia fruticosa and Prinsepia utilis*. Among herbs, *Chrysopogon montanus, Heteropogon contortus, Themeda anathera, Apluda mutica* and *Chrysopogon gryllus* were the dominant and commonly occurring species. Understorey shrub and herb association in different types of forests varied according to main tree crop. In horticulture land use, the presence of shrubs was not observed, however, presence of *Apluda mutica, Themeda anathera* and forbs under pear, mixed fruit trees and olive trees were common. In cultivated landuse, the presence of

Themeda anathera was peculiar. Maximum similarity in vegetation was observed between forest and miscellaneous land use, whereas, minimum in grassland and miscellaneous landuse.

6.3 Biomass production

The biomass studies were conducted on 40 tree and 26 shrub species, whereas, for herb biomass, estimation was done on the basis of land use type only. Maximum aboveground total biomass was obtained as 3502.24 q/ha in *Populus* sp., whereas, minimum (9.22 q/ha) in *Punica nana*. On the basis of contribution of stem biomass to total biomass, maximum stem portion was in *Grewia optiva* and least in *Cedrus deodara*. Maximum exploitable biomass content was obtained in *Eucalyptus* spp. In shrubs, *Berberis lycium* recorded maximum total biomass (6445.76 kg/ha), whereas, minimum was obtained in *Hypericum cernuum*. On the percentage basis, maximum (83.19%) contribution of branch biomass to total biomass was of *Rubus ellipticus*, whereas, minimum contribution of branch biomass (41.59%) was recorded in *Murraya koenigii*. The herbaceous biomass was recorded maximum (4805.99 kg/ha) in grassland and minimum (3772.43 kg/ha) in cultivated landuse.

6.4 Soil profile status and drainage pattern

All soil profile horizons were characterized by common hue. The dark matrix colour was observed in all horizons of forest followed by horticulture landuse indicating the higher presence of organic matter in the soils..All land uses except horticulture and miscellaneous land use, A and C horizons were observed indicative of their initial stage of development. The drainage was found to be fern shaped for individual rivulet and fan shaped when overviewed for whole University area.

6.5 Economic production of different land uses

The economic data was recorded under 9 main units for three financial years. It was observed that maximum contribution to university exchequer was made by Department of Silviculture and Agroforestry through its income from Dairy Section from the sale of milk and milk products as well as auction of livestock. However, in horticulture maximum contribution was from sale of horticulture nursery plants.

CONCLUSIONS

- Amongst the five land uses, it was recorded that 60.04 per cent of total area of university campus comes under miscellaneous landuse. Forest covered 20.46 per cent, horticulture 10.54 per cent, cultivated land 8.83 per cent and grassland 0.13 per cent area.

- Various tree species encountered in the campus exhibited exploitable diameter and thus can be harvested for economic gains.

- Estimated grassland productivity was 3.7 to 4.8 tons/ha which can be enhanced by proper management viz. fertilization and weed control.

- Overall soil productivity status was good. Soil was fairly fertile and the whole area had good drainage system. Thus, area under miscellaneous landuse can be considered for improvement by adopting alternative landuse for sustainable productivity and economic gains.

- The perennial rivulets were evenly distributed over the entire university area and measured 12.93 km and shows good potential as irrigation source if managed properly.

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APPENDICES

TREE COMPONENT BIOMASS (PERCENTAGE)

