

**FLORAL SPECTRUM AND PRODUCTIVITY OF
DIFFERENT LAND USES IN LEH REGION OF
HIMALAYAN COLD DESERT**

Thesis

by

**JIGMET NAMGIAL
(F-2016-16-M)**

submitted to



**Dr YASHWANT SINGH PARMAR UNIVERSITY
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SOLAN (NAUNI) HP -173 230 INDIA**

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CERTIFICATE – I

This is to certify that the thesis entitled **“Floral spectrum and productivity of different land uses in Leh region of Himalayan cold desert”** submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE (FORESTRY) AGROFORESTRY** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) is a record of bonafide research work carried out by **Mr. Jigmet Namgial (F-2016-16-M)** son of Sh. Tsering Dorje under my guidance and no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations have been fully acknowledged.

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CERTIFICATE - II

This is to certify that the thesis entitled, "Floral spectrum and productivity of different land uses in Leh region of Himalayan cold desert" submitted by Mr. Jigmet Namgial (F-2016-16-M) son of Sh. Tsering Dorje to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) India in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (FORESTRY) AGROFORESTRY** has been approved by the Advisory Committee after an oral examination of the same in collaboration with the external examiner.


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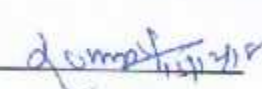
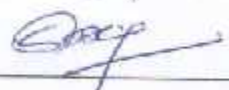
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Place: Nauni
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ABBREVIATIONS USED

%	:	per cent
°C	:	Degrees Celsius
A	:	Agriculture
AFS	:	Agroforestry systems
AH	:	Agrihorticulture
AHS	:	Agrihortisilviculture
Amsl	:	Above mean sea level
AS	:	Agrisilviculture
BD	:	Bulk density
BEF	:	Biomass expansion factor
Ca	:	Calcium
cm	:	centimeter
CD	:	Critical difference
CV	:	Coefficient of Variation
DBH	:	Diameter breast height
EC	:	Electrical conductivity
<i>et al.</i>	:	Etalia (coworkers)
g	:	gram
GIS	:	Geographical Information System
H	:	Horticulture
ha	:	Hectare
ha ⁻¹	:	Per hectare
HP	:	Himachal Pradesh
HSP	:	Hortisilvipasture
i.e.	:	That is
K	:	Potassium
m	:	meter
Mg	:	Magnesium
N	:	Nitrogen

NS	:	Non significant
OC	:	Organic carbon
OM	:	Organic matter
P	:	Phosphorus
pH	:	Puissance d'hydrogen
ppm	:	parts per million
q	:	quintal
RBD	:	Randomized block design
SP	:	Silvipasture
sq. km	:	Square Kilometer
t	:	tonnes
t ha ⁻¹	:	tonnes per hectare
UV	:	Ultra Violet
viz.	:	<i>Videlicet</i> (namely)

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Chapter-1

INTRODUCTION

Land is the most important natural resource which embodies soil, water and associated flora and fauna involving total ecosystem. The term 'land use' refers to the human activity or economic function associated with a specific piece of land whereas the 'land cover' relates to the type of feature present on the surface of the earth. The land use/land cover is the result of permanent adjustment between the constraining properties of land and the socio-economic attributes whereas the land utilization type defines the technical details about cultivation/form details.

The knowledge of land use and land cover is important for many planning and management activities as it is considered as an essential element for modeling and understanding the earth feature system. Land use inventories are assessed for its importance in various sectors like agricultural planning, settlement and cadastral surveys, environmental studies and operational planning based on agro-climatic zones. Information on land use or land cover allows a better understanding of the land utilization aspects like cropping patterns, fallow lands, forests, pasture lands, wastelands and surface water-bodies which are vital for development planning (Lillesand and Kiefer, 2000).

The Himalaya is a vast mountain system covering partly/fully 8 countries i.e. Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan. It consists of various kinds of land uses, like forest (Government forest, Village forest, and Municipal forest), cultivated and fallow land, non-cultivable land and alpine pastures (Anonymous, 1982).

North western Himalaya is basically an agro-ecosystem, where 90 per cent of its total population lives in villages whose economy is dependent on agriculture, horticulture and animal husbandry (Atul and Khosla, 1994). Various fodder, fuelwood and timber trees are deliberately retained on bunds of agriculture fields. The species composition varies depending on land holdings and basic requirement of the farmers (Toky *et al.*, 1989).

There is limited scope for mechanized farming and industrialization in Himalayan region due to rugged topography and very steep slopes (Anonymous, 2001).

In India, cold desert comes under the trans Himalayan zone which is approximately 1,03,11,300 hectares of area (Gupta and Arora, 2016). These arid areas are not benefited by the south east monsoon because they lie in the rain shadow area of the Himalayan mountain system. A cold desert ecosystem refers to an area where the climate has characteristics of great extremes of being hot and cold combined with excessive dryness. Temperature in these tracts normally ranges from -45°C during winters to +35°C in summers. In addition, scanty rainfall, massive snowfall, high wind velocity, sparse vegetation, high UV radiation, and extremely xeric conditions are the common features of this region (Devi and Thakur, 2011).

The soil of cold desert is generally grey and light, characterized by low fertility status coupled with poor water retention capacity and scanty plant cover. In absence of any substantial leaching of minerals from the soil, the bases are continuously added to the soil complex, thereby rendering the pH values on alkaline side (Tundup *et al.*, 2018). However, due to huge variations in the geology of the region, the nature and composition of the soil varies. Summers (June to September) the major growth period for the plants, is quite short and because of this plants require more time to establish themselves in such harsh areas (Tiwari and Kapoor, 2013).

Ladakh in Jammu and Kashmir and Lahaul and Spiti in Himachal Pradesh form the cold desert. In India, major part of cold desert in the country is confined to Ladakh with approximately 82,665 sq. Km area. 37,555 sq. Km of this area is under the illegal occupation of Pakistan and China (Butola *et al.*, 2012). Hence area with India is 45,110 sq. Km, representing 87.40 per cent of total cold arid region.

The Ladakh region consists of 2 districts, namely Leh and Kargil. This region is enclosed by the Ladakh and Karakoram range in the north and Zaskar mountains and the Great Himalaya in the south. Land based economy of this region consists of agriculture and allied sectors. The Himalaya is ecologically fragile and subsistence agriculture is the backbone of local livelihoods. Agroforestry in this region has a potential to provide options for improvement in livelihood through simultaneous production of food, fodder and firewood. Agroforestry is one of the important terrestrial

carbon sequestration system that helps in mitigation of the impact of climate change (Tiwari, 2000).

However, in recent years, the significance of the land based economy has reduced greatly in this region because of increasing shift in employment avenues other than land based occupations. There is very less information on the importance of land uses, their productivity, type of soil and carbon storage for this region. It is very important to carry out diagnosis and descriptive research prior to long-term experimental programmes in order to improve the efficiency of indigenous land use systems, as well as to assess the performance of improved technologies that ultimately will improve the sustenance of land based economy and play a pivot role in the era of global warming and climate change in the cold desert of India.

Therefore, the present study entitled "**Floral spectrum and productivity of different land uses in Leh region of Himalayan cold desert**" was undertaken with following objectives:

1. To identify different land uses.
2. To study the floral spectrum of different land uses.
3. To study the productivity and carbon storage of different land uses.
4. To study the nutrient status of soil of different land uses.

Chapter-2

REVIEW OF LITERATURE

In this chapter, relevant information related to the present study entitled "**Floral spectrum and productivity of different land uses in Leh region of Himalayan cold desert**" has been reviewed under the following headings:

- 2.1 Identification of different land use system
- 2.2 Floristic composition
- 2.3 Biomass and carbon stock
- 2.4 Soil nutrient status

2.1 IDENTIFICATION OF DIFFERENT LAND USE SYSTEM

Bhati and Gopalkrishnan (1978) concluded that in western Himalayan region, diversified farming systems which include cultivated lands, animal husbandry, orchards and forestry should be optimally developed in an appropriately integrated manner depending on land capability. They further suggested that regional development plans should be based on the principles of comparative advantage, agro climatic conditions and ecological considerations.

Ives and Messerli (1989) undertook a study in central and western Himalaya. They found that in crop and livestock mixed settled farming, the local people were dependent on forest to provide fodder to the livestock and the forest leaf litter mixed with livestock excreta was used as manure.

Mazumdar (1991) identified five farming systems at Nauni (H.P.) viz. agricultural system, hortiagriculture, hortisilvipastoral, grassland and wasteland. He found that out of these five systems, agrihorticulture system was the dominating farming system in the study area.

Aminu *et al.*, (1992) identified three distinct farming systems: coffee + banana farming system; maize + beans farming system; and extensive livestock farming system during a study in Mount Kilimanjaro.

Dadhwal *et al.*, (1995) conducted a diagnostic survey for appraisal of existing land use systems and agroforestry practices in north-western plains of Uttar Pradesh. They identified the major farming constraints and suggested some potential agroforestry interventions. They also reported that farmers show greater interest for agrihorticulture followed by agrihortisilviculture system, combined with livestock component for immediate cash returns.

Misri (1995) found that continuous and heavy grazing of pastures has deteriorated forest areas to critical levels in the Himalayan region. He stated that some species of grasses and legumes have vanished and most of the pastures are being replaced with noxious weeds like *Stipa*, *Sambucus*, *Aconitum*, *Cincifuga*, *Adonis*, *Sibbaldia spp.* etc.

Sundriyal *et al.*, (1994) found that about 80 per cent of the population depends on land for their livelihood in Mamlay watershed in south Sikkim. The land use systems include agriculture, agroforestry, horticulture and animal husbandry. Trees were maintained on the farms mainly for leaf fodder and rarely for fuel purposes. The cropping pattern was characterized by cultivation of cereals and cash crops to ensure supply of food grains and economic returns.

Moss (1995) reported that integration of trees into farming systems contribute more towards achieving sustainability and it would increase the scope for addition of trees into agricultural land use system.

Nautiyal *et al.*, (1998) studied different land use and land cover types in the rural landscape of Garhwal Himalaya and reported that simultaneous agroforestry, sequential agroforestry, home garden and community forests accounted for 27.47 per cent, 27.47 per cent, 1.10 per cent and 43.96 per cent of the total geographical area of the village.

Dixon *et al.*, (2001) conducted a study in Rome and reported that diversification through agroforestry in agricultural enterprises is one of the oldest practice adopted by the farmers to reduce the risk and capitalize the opportunities associated with variable climate through better exploitation of potential synergies and complementarities among different farm enterprises. It makes an adjustment to the farm enterprise pattern in order to increase farm income by reducing risk, exploiting new market opportunities and

existing market niches, diversifying not only production, but also on-farm processing and other farm-based income generating activities.

Rao and Pant (2001) quantified the spatial and temporal change patterns of land use in the central Himalaya by interpreting remote sensing (RS) data and use of geographical information system (GIS). The study revealed that the vegetal cover was altered drastically with increasing population pressure, agricultural activities and industrial raw material extraction activities. It showed that although development interventions such as World Bank aided Integrated Watershed Development Programme (IWDP) showed promising results in regenerating the resources, the lack of follow up required after programme withdrawal might cause the deterioration of resources accrued during such regeneration activities.

Srinivas *et al.*, (2001) made an attempt to develop a self sustaining land use system on a small farm under dry land conditions. A micro-watershed (1.66 ha) was selected at the Hayathnagar Research Farm of the Central Research Institute for Dryland Agriculture, Hyderabad. Depending on the land capability and farmer requirements, the watershed was divided and the different areas were allocated to food, fodder, vegetables, fruit, organic nutrient and cash crops. The productivities of different components were recorded over a period of four years from 1992 to 1996. Results indicated that it is possible to operate a self sustaining land use system on small dryland holdings.

Najib and Mahmud (2002) carried out a study in Malaysia to analyse the productive and protective functions of agroforestry systems. They concluded that agroforestry as a traditional land-use practice is capable in maintaining livelihood improvement through synchronized production of multiple products as well as other non-tangible environmental services.

Thapa and Paudel (2002) revealed that the hill farming system features a complementary relationship among crops, trees and livestock. Assorted species of trees and shrubs grown on farms are the integral component of local economies. Besides providing for human needs, crops and trees supply food, fodder and bedding materials (litter) to livestock. Animals contribute to the system by providing manure to crops and trees. The system is sustained through the recycling of organic matter within the farm as well as through the utilization of forest products.

Semwal *et al.*, (2004) revealed that during 1963-1993 periods, agricultural land use increased by 30 per cent at the cost of loss of 5 per cent of forest land. About 60 per cent of agricultural expansion occurred in community forest as compare to 35 per cent in protected forest and 5.00 per cent in reserve forest. Agricultural expansion was most conspicuous at higher elevations (1800-2600 m) and on medium slopes (10 - 30°) and changes in land use and management have improved house hold income but at the cost of increase in intensity of biomass removal from forests and loss of forest cover.

Bertomeu (2006) conducted the research on intercropping system in Philippines and suggested that farmers with scarce labour and capital would increase their income by establishing timber-based agroforestry systems on their land. He also suggested that for many small upland farmers in Philippines, integrating widely-spaced tree hedgerows in their farming systems is a feasible option to generate income and other benefits derived from planted trees, while supplying scarce timber to the local wood industry.

Milne (2006) revealed that domestication of forest fruit trees and other species grown in agroforestry systems offer significant opportunities for livelihood improvement through the nutritional and economic security of poor people in tropics.

The findings of Rasul (2009) demonstrated the trade offs and synergies between relatively more environmentally sustainable and harmful land use practices. Land degradation due to inappropriate agricultural activities, as well as environmental and social effects associated with these practices is accelerating in many developing regions of the world. Their study examines different financial incentive mechanisms including payment for environmental services and makes policy recommendations.

Rivest *et al.*, (2009) found that tree based intercropping is considered to be a potentially useful land use system for mitigating negative environmental impacts such as nutrient leaching and green house gas emission from intensive agriculture management practices.

Dey and Dutta (2010) focussed their study on the cultivation of medicinal plants in agroforestry systems for augmenting livelihood conditions and managing rural health needs to preserve floral diversity. With growing demands of medicinal plants day by day in the Indian system of medicines, majority of medicinal plant species are being

collected widely from forest and natural habitats leading to rarity, threat, extinction or genetic loss of many important plants. Conservation of medicinal plants through the practice of sustainable farming and understanding the need for more equitable management of natural resources should be given utmost importance.

A study was carried out by Bijalwan (2012) in mid hill areas of district Tehri Garhwal (Uttarakhand) between the elevation of 1000 to 2000 m amsl. The study disclosed that the majority of land uses fall in forest area adjacent to different villages followed by the area under cultivation including traditional agroforestry practices. Such agroforestry systems recorded in the area were: agrisilviculture (AS), agrihortisilviculture (AHS), agrihorticulture (AH), agrisilvipasture (ASP), silvipasture (SP) and hortisilviculture (HS). Out of which the predominant systems were: agrisilviculture, agrihortisilviculture and agrihorticulture.

Butola *et al.*, (2012) studied the livelihood diversification in cold arid desert of Indian Himalaya and found that the land utilization pattern of Leh has only 2.64 per cent of arable area. Of which only 9.66 per cent area was under cultivation.. The lower percentage of arable land is restricted only to flat valleys and in lower slopes where water availability is ensured. In high ridges, the wild plant species depends upon the good amount of snowfall because of acute scarcity of water on the barren mountains.

Lallianthanga and Hmingthanpuii (2013) studied the land use planning for improved land use system in Aizawl district, Mizoram by an integrated approach of land use planning using geospatial techniques. The study incorporated remote sensing and GIS techniques to map land use/cover and to formulate viable land resource management plans to improve land use system which will be more sustainable and productive. The study revealed that the district has a very good potential for agrihorticultural land use system which will increase the productivity of land use systems.

Himshikha (2016) analyzed the existence of agroforestry in Haridwar and found a total of four practices comprising poplar, eucalypt and other tree species along with agricultural and fodder crops. The results show that agroforestry is most suitable and profitable type of land use prevalent in the region with 86.00 per cent adoption rate. It was also found that boundary plantation pattern is widely adopted by the farmers

followed by block and scattered plantation patterns. Major cereal crops grown were wheat, paddy and sugarcane.

Shafiq *et al.*, (2017) studied the present state of land use/cover in Lolab watershed of Kashmir valley in western Himalayan environment from 2002 to 2004. They found that the land cover/use was under tremendous anthropogenic pressure. A total of seven land use categories were delineated during the study. They revealed that forest land use system decreases from 45.31 per cent in 2002 to 44.61 per cent in 2004 i.e. 0.70 per cent decrease while horticulture land use system showed an increase from 8.05 per cent in 2002 to 9.91 per cent in 2004, thus, registering an increase of 1.86 per cent. Agriculture has decreased to 1.04 per cent during the study period.

2.2 FLORISTIC COMPOSITION

Adhikari and Babu (2008) studied the floral diversity of Banganga wetland, Uttarakhand, India. The study was undertaken to assess the status and distribution of flora. The plants were classified based on their habit and their presence was visually observed. A total of 279 plant species were recorded, of which 40 species (hydrophytes) were found in aquatic habitat, 122 species on moist shores and 117 species in upland habitat. They also found that majority of plant species (40) were from Indian oriental region.

Dad and Khan (2010) studied the floristic composition of high-altitude alpine grassland located in Bandipora district of Jammu and Kashmir, India. A total of 88 plant species belonging to 35 families and 70 genera were recorded in the grassland. Five dominant families were Asteraceae (15 spp.), Lamiaceae (8 spp.), Polygonaceae (5 spp.), Boraginaceae (4 spp.) and Rosaceae (3 spp.). The number of species was highest (40) in upper slope sites protected by nomads, while it was lowest (18) in an abandoned site in the flat valley.

Krishnamurthy *et al.*, (2010) studied the vegetation structure and floristic composition of a tropical dry deciduous forest in Bhadra wildlife sanctuary, Karnataka, India. Combretaceae was the most abundant family in the forest with importance value index (IVI) of 68.30 and basal area of 12.93 m²ha⁻¹.

Rawat *et al.*, (2010) studied the diversity, distribution and assessed a vegetation of Jalhlmanal watershed in cold desert of the Lahaul valley, north-western Himalaya,

India. They found that the agroforestry system along the watershed consisted of 30 per cent trees, 35.00 per cent small trees and 35.00 per cent shrubs species. Shrubs contributed the highest density with 59.10 per cent of the total, followed by density of trees (29.50 %) and small trees (11.30 %).