Species	Stem Biomass	Branch + Twig biomass
Acacia mollissima	70.05	29.95
Acrocarpus fraxinifolius	65.98	34.02
Grewia optiva	96.05	3.95
Cupressus torulosa	79.67	20.33
Ulmus villosa	83.59	16.41
Ficus palmata	85.67	14.33
Punica nana	79.54	20.46
Morus alba	86.44	13.56
Toona ciliata	84.66	15.34
Acer oblongum	86.44	13.56
Robinia pseudoacacia	58.93	41.07
Quercus leucotricophora	77.19	22.81
Pistacia integerrima	86.72	13.68
Sapium sebiferum	71.48	28.52
Bauhinia variegata	93.74	6.26
Melia azedarach	92.10	7.90
Grevillea robusta	82.73	17.27
Jacaranda mimosaepholia	90.73	9.27
Celtis australis	84.68	15.32
Albizia lebbek	78.45	21.55
Pyrus pashia	71.06	28.94
Aesculus indica	80.12	19.88
Salix alba	82.54	17.46
Alnus nitida	84.90	15.10
Cedrus deodara	50.21	49.79
Citrus jhambhiri	67.28	32.72
Mallotus philippinensis	76.83	23.17
Litsea chinensis	78.20	21.80
Callistemon lanceolatus	82.86	17.14
Oogenia oojeinensis	84.67	15.33
Butea monosperma	70.87	29.13
Prunus pudum	82.87	17.13
Quercus glauca	84.89	15.11
Myrica esculenta	83.42	16.58
Albizia chinensis	80.00	20.00
Populus spp.	89.36	10.64
Acacia catechu	83.10	16.90
Dalbergia sissoo	69.35	30.65
Eucalyptus spp.	86.14	13.86
Pinus roxburghii	82.25	17.75

SHRUB COMPONENT BIOMASS (PERCENTAGE)

Species	Leaves + Twig	Branch
Prinsepia utilis	40.48	59.52
Berberis lycium	40.32	59.68
Coriaria nepalensis	37.12	62.88
Carissa carandus	41.37	58.63
Woodfordia fruticosa	48.37	57.63
Osyris arborea	39.32	60.67
Mimosa himalayana	49.03	50.97
Rhamnus triquetra	43.93	56.87
Rubus elipticus	16.81	83.19
Justacea adhatoda	29.25	70.75
Debregeasia hypoleuca	48.74	51.26
Murraya koenigii	58.41	41.59
Meriandra strobilifera	21.47	78.53
Hypericum cernuum	38.34	61.66
Verbaena bonariensis	49.64	50.36
Elaegnus umbellata	46.78	53.22
Indigofera pulchella	20.00	80.00
Xanthoxylum alatum	34.66	65.34
Myrsine Africana	40.83	59.17
Lantana camara	40.00	60.00
Zizyphus oxyphylla	43.49	56.51
Rhus virgata	41.99	58.09
Rhus cotinus	25.87	74.13
Artemesia variegata	49.55	50.45
Rhus parviflora	18.19	81.81
Zizyphus numularia	27.49	72.51

APPENDIX-III

HERB COMPONENT BIOMASS (PERCENTAGE)

Land use type	Belowground (BG)	Aboveground (AG)
Forest	16.64	83.36
Grassland	17.69	82.31
Horticulture	22.64	77.36
Cultivated land	17.82	82.18
Miscellaneous	18.94	81.06

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ABSTRACT

Present investigations entitled "Assessment of land uses and their productivity status in Parmar University,Nauni" were carried out with the aim to study the land use types of Nauni University Campus with detailed investigation on phytosociology, biomass and soil characteristics of the areas under different land uses. The area was classified into five land use types viz. forest, horticulture, cultivated land, miscellaneous and grassland. The maximum area was recorded under miscellaneous land use which was followed by forest. Only 19.37 per cent area was recorded under intensive cultivation. Among the trees *Acacia catechu* had maximum average density whereas, *Ficus palmata* had minimum density. Among the different land uses, shrub species viz. *Carissa carandus, Berberis lysium, Woodfordia fruticosa* and *Prinsepia utilis* were dominant, whereas, among herbs *Chrysopogon montanus, Heteropogon contortus, Themeda anathera, Apluda mutica* and *Chrysopogon gryllus* were dominant. Maximum aboveground biomass was observed in *Populus* sp. (3502.24 q/ha) and minimum (9.22 q/ha) in *Punica nana*. Among the srubs, *Berberis lycium* recorded maximum biomass whereas, minimum was observed in *Hypericum cernuum*. Herbaceous biomass was recorded maximum in grasslands and minimum in cultivated land use. All soil profiles were characterized by common hue. In all land uses except horticulture and miscellaneous land uses, A and C horizons were observed indicative of their initial stage of development. The overall drainage was found to be good with perennial rivulets distributed over the entire University area.

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