Ahmad *et al.*, (2015) conducted a study to describe and analyze the floristic composition and vegetation types, as well as to determine the effect of recent land uses on the vegetation structure in Omayed Biosphere Reserve, Egypt. They found that the coastal dunes had the highest species richness (α -diversity), followed by cultivated lands. While inland plateau had the lowest; but saline depressions had the highest species turn over (β -diversity). They also concluded that the recent land use (over grazing, wood cutting and construction of summer resorts and irrigation canals for agriculture) led to the emergence of new invasive species, which may severely affect the plant diversity and community structure of this hot spot biodiversity.

Jyotsna and Kumar (2015) studied biodiversity floristic composition and structure of medicinal plants in the eighteen blocks of district Darbhanga Bihar, India. They reported that trees were the most dominant type of life form (46.50 %) followed by lianas (14.80 %), herbs (9.90 %), epiphytes (7.90 %), shrubs (2.90 %) and the others (3.70 %). Fabaceae, Moraceae and Meliaceae were the most diverse families distributed in all the eighteen blocks of Darbhanga.

Mlilo (2015) studied plant species composition and distribution in relation to land use patterns in Serengeti ecosystem in Tanzania. They reported that the variations in plant species composition ranged from 35.69 per cent to 65.92 per cent. There was no significant difference in stem density between protected and unprotected areas of the ecosystem. They also concluded that the decrease of plant species diversity and density in unprotected area is because of habitat degradation associated with exploitation pressure, livestock grazing and other forms of disturbance related with anthropogenic activities.

Neelo *et al.*, (2015) studied the stand structure, diversity and regeneration status of woody species in open and exclosed dry woodland sites around Molapo farming areas of the Okavango Delta, northeastern Botswana. They recorded a total of 47 species, representing 16 families and 24 genera. The most diverse family was Fabaceae followed by Combretaceae and Tiliaceae.

Thakur (2015) studied the floristic composition of tropical dry deciduous forest in Sagar district Madhya Pradesh, India. A total of 82 species belonging to 72 genera and 33 families of angiosperm were recorded during the sampling. Based on species contribution Fabaceae, Asteraceae, Rubiaceae, Combretaceae, Malvaceae, Mimosaceae and Euphorbiaceae were found as dominant families.

2.3 BIOMASS AND CARBON STOCK

Toky *et al.*, (1989) analyzed species composition and biomass productivity patterns of three types of traditional agroforestry systems, namely: agrisilviculture, agrihortisilviculture and agrihortisilvipasture in western Himalaya. They reported that species composition in a system varied depending upon the size of land holding and the basic requirement of the farmers. Agrihortisilviculture system was highly diverse in vegetation, with 13 trees and 5 agricultural crops mixed together and gave highest productivity ($25.8 \text{ t ha}^{-1} \text{ yr}^{-1}$) and total above ground biomass (48 t ha^{-1}) in agrihortisilvicultural system.

Mazumdar (1991) carried out a research on biomass production pattern in traditional agroforestry systems in western Himalaya. He reported that hortisilvipastoral system gave the highest standing biomass (355.50 q ha^{-1}) compared to horticultural system (301.50 q ha^{-1}) and grassland (63.20 q ha^{-1}). In hortisilvipastoral system, the contribution to annual biomass was figured as 26.00 per cent by fodder trees and 20.70 per cent by timber/fuelwood trees. In grassland system, timber/fuelwood species contributed the maximum share by 51.10 per cent to system productivity.

Dinssa (1994) reported that the growth and yield of soyabean, blackgram, horsegram and cowpea was higher under monoculture as compared to intercropping with *Morus alba*.

Maiti *et al.*, (1993) found that a maximum yield of maize (herbage), rice (grain), sorghum (herbage) and mustard (grain) figuring to 69.10, 19.20, 87.90 and 10.20 q ha^{-1} was achieved under sole cropping as compared to the yield obtained under alley cropping with *Leucaena leucocephala* having values 32.00, 8.60, 19.90 and 4.90 q ha^{-1} .

Sharma *et al.*, (1993) studied the effect of *Acacia tortilis* and *Zizyphus rotundifolia* trees on the productivity of understory grasses viz. *Cenchrus ciliaris* and *Lasiurus sendicus* in arid environment of Rajasthan. They found that dry forage yield of grasses decreased when grown in association with trees. The reduction in yields under *Acacia tortilis* was higher than *Zizyphus rotundifolia*

Hocking *et al.*, (1997) studied the effect of traditionally managed trees on the cereal crop yield in Bangladesh. They found a variable depression of rice and wheat yield levels under different tree species which ranged from 18.00 per cent for light canopied *Acacia catechu* to 40.00 per cent for the dense canopied *Artocarpus heterophyllus* and *Mangifera indica*.

Korwar and Radder (1997) evaluated the biomass of *Leucaena leucocephala* intercropped with sorghum in semi arid region of India. They found that *Leucaena* produced an average 2.47 t ha⁻¹ of pruning biomass and 1.57 t ha⁻¹ of wood annually.

Yadav (1997) evaluated the biomass productivity of *Morus alba* and *Leucaena leucocephala* based silvipastoral systems in H.P. India. He observed that when tree was pollarded at 2.00 m height, *Morus alba* based silvipastoral system contributed 5.03 q ha⁻¹ leaf biomass and 14.03 q ha⁻¹ branch wood biomass. Whereas, in *Leucaena leucocephala* based silvipastoral system, maximum tree leaf biomass was found to be 12.73 q ha⁻¹ and branch wood biomass 58.58 q ha⁻¹ when tree was pollarded at 2.00 m height.

Kushwaha *et al.*, (2000) conducted an experiment in northern alluvial plains of Madhya Pradesh in which they pollarded eight years old multipurpose tree species viz. *Leucaena leucocephala*, *Eucalyptus spp.* and *Moringa oleifera*. After pollarding, blackgram and sorghum were intercropped. They recorded the yield of black gram as 254.20, 225.20 and 241.90 kg ha⁻¹ and sorghum as 29.72, 89.57 and 88.80 q ha⁻¹ under *Leucaena leucocephala*, *Eucalyptus spp.* and *Moringa oleifera*. The yield of black gram and sorghum were 268.30 kg ha⁻¹ and 93.43 kg ha⁻¹ when grown in open conditions.

Verma *et al.*, (2002) conducted a study on tree crop interaction in agrihorticulture system in the mid hills of Himachal Pradesh. They found that the fruit tree crop combinations suppressed growth and yield attributes of wheat. The yield of wheat

in different crop combinations were: grewia + almond + wheat (17.85 q ha^{-1}), morus + almond + wheat (17.10 q ha^{-1}), grewia + wheat (16.26 q ha^{-1}) and morus + wheat (15.61 q ha^{-1}), respectively. They further found that the reduction in wheat yield over sole cropping was 17.90, 21.30, 25.20 and 28.20 per cent.

Kumar (2003) studied different agroforestry systems viz., hortipastoral, silvipastoral, agrihorticulture, agrisilviculture, agrihortisilviculture and natural grassland in mid hills of Himachal Pradesh. They found that different systems had significant variation in their total biomass production potential. The biomass production of hortipastoral, silvipastoral, agrisilviculture, agrihorticulture and agrihortisilviculture were 3.15, 10.31, 3.55, 3.75 and 3.97 times higher over natural grassland. The silvipastoral (59.72 t ha^{-1}) system produced the highest biomass, whereas natural grassland (5.79 t ha^{-1}) produced the lowest.

Evrendik *et al.*, (2006) studied the carbon storage potential in Mediterranean Forest of Turkey. Mean carbon stock in the conifer forest was estimated as $97.80 \pm 79 \text{ Mg C ha}^{-1}$. This consisted $83.02 \pm 67 \text{ mg C ha}^{-1}$ (above ground) and $14.81 \pm 12 \text{ Mg C ha}^{-1}$ (below ground).

Bijalwan *et al.*, (2008) studied the productivity of traditional agrisilviculture system in the six study sites of district Tehri Garhwal. The productivity of different components of agrisilviculture system viz. trees, shrubs, herbs and agriculture crops were studied. The overall productivity in agrisilviculture system was $9039.00 \text{ kg ha}^{-1} \text{ yr}^{-1}$ which was much higher than the sole agriculture productivity ($5792.00 \text{ kg ha}^{-1} \text{ yr}^{-1}$). In this system, the tree productivity varied from $1757 \text{ kg ha}^{-1} \text{ yr}^{-1}$ to $3775 \text{ kg ha}^{-1} \text{ yr}^{-1}$, shrub productivity from $817.00 \text{ kg ha}^{-1} \text{ yr}^{-1}$ to $1163.00 \text{ kg ha}^{-1} \text{ yr}^{-1}$, herb productivity from $1072.00 \text{ kg ha}^{-1} \text{ yr}^{-1}$ to $1454.00 \text{ kg ha}^{-1} \text{ yr}^{-1}$. The agriculture productivity under trees ranged from $3505.00 \text{ kg ha}^{-1} \text{ yr}^{-1}$ to $4594.00 \text{ kg ha}^{-1} \text{ yr}^{-1}$ as compared to $5663.00 \text{ kg ha}^{-1} \text{ yr}^{-1}$ to $6747.00 \text{ kg ha}^{-1} \text{ yr}^{-1}$ as sole agriculture crop. The reduction in biological productivity under agrisilviculture system varied from 30.00 to 37.00 per cent as compared to sole agriculture crop. The annual productivity of grain varied from $1038.00 \text{ kg ha}^{-1} \text{ yr}^{-1}$ to $1328.00 \text{ kg ha}^{-1} \text{ yr}^{-1}$. The average harvest index (HI) which is a parameter to measure the grain productivity varied from 32.91 to 36.10 per cent.

Minj (2008) studied the biomass in pure poplar plantation, agrisilviculture, silvipasture, pure agriculture and pure grassland system. He recorded a maximum

biomass of 237.70 t ha⁻¹ in pure poplar plantation. He further recorded that the rate of biomass production (t ha⁻¹) declined from sub-tropical sub-montane low hills (zone I) to sub-temperate sub-humid mid hills (zone II) of Himachal Pradesh. The mean total biomass production of all the systems in zone I and zone II were (98.14 t ha⁻¹) and (46.99 t ha⁻¹).

Kumar *et al.*, (2009) conducted a survey in Nubra valley (Ladakh) in order to estimate carbon sequestration with special reference to agroforestry. In their study, sequestered organic carbon in willow and poplar plantations in Hundar and Turtuk villages were analyzed for maximum organic carbon pools of 6394 tonnes and 6100 tonnes respectively. They also found that 75,000 tonnes of carbon had been sequestered and stored in the form of living biomass through plant organic carbon by these two agroforestry species i.e. willow and poplar.

Saravanan *et al.*, (2009) studied biomass production under four year old *Casuarina* based black gram agroforestry system in mid hills of Himachal Pradesh. The dry matter production of tree was recorded as 8.32t ha⁻¹ of which 50.00 per cent was contributed by stem, 27.00 per cent by leaf and 23.00 per cent by branch.

Chauhan *et al.*, (2010) estimated the carbon sequestration potential under one to six years old block plantation of poplar in Punjab, India. They reported more enrichment of the soil organic carbon through leaf litter and roots in the surface layer of soil (0-15 cm) under intercropping of wheat with poplar as compared sole wheat crop. The carbon storage potential in agroforestry system was recorded very high in comparison to sole crop and it increased with the age of the plantation and the major contribution came from the timber, roots and leaf litter.

Heinrichs and Schmidt (2010) estimated aboveground biomass and nutrient pools of understory plants in Spruce forests of Norway by non-destructive method. By using the relationship between species cover, biomass and mean shoot length, they found that density and leaf dry matter content (LDMC) was higher under high light conditions as compared to low light.

Rizvi *et al.*, (2011) studied biomass production and carbon stock of poplar based agroforestry system in Yamunanagar and Saharanpur district in north western

India. They found that the contribution of Poplar plantation to carbon storage was 27-32 t ha⁻¹ in boundary plantation, whereas it was 66-83 t ha⁻¹ in agrisilviculture system.

Kanime *et al.*, (2013) conducted a study for assessment of biomass production in different tree based systems of central Himalayan Tarai region. They reported that highest aboveground (9.48 Mg ha⁻¹) and belowground (16.90 Mg ha⁻¹) biomass was recorded in *Dalbergia sissoo* plantation and lowest aboveground (1.23 Mg ha⁻¹) and belowground (0.30 Mg ha⁻¹) biomass was recorded in *Populus deltoides* boundary plantation.

Chauhan *et al.*, (2015) studied the biomass production, carbon sequestration and economics of on-farm poplar plantations in Punjab, India. They found that the total biomass was higher with block plantation (96.31 t ha⁻¹) than boundary plantation (30.14 t ha⁻¹) but per tree biomass was more in boundary plantation than in the block plantation.

Liu *et al.*, (2015) estimated the above ground biomass of alpine shrubs in Heihe river basin, north western China. The results revealed that above ground shrub biomass increased with D²H (D = basal diameter and H = height) for *Salix cupularis* and *Caragana jubata*.

Rajput *et al.*, (2015) studied the carbon dioxide mitigation potential and carbon density of different land use systems along an altitudinal gradient in north-western Himalaya. They estimated the biomass, carbon density and carbon dioxide mitigation potential of different land use systems along an altitudinal gradient in valley ecosystem showing variation in biodiversity because of changing climatic conditions. The results revealed that different land use systems have significant influence on the production of above ground biomass, below ground biomass, carbon density and carbon mitigation potential.

Singh and Singh (2015) estimated the biomass production and carbon stock in silviculture land use system in arid region of Rajasthan. They found that biomass production was higher in silviculture system as compared to respective control plots.

Yadav *et al.*, (2015) revealed that fruit tree based land use system in Indian Himalaya have higher potential for carbon accumulation in above ground biomass.

They concluded that agroforestry system accumulated higher carbon stock than pure agriculture land use system.

Rajput *et al.*, (2016) studied the factors influencing biomass and carbon storage potential of different land use systems along an elevation gradient in Kullu district of Himachal Pradesh, India. The results showed that maximum total biomass, carbon sequestration potential and carbon density was accumulated by forest land use system and followed a decreasing trend in the order as forest > silvipasture > agro-horticulture > horticulture > agriculture.

Gupta *et al.*, (2017) studied the potential of tree component in agroforestry system for carbon sequestration. They revealed that the agroforestry systems which integrated trees with crop and animal have a higher potential to sequester carbon than sole pastures or field crops.

Podong and Permpool (2017) studied the carbon stock of upland agroforestry system in Thailand. They found that the total above ground carbon in upland agroforestry system was 451,260 Kg C ha⁻¹.

Geelani *et al.*, (2018) estimated the total carbon stock of different land use systems viz. wasteland, agriculture (rice + mustard, rice + oats), vegetable (bean-chilli), horticulture (apple alone), agrihorticulture (vegetable + apple), agrisilviculture (rice and mustard + apple), willow plantation, poplar plantation, natural forest (blue pine) and grassland. They found that maximum carbon sequestration potential (2043.20 t ha⁻¹) was exhibited by natural forest (blue pine) which was higher than any other land use system. The lowest carbon sequestration potential (3.22 t ha⁻¹) was demonstrated by grassland.

2.4 SOIL NUTRIENT STATUS

Montagnini and Sancho (1990) determined the influence of trees on soil properties for native species of Atlantic lowlands of Costa Rica. Soil fertility parameters were compared in three types of land use viz. a 2.5 year old plantation, grassland and a 20 year old secondary forest. Soil extractable calcium, magnesium, potassium, phosphorus, iron, manganese, copper, zinc, nitrogen, organic matter and pH were studied in all the land uses. Higher soil nitrogen, calcium, phosphorus and organic

matter were found in the tree plantation than under grassland with values close to those in the secondary forest.

Kater *et al.*, (1992) conducted a study in south Mali and reported more soil organic carbon, magnesium, calcium and potassium in top soil (0-20 cm) zones covered by the trees as compared to soils in the open.

Mathan and Kannan (1997) studied the effect of addition of dry matter and nutrients through leaf litter under apple, pine, pear, eucalypt, coffee, and wattle (Acacia) plantations. In this study, bi-monthly collected leaf litter were analysed for total nitrogen, phosphorus, potassium, calcium and magnesium. The results showed that eucalypt and apple plantations had the highest and the lowest amount of dry matter fall that figured to 3449 kg ha⁻¹ and 2088 kg ha⁻¹, respectively. Similarly, nitrogen addition through leaf litter was also higher (55.18 kg ha⁻¹) for eucalypt and lowest (24.68 kg ha⁻¹) for apple plantation.

Rossi and Villagra (2003) analysed the effect of *Prosopis flexuosa* on soil properties in arid Argentina. The results indicated that this species significantly affected the soil properties. Concentrations of organic matter, nitrogen, potassium and phosphorus were significantly higher under *P. flexuosa* canopies than outside. Electrical conductivity and concentrations of Na⁺, Ca⁺ and Mg⁺⁺ were also higher. They concluded that *P. flexuosa* modified the spatial pattern of plant species in the shrub and herbaceous layers and the chemical conditions of the soil.

Abbasi and Rasool (2005) studied the effects of different land use types on soil quality in the hilly area of Rawalakot Azad Jammu and Kashmir. They selected natural forest land, grassland and arable land. The study revealed that highest clay content was present in forest land whereas, highest sand content was recorded in arable land. Forest land had relatively higher level of organic matter, macro and micro-nutrients. The arable land exhibited lowest nutrient status with poor physical conditions, indicating a degrading effect of arable cultivation practices on the soil.

Dechert *et al.*, (2005) while conducting a study in Central Sulawesi, Indonesia on nutrient cycling in different land use systems reported that nutrient input - output balances are often used as indicators for the sustainability of land use systems. Nutrient balances in natural forest where soil was fertile were found to be negative for nitrogen,

calcium, potassium and magnesium. On less fertile soils, leaching of nitrogen and potassium in natural forest was lower than inputs by precipitation. In agroforestry land use system where coffee + cacao trees were raised showed highest nutrient losses. It was followed by agriculture in which sole maize was grown and then in natural forest stands. Forest conversion into agricultural land resulted in increased nutrient losses. The main output pathway of nitrogen, phosphorus and potassium was through harvesting, whereas main output pathway for calcium and magnesium was through leaching.

Dwivedi *et al.*, (2005) studied the soils of cold arid region of Ladakh and revealed that more than 60 per cent soil samples of the region (Leh and Kargil) showed deficiency in extractable micronutrients (zinc, iron and manganese) and none of the soil samples were deficient in copper. Organic carbon and available potassium in soils of Leh district falls under medium class and available Phosphorus falls under low class.

Lin *et al.*, (2005) conducted a study in north China on nutrient status in forest litter. The annual nutrient return through litter amounted to 51.27 kg m⁻² nitrogen, 2.79 kg m⁻² phosphorus and 29.41 kg m⁻² potassium. Annual nitrogen and phosphorus return were higher in Chinese fir (*Cunninghamia lanceolata*) plantation than any other coniferous forest.

Sundaravalli and Kailash (2005) studied the net primary production and nutrient cycling in the semi arid grazing land of Madurai, Tamil Nadu. The total net production of the grazing land was 1618.30 gm m⁻²yr⁻¹. Of the total net production, approximately 64.00 per cent was attributed by the aboveground and 36.00 per cent by the belowground production. Similarly, maximum concentration of nutrients occurred in the shoot portion as compared to belowground parts. The litter in this land use had the lowest concentration of all the nutrients.

Tripathi and Sharma (2005) found a positive and significant correlation among organic carbon, nitrogen, phosphorus, soil respiration and dehydrogenase activity which reflects increase in soil nutrients with the increase in microbial and other biotic activity in desert Pedoecosystem. An agroforestry system containing trees of *Prosopis Cineraria* was found to be the best pedoecosystem, while *Cuminum cyminum* was found to be best for cultivation as winter crop in desert agroforestry land use system.

Baber *et al.*, (2006) undertook a study in Peshawar, Pakistan to investigate the physico-chemical characteristics of soil under agroforestry system. Soil samples were analyzed for pH, electrical conductivity, organic matter, phosphorus, potassium and micronutrients (zinc, copper, iron and Manganese). The various soil properties such as pH, Electrical conductivity, organic matter, phosphorus and potassium decreased with distance from the tree in the surface soil, whereas in the subsoil, organic matter and phosphorus decreased with distance and pH, electrical conductivity and potassium increased.

Sharma *et al.*, (2006) analyzed the soil of Leh district of cold arid region of Ladakh in relation to its characteristics. They found a significant positive correlation between available phosphorus and potassium with soil pH. The study indicated that available forms of micronutrients like iron, copper and manganese as well as electrical conductivity were non-significant and negatively correlated with soil pH whereas, phosphorus and potassium were positively correlated.

Hua *et al.*, (2007) investigated chemical properties of soil in shrub dominated area of Alxa desert steppe in China. The results showed that soil under the periphery of canopy of the shrubs viz. *Zygophyllum xanthoxylum* and *Ammopiptanthus mongolicus* exhibited significantly higher contents of organic carbon, total nitrogen, total phosphorus and lower soil pH as compared to the soil away from the canopy of shrubs. This study showed that shrubs play a vital role in accumulating soil organic carbon and nutrients as well as maintained the soil fertility.

Somasundaram *et al.*, (2009) studied the micronutrient status of soil under different land use systems in Chambal ravines. They found that content of micronutrients was in the order manganese > iron > zinc > copper. These micronutrients showed positive correlation with organic carbon. Micronutrient content was low in agricultural fields and ravine lands as compared to the other land use. The study also indicated that iron (Fe) and zinc (Zn) deficiencies were the major disorders in marginal agricultural fields along the Chambal ravine systems.

Tobo *et al.*, (2010) compared physical properties of various volcanic soils of northern Costa Rica. They found that despite their predominantly sandy texture, the soils were rich in organic matter and non crystalline material such as allophone. Bulk density was very low for corresponding soil horizons, except in top soil of pasture land

which was more compact. Soil porosity was very high throughout the profile and dominated by macropores and mesopores, again with an exception of the pasture top soil.

Tripathi and Sharma (2010) studied the impacts of different land use systems on soil faunal density, nutrient dynamics and biochemical properties of soil in Indian Thar desert. They concluded that soil under agrisilviculture system showed increasing trend in soil faunal population with improved physical and biological properties as compared to other types of land uses.

Rahman *et al.*, (2012) investigated the soil physical properties viz. moisture content, particle density, organic matter, bulk density and porosity of forest plantation and deforested site in north-eastern Bangladesh. They found that the moisture content was significantly higher ($p \leq 0.05$) in planted site than on deforested site. The forest plantation also had a significant effect on soil binding process as was established by increase in soil particle density and bulk density. Deforested site contained lower mean soil organic matter than that of forest plantation site.

Mandal *et al.*, (2013) studied different land use systems namely sal forest, agroforestry, rainfed cropland and irrigated cropland in north western Himalayan region. The study revealed that soil quality index (SQI) values varied from 337 in sal forest to 257 in rainfed cropland indicating the superiority of forest land use system in terms of maintaining greater SQI than other land use system. They concluded that by reducing the intensive tillage practices and increased use of organic fertilizers replenished the degraded soil quality in the study area.

Gupta and Arora (2016) concluded that most soils of Ladakh region are coarse textured with 57.00-91.00 per cent sand and 1.21-14.82 per cent clay content. They are neutral to moderately alkaline with pH ranging from 7.41-8.91 and are characterised by low available nitrogen content. The available phosphorus and potassium content varied from medium to high whereas, the amount of the micronutrients (copper, iron and magnesium) lied in the normal range.

Kumar and Paliyal (2016) studied the effect of altitude on soil properties in cold arid region of Spiti valley in Himachal Pradesh. They found that nitrogen, phosphorus and potassium decreased with increase in altitude whereas, copper showed decreasing

trend with increase in altitude. There was no effect on Sodium, boron and nickel with change in altitude.

Sarvade *et al.*, (2016) studied the soil carbon storage potential of different land use systems in upstream catchment area of Gobind sagar reservoir, Himachal Pradesh. Forest system recorded lower soil pH (6.76 ± 0.17), electrical conductivity (0.15 ± 0.029), soil bulk density (1.13 g cm^{-3}) and higher organic carbon (1.66-2.42 %) in comparison to other systems. The sites closer to the reservoir showed lower soil bulk density ($p < 0.05$) and higher organic carbon ($p < 0.01$).

Tundup *et al.*, (2016) studied the soil salinity status of cold arid region of Ladakh, India. They concluded that the soil of this region was sodic but not saline and the salt accumulation in the top layer was due to high sunlight intensity and low precipitation.

Kumar *et al.*, (2017) analyzed the soil samples of Spiti valley of Himachal Pradesh for physico-chemical properties and found that the soil of the valley was low in available nitrogen, low to medium in available potassium, medium to high in available phosphorus and high in available calcium and sulphur content.

Sheoran *et al.*, (2017) studied the impact of different land use systems on soil properties such as electrical conductivity, pH and the carbon sequestration potential of soils. Agroforestry provided a unique opportunity to combine the twin objectives of capturing atmospheric CO_2 to ameliorate environment and in improving the soil nutrient status. Soil organic carbon was recorded abundantly in agroforestry systems than other land use systems.

Wani *et al.*, (2017) studied the soil physico-chemical properties across three different elevations in pear growing orchards of district Pulwama, Jammu and Kashmir, India. He found that organic matter, organic carbon and sand percentage increased with increase in altitude. Whereas percentage of silt, clay, cation exchange capacity and pH decreased with increase in altitude.

Tundup *et al.*, (2018) analyzed the soils under different polyhouses in cold arid Ladakh region. They concluded that the soils of the region were rich in inorganic carbon, available nitrogen, phosphorus, potassium and sulphur. However, majority of the soils were deficient in available zinc content.

Chapter 3

MATERIALS AND METHODS

The present study entitled “**Floral spectrum and productivity of different land uses in Leh region of Himalayan cold desert**” was conducted in two blocks of Leh district of Jammu and Kashmir during the years 2017-2018. The details of experimental sites and the methodology/techniques followed during the course of investigation are given below:

- 3.1 Study area**
- 3.2 Selection of study sites**
- 3.3 Treatment details**
- 3.4 Experimental methodology**
- 3.5 Statistical analysis**

3.1 STUDY AREA

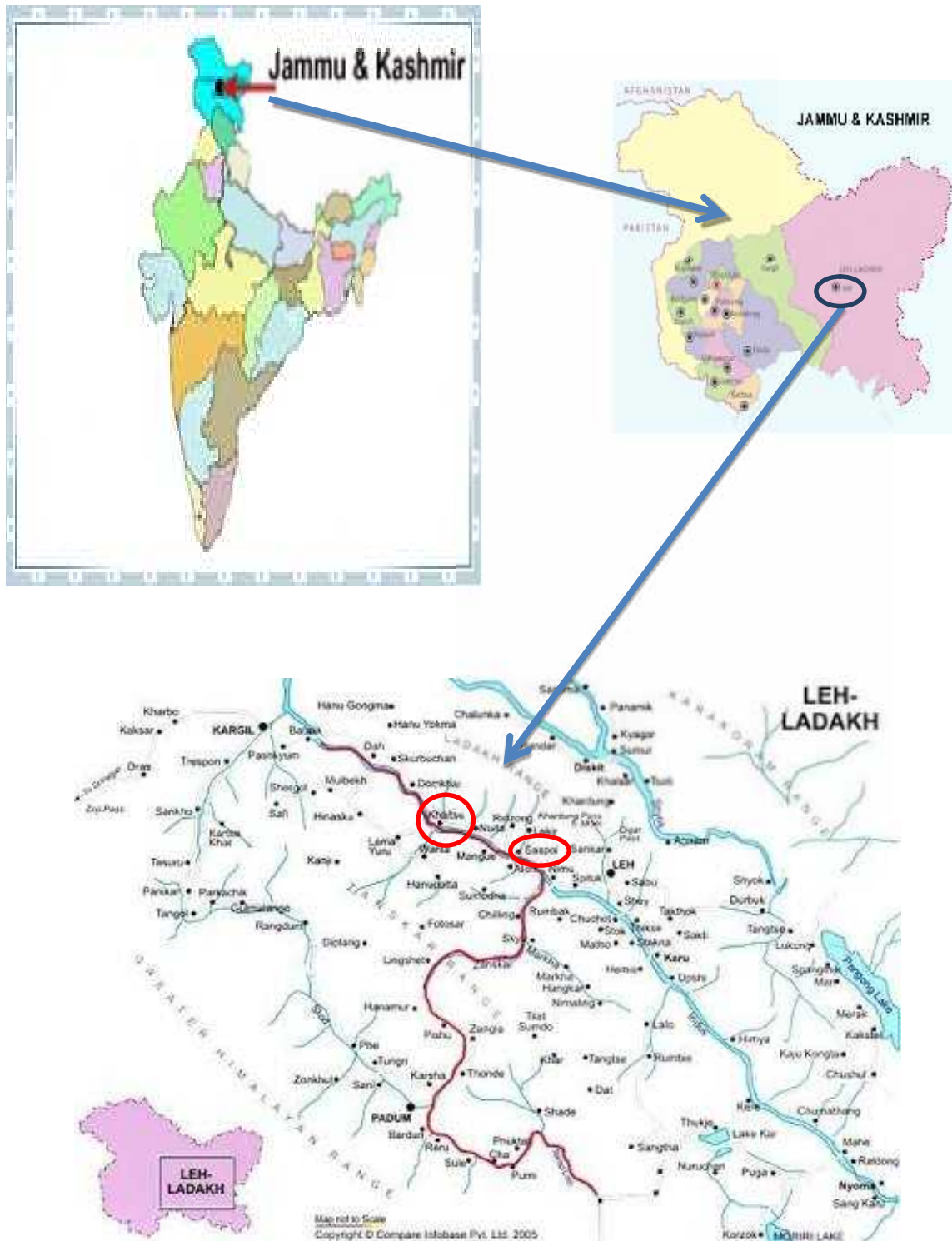
The present study was carried out in two blocks i.e. Khaltsi and Saspol block of Leh district of Jammu and Kashmir. This region is enclosed by the Ladakh and Karakoram range in the north and Zaskar mountains and The Great Himalaya in the south. The average altitude of the region is 3200 m amsl. Precipitation is very low and mainly occurs in the form of snow in the winter months.

Table no. 1: Locality factors of the study area

Latitude	34°10” N
Longitude	77°35” E
Altitude	2900-3500 m
Climate type	Dry temperate
Soil Texture	Coarse and sandy

3.1.1 Location of the study area

Fig. 1 Location map of the study area



3.2 SELECTION OF STUDY SITES

The study sites were selected through multi stage random sampling technique. Leh district consisted of 16 blocks and out of all the blocks, Khaltsi and Saspol block were selected for the study. In the first stage, 2 panchayats viz. Khaltsi and Tingmosgang panchayat from Khaltsi block, Saspol and Gera panchayat from Saspol block were selected. In the second stage, from each panchayat, 2 villages viz. Khaltsi and Skindiyang village from Khaltsi panchayat, Nurla and Tingmosgang village from Tingmosgang panchayat, Saspol and Saspochey village from Saspol panchayat and lastly Gera and Alchi village from Gera panchayat were selected. In the 3rd stage, from each village, 9 households were selected in such a way that three farmers were small, three farmers were medium and three farmers were large according to their land holding. Thus, from each block 36 households were selected and a total of 72 households were selected from both the blocks for the study. The primary data about the study was collected from the household itself.

Table 2: Multi-stage random sampling method for choosing the study sites

Sr. no.	Block	Panchayat	Village	Farmer (9 farmers from each village according to their land holding)
1.	Khaltsi	Khaltsi	I. Khaltsi II. Skindiyang	• Three marginal farmer(<1 hectare) • Three small farmer (1-2 hectare) • Three medium farmer (2-5 hectare)
		Tingmosgang	I. Tingmosgang II. Nurla	• Three marginal farmer(<1 hectare) • Three small farmer (1-2 hectare) • Three medium farmer (2-5 hectare)
2.	Saspol	Saspol	I. Saspol II. Saspochey	• Three marginal farmer(<1 hectare) • Three small farmer (1-2 hectare) • Three medium farmer (2-5 hectare)
		Gera	I. Gera II. Alchi	• Three marginal farmer(<1 hectare) • Three small farmer (1-2 hectare) • Three medium farmer (2-5 hectare)

3.3 TREATMENT DETAILS

Treatments = 7 (no. of land use systems identified)

- T₁ = Agriculture land use system
- T₂ = Horticulture land use system
- T₃ = Agrisilviculture land use system
- T₄ = Agrihortisilviculture land use system
- T₅ = Silvipasture land use system
- T₆ = Hortisilvipasture land use system
- T₇ = Agrihorticulture land use system

Replications = 4 (villages)

Statistical design = RBD

3.4 EXPERIMENTAL METHODOLOGY

3.4.1 Identification of different land uses

The selected farmers were first interviewed regarding the details of the different crops being cultivated by them and were noted down. Fields of the farmers were visited and then based on the principal and associated components, the different land use systems were identified. Agroforestry systems existing in the study area were further classified on the basis of structure (nature and arrangement) and function (role/output) of components as suggested by Nair (1985). Primary and secondary components of each system type were identified after recognizing the structure of the system and specific function of the components.

- **Primary component**

The component, which occupied the larger area of the total unit area and serve the major function i.e. production of primary outputs needed by the farmers.

- **Secondary component**

The component, which occupied relatively lesser area of the total unit area compared to the area under primary component and yielding secondary outputs needed by the farmers.



**Agriculture land use
(wheat)**



**Horticulture land use
(apricot trees)**



**Agrisilviculture land use
(wheat+poplar)**



**Agrihortisilviculture
(wheat+apricot+poplar)**

Plate 1. Different land use systems of Leh region



Agrihorticulture (wheat+apricot)



Silvipasture (poplar+alfalfa)



Hortisilvipasture (apricot+salix+alfalfa)

Plate 2. Different land use systems of Leh region

3.4.2 To study the floral spectrum of different land use systems

The different tree species, grasses and agriculture crops present in the study area were identified with the help of local people, literature and the forest department of Leh Forest Division. The herbarium of the species of trees and grasses were also prepared.

3.4.3 Biomass production

3.4.3.1 Trees

The tree productivity refers to increase in tree biomass per unit area. Measurement of tree diameter and volume was made to estimate the standing biomass. For it, five sample plots of $30 \times 10 \text{ m}^2$ were laid in each land use system. The tree species from different quadrates were recorded in the intercropping system and sole tree system. The detailed volume and biomass estimation of trees was done as follows:

Volume estimation of stem

The diameter of trees was measured for each existing land use systems in each quadrate for computation of standing volume of different tree species. The data was collected for trees from all the quadrates of different land use systems. The different volume equations were used to compute the volume of the different tree species.

Above ground biomass (AGB)

In order to estimate the tree biomass, the volume of individual trees in each sampling quadrate was multiplied with its specific gravity (SG) and thus stem biomass (SB) was derived. Later, the stem biomass was multiplied with the biomass expansion factor (BEF) to derive above ground biomass. BEF is the value to take into account the biomass of the other aboveground components of trees (leaves, twigs and branches).

$$\text{AGB} = \text{SB} \times \text{BEF}$$

Stem volume of different tree species were calculated from the volume equations and specific gravity of respective tree species were taken from literature.

$$\text{SB} = \text{volume} \times \text{specific gravity}$$

Where,

$$\text{SB} = \text{Stem biomass}$$

$$\text{BEF} = \text{Biomass expansion factor}$$

Below ground biomass of trees (BGB)

Below ground biomass of trees was calculated by multiplying above ground biomass (AGB) with root: shoot of tree species (IPCC, 1996).

$$\text{BGB} = \text{AGB} \times \text{Root: Shoot}$$

3.4.3.2 The Herbs

Above ground biomass

A herb is a plant whose stem is tender and height is usually not more than one meter. For estimation of herb biomass, quadrates of 50×50 cm² size were laid out in the different land use systems in the study sites. All the herbs from quadrates were harvested and oven dried at 65±5°C to the constant weight.

3.4.3.3 Agriculture Crops

Above ground biomass

Crop biomass was estimated using 1×1 m² plots. All the crop plants within the border of quadrates were harvested and collected samples were weighed, sub sampled (separated into root and shoot) and oven dried at 65±5°C to a constant weight.

Below ground biomass of herbs and crops

Below ground biomass of crops and grasses (herbage) was determined by removing crops and grasses with roots carefully. Soil was separated by tapping and roots were washed and segregated species wise. Roots of each species were stored in paper bags and then were dried in oven at 65±5°C to a constant weight.

3.4.4 Carbon stock

Biomass of trees, herbage and crops was converted into biomass carbon by multiplying total biomass with a factor of 0.50 (IPCC, 1996).

$$\text{Carbon Stock} = \text{Total biomass} \times 0.50$$

3.4.4 Soil analysis

Collection and preparation of soil samples

Soil samples were collected at 0-30 cm depth from different land use systems identified in the study area. The soil samples were collected separately from all the 8 villages and the samples from the same land use system were then mixed thoroughly and the bulk

was then reduced by using quartering method so that about 500 gram of composite soil sample was retained for each land use system. The Samples were then air dried in shade, grinded and allowed to pass through 2 mm sieve and further was brought to the lab for physico-chemical analysis. The soil parameters analyzed in the laboratory are as follows:-

- **Soil pH**

The pH of soil was estimated in soil-water suspension by taking 20g of soil in a 50 ml beaker and then adding 40ml of distilled water to it. The soil-water suspension was stirred at least four times within a period of half an hour. At this time soil and water attained equilibrium. After half an hour the soil suspension was stirred again and the pH of the soil was measured on a pH meter.

- **Electrical conductivity**

The electrical conductivity in 1:2.5 soil suspensions was measured by Systronic's conductivity meter and expressed as dSm^{-1} .

- **Soil organic carbon**

2 g of soil was weighed and transferred into a 250 ml conical flask. To this 10 ml of 1N $\text{K}_2\text{Cr}_2\text{O}_7$ solution was added and mixed thoroughly. 20ml of concentrated H_2SO_4 was added and was left undisturbed to complete the reaction. Then added approximately 2 g of NaF powder (NaF is the flocculation agent), 100 ml of distilled water and it was shaken vigorously. Then 10 drops of diphenylamine indicator was added to it, which gave a violet colour to the suspension. The contents of the flask with 0.5 N ferrous ammonium sulphate solution were titrated. At end point in this titration, there was a change of the colour from blue violet to bright green. The volume of the ferrous ammonium sulphate solution used was noted and the results were calculated.

- **Bulk density (BD)**

Bulk density determination was done by Pycnometer method for disturbed soils in laboratory and expressed as (g cm^{-3})

$$\text{Bulk density of soil } (\text{g cm}^{-3}) = \frac{w_2 - w_1}{V_t}$$

Weight of empty pycnometer (g) = w_1

Weight of pycnometer + soil (g) = w_2

Weight of soil (g) = $w_2 - w_1$

Volume of soil/volume of water needed to fill the Pycnometer, $\text{cm}^{-3} = V_t$

- **Available N**

Twenty grams of soil was weighed and moistened with distilled water. Then, the weighed soil was added to distillation flask and 100 ml of 0.32 per cent KMnO_4 and 100 ml of 2.5 per cent NaOH were added to the flask and a cork was fitted immediately. 25 ml of 0.02N H_2SO_4 was taken in a conical flask and 2-3 drops of methyl red indicator was added to it. After the setup was complete, hot plate was switched on and 25-30 ml of distillate was collected in the same conical flask containing 0.02N H_2SO_4 . The excess of H_2SO_4 collected in the conical flask was titrated against 0.02N NaOH and change in colour from pink to yellow was noted as end point.

$$\text{Available Nitrogen (\%)} = \frac{(25-A) \times 0.00028 \times 100}{\text{Weight of soil}} \times 100$$

Where,

A = Volume of 0.02N NaOH used

Parts per million (ppm) of available nitrogen in soil = Available nitrogen (%) $\times 10000$

Available Nitrogen (kg ha^{-1}) = ppm $\times 2.24$

- **Available Phosphorus**

0.5 gram of soil was taken in a 100 ml conical flask followed by the addition of a pinch of Darco-G 60 and 20 ml of 0.5N sodium bicarbonate. The contents were shaken for thirty minutes and filtered to obtain clear filtrate. Now, to 2.5 ml of filtrate 5 ml of ammonium molybdate was added and the mixture was shaken thoroughly to remove the CO_2 evolved and 10 ml of distilled water was added to the content. Thereafter, 1 ml of working solution of stannous chloride was added and final volume of 25 ml was made. The contents were mixed thoroughly and the blue colour intensity was measured after five minutes at 660 nm keeping blank appropriately.

Parts per million (ppm) of available phosphorus in soil = A $\times$ total dilution

Where,

Concentration of P read from the standard curve = A

Available Phosphorus (kg ha^{-1}) = ppm $\times 2.24$

- **Available Potassium**

2.5 g of soil was transferred to a 150 ml of conical flask. 25 ml of neutral ammonium acetate solution was added and the contents were shaken for five minutes on electric shaker. The contents of the conical flask were filtered and the filtrate was fed to the atomizer of the flame photometer. The reading was noted and expressed in ppm.

$$\text{Parts per million (ppm) of available potassium in soil} = Y \times \text{Total dilution}$$

Where,

$$Y = \text{ppm as read from the standard curve}$$

$$\text{Available potassium (kg ha}^{-1}\text{)} = \text{ppm} \times 2.24$$

- **Available Magnesium and Calcium**

4g of soil sample was transferred to a 250 ml conical flask. 25 ml of ammonium acetate solution was added and the content was shaken for 5 minutes on electric shaker. The contents of the conical flask were filtered. 2 ml of the extract was then transferred to 50 ml volumetric flask and the final volume was made 50 ml. The reading was noted and expressed in ppm.

Table 3: Soil chemical analysis methods

Chemical Characteristics	Method employed
1. Soil pH	1:2.5 soil: water suspension, with the help of digital pH meter (Jackson,1973)
2. EC (dSm ⁻¹)	1:2.5 soil: water suspension, with the help of digital EC meter (Jackson,1973)
3. Bulk density (g cm ⁻³)	Specific gravity method (Singh,1980)
4. Organic carbon (%)	Walkley and Black method (1934)
5. Available nitrogen (kg ha ⁻¹)	Alkaline potassium permanganate method of Subbiah and Asija (1956)
6. Available phosphorus (kg ha ⁻¹)	(Olsen <i>et al.</i> 1954)
7. Available potassium (kg ha ⁻¹)	Merwin and Peech (1951) Determined on Flame photometer

3.5 STATISTICAL ANALYSIS

The data obtained were subjected to statistical analysis as per the procedure suggested by Gomez and Gomez (1984). Wherever, the effects exhibited significance at 5 per cent level of probability, the critical difference (CD) was calculated. Analysis was carried out on computer using “OPSTAT”.

Chapter-4

RESULTS AND DISCUSSION

The results obtained from the present investigation entitled, “**Floral spectrum and Productivity of different land uses in Leh region of Himalayan cold desert**” are presented in this chapter under the following headings:

4.1 IDENTIFICATION OF DIFFERENT LAND USE SYSTEMS

4.2 FLORISTIC COMPOSITION OF DIFFERENT LAND USE SYSTEMS

4.3 ABOVE GROUND, BELOW GROUND, TOTAL BIOMASS AND CARBON STORAGE OF DIFFERENT LAND USE SYSTEMS

4.4 SOIL NUTRIENT STATUS OF DIFFERENT LAND USE SYSTEMS

4.1 IDENTIFICATION OF DIFFERENT LAND USE SYSTEMS

In the study area, a total of seven land use systems viz., agriculture, horticulture, agrisilviculture, agrihortisilviculture, silvipasture, hortisilvipasture and agrihorticulture were identified in the fields of different farmer’s category. The climatic conditions of the area allow a very short growing period which extends from April to September. Therefore, the farmers of the region harvest single crop a year i.e. Kharif season crops. These systems may be attributed to agro climatic conditions of the area and needs of the farmer i.e. food, fodder, fuelwood and timber.

In Khaltsi block, on the fields of marginal, small and medium categories of farmers, total system units in agriculture land use were 8, 10 and 20; in agrisilviculture land use, total system units were 6, 7 and 11. The system units in agrihortisilviculture land use were 12, 15 and 21 similarly in case of hortisilvipasture land use, total system units were 5, 10 and 14. However horticulture, silvipasture and agrihorticulture land use system was present only in case of small and medium category of farmers with respective system units (3 and 6), (11 and 15) and (9 and 10) (Table 4).

Table 4: System units in different land use systems in Khaltasi block and Saspol block under different farmers' category

Land use Systems	Farmers category in Khaltasi block			Farmers category in Saspol block		
	Marginal	Small	Medium	Marginal	Small	Medium
	Number of system units					
Agriculture	8	10	20	5	7	14
Horticulture	-	3	6	-	-	4
Agrisilviculture	6	7	11	5	6	9
Agrihortisilviculture	12	15	21	8	9	24
Silvipasture	-	11	15	-	8	10
Hortisilvipasture	5	10	14	4	15	11
Agrihorticulture	-	9	10	-	-	8

A perusal of Table 4 further reveals that in Saspol block, on the fields of marginal, small and medium categories of farmers, total system units in agriculture land use were 5, 7 and 14; in agrisilviculture land use, total system units were 5, 6 and 9. The system units in agrihortisilviculture land use were 8, 9 and 24 and in case of hortisilvipasture land use, total system units were 4, 15 and 11. The horticulture and agrihorticulture land use systems were present only in case of medium category of farmers with system units of 4 and 8 whereas, silvipasture land use system was present only in small and medium category of farmer with system units of 8 and 10.

4.1.1 Land use systems and their system units in the study area

(A) Khaltasi block

1) Agriculture land use system

The data presented in Table 5 revealed that in agriculture land use system, cereal crops grown were- Wheat, Foxtail Millet, Buckwheat and Barley; vegetable crops consisted of Cauliflower, Cabbage, Pea, Turnip, Beans, Onion, Tomato and Potato. In this land use system, commonly a single field was cropped in parts by planting various crop combinations - (i) Buckwheat + Foxtail Millet (ii) Pea + Potato + Beans (iii) Wheat + Turnip+ Onion (iv) Cabbage + Cauliflower + Beans + Tomato. Some of the agricultural fields were planted with sole crops of Wheat and Barley.

Table 5: System units and their constituent agriculture crops in agriculture land use system practiced by farmers of Khaltisi block

Sr. no.	Agriculture crops
1	<i>Triticum aestivum</i> (Wheat)
2	<i>Hordeum vulgare</i> (Barley)
3	<i>Fagopyrum esculentum</i> (Buckwheat) + <i>Setaria italica</i> (Foxtail Millet)
4	<i>Pisum sativum</i> (Pea) + <i>Solanum tuberosum</i> (Potato) + <i>Phaseolus vulgaris</i> (Beans)
5	<i>Triticum aestivum</i> (Wheat) + <i>Brassica rapa</i> (Turnip) + <i>Allium sepa</i> (Onion)
6	<i>Brassica oleracea</i> var. <i>botrytis</i> (Cabbage) + <i>Brassica oleracea</i> var. <i>capitata</i> (Cauliflower) + <i>Phaseolus vulgaris</i> (Beans) + <i>Solanum lycopersicon</i> (Tomato)

2) Horticulture land use system

In horticulture land use system, the constituent fruit tree species were Apricot, Apple, Mulberry and Walnut. In this land use system the main fruit tree species was Apricot that was either managed as pure orchard (Table 6) or other fruit tree species- Apple, Mulberry and Walnut were also grown along with it by the farmers.

Table 6: System units and their constituent fruit trees in horticulture land use system practiced by farmers of Khaltisi block

Sr. No.	Fruit trees
1	<i>Prunus armeniaca</i> (Apricot)
2	<i>Prunus armeniaca</i> (Apricot) + <i>Malus domestica</i> (Apple) + <i>Morus alba</i> (Mulberry)
3	<i>Prunus armeniaca</i> (Apricot) + <i>Malus domestica</i> (Apple) + <i>Juglans regia</i> (Walnut)

3) Agrisilviculture land use system

In agrisilviculture land use system, agriculture crops were cereals- Wheat, Buckwheat, Foxtail Millet and Barley; oil seeds- mustard; vegetables- Pea, Turnip, and Potato. It was recorded that in all the system units trees of *Populus nigra* and *Salix alba* were retained by farmers on the bunds of their field. The different combinations of crops are given in the Table 7.

Table 7: System units and their constituent agriculture crops and trees in agrisilviculture land use system practiced by farmers of Khaltsi block

Sr. No.	Agriculture crop	Fodder/Timber/Fuelwood
1	<i>Triticum aestivum</i> (Wheat)	<i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)
2	<i>Triticum vulgare</i> (Barley)	<i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)
3	<i>Fagopyrum esculentum</i> (Buckwheat) + <i>Setaria millet</i> (Foxtail Millet)	<i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)
4	<i>Pisum sativum</i> (Pea) + <i>Solanum tuberosum</i> (Potato)	<i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)
5	<i>Brassica rapa</i> (Turnip) + <i>Brassica juncea</i> (Mustard)	<i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)

4) Agrihortisilviculture land use system

In agrihortisilviculture land use system, the farmers of Khaltsi block farmed six main crops i.e. Wheat, Cabbage, Cauliflower, Turnip, Rajmash and Pea. The tree species of *Populus nigra* and *Salix alba* were retained by farmers on the bunds of their field whereas fruit tree species of Apricot and Apple were planted by the farmers across their agricultural fields. The different combination of agriculture crops with different tree species in agrihortisilviculture land use system is exhibited in Table 8.

Table 8: System units and their constituent agriculture crops and trees in agrihortisilviculture land use system practiced by farmers of Khaltsi block

Sr. no.	Agriculture crop	Fruit/Fodder/Timber/Fuelwood trees
1	<i>Triticum aestivum</i> (Wheat)	<i>Prunus armeniaca</i> (Apricot) + <i>Malus domestica</i> (Apple) + <i>Populus nigra</i> (Poplar)
2	<i>Pisum sativum</i> (Pea) + <i>Brassica rapa</i> (Turnip)	<i>Prunus armeniaca</i> (Apricot) + <i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)
3	<i>Brassica oleracea</i> var. <i>botrytis</i> (Cabbage) + <i>Brassica oleracea</i> var. <i>capitata</i> (Cauliflower) + <i>Pisum sativum</i> (Pea)	<i>Prunus armeniaca</i> (Apricot) + <i>Populus nigra</i> (Poplar)
4	<i>Brassica rapa</i> (Turnip) + <i>Phaseolus vulgaris</i> (Rajmash)	<i>Prunus armeniaca</i> (Apricot) + <i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)

5) Silvipasture land use system

The tree components in this system were: *Populus nigra* and *Salix alba*. The pasture components consisted of *Medicago sativa*, *Medicago falcata* and *Iris lactea*. The different combinations of trees and pasture crops are presented in Table 9.

Table 9: System units and their constituent trees and grasses in silvipasture land use system practiced by farmers of Khaltsi block

Sr. No.	Fodder/Timber/Fuelwood trees	Grasses
1	<i>Populus nigra</i> (Poplar)	<i>Medicago sativa</i> (Alfalfa) + <i>Medicago falcata</i> (Alfalfa) + <i>Iris lactea</i> (Iris)
2	<i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)	<i>Medicago sativa</i> (Alfalfa) + <i>Medicago falcata</i> (Alfalfa)
3	<i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)	<i>Medicago sativa</i> (Alfalfa)

6) Hortisilvipasture land use system

The different tree species in hortisilvipasture land use system were *Prunus armeniaca*, *Malus domestica*, *Populus nigra* and *Salix alba*, whereas, *Medicago sativa*, *Medicago falcata* and *Iris lactea* constituted the pasture component. The various combinations of trees and pasture crops are given in Table 10.

Table 10: System units and their constituent trees and grasses in hortisilvipasture land use system practiced by farmers of Khaltsi block

Sr. No.	Fruit/Fodder/Timber/Fuelwood trees	Grasses
1	<i>Malus domestica</i> (Apple) + <i>Populus nigra</i> (Poplar)	<i>Medicago sativa</i> (Alfalfa) + <i>Medicago falcata</i> (Alfalfa)
2	<i>Prunus armeniaca</i> (Apricot) + <i>Malus domestica</i> (Apple) + <i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)	<i>Medicago sativa</i> (Alfalfa) + <i>Iris lactea</i> (Iris)
3	<i>Prunus armeniaca</i> (Apricot) + <i>Juglans regia</i> (Walnut) + <i>Salix alba</i> (Willow)	<i>Medicago sativa</i> (Alfalfa)
4	<i>Prunus armeniaca</i> (Apricot) + <i>Salix alba</i> (Willow) + <i>Morus alba</i> (Mulberry)	<i>Medicago falcata</i> (Alfalfa) + <i>Iris lactea</i> (Iris)

7) Agrihorticulture land use system

In agrihorticulture land use system, the farmers mainly raised six agriculture crops viz. Wheat, Potato, Pea, Beans, Turnip and Tomato. The tree component comprised of Apricot and Apple. The various combinations of agriculture crops and fruit trees are given in Table 11.

Table 11: System units and their constituent agriculture crops and trees in agrihorticulture land use system practiced by farmers of Khaltsi block

Sr. No.	Agriculture crop	Fruit trees
1	<i>Triticum aestivum</i> (Wheat)	<i>Prunus armeniaca</i> (Apricot) + <i>Malus domestica</i> (Apple)
2	<i>Solanum tuberosum</i> (Potato) + <i>Pisum sativum</i> (Pea) + <i>Phaseolus vulgaris</i> (Beans)	<i>Prunus armeniaca</i> (Apricot) + <i>Malus domestica</i> (Apple)
3	<i>Brassica rapa</i> (Turnip) + <i>Solanum lycopersicon</i> (Tomato)	<i>Prunus armeniaca</i> (Apricot)

(B) Saspol block

1) Agriculture land use system

The data presented in the Table 12 revealed that in agriculture land use system, cereals crops grown were- Wheat, and Barley; oil seed and pulses- Mustard and Rajmash; vegetable crops consisted of Cauliflower, Cabbage, Pea, Turnip, Beans, Onion, Tomato and Potato. In this land use system commonly a single field was cropped in parts by planting various crop combinations (i) Pea + Potato + Tomato + Beans (ii) Wheat + Turnip+ Cabbage (iii) Mustard + Cauliflower + Beans + Rajmash. Some of the agricultural fields were planted with sole crops of Wheat and Barley.

Table 12: System units and their constituent agriculture crops in agriculture land use system practiced by farmers of Saspol block

Sr. No.	Agriculture crops
1	<i>Triticum aestivum</i> (Wheat)
2	<i>Hordeum vulgare</i> (Barley)
3	<i>Solanum tuberosum</i> (Potato) + <i>Pisum sativum</i> (Pea) + <i>Phaseolus vulgaris</i> (Beans) + <i>Solanum lycopersicon</i> (Tomato) + <i>Allium sepa</i> (Onion)
4	<i>Triticum aestivum</i> (Wheat) + <i>Brassica rapa</i> (Turnip) + <i>Brassica oleracea</i> var. <i>botrytis</i> (Cabbage)
5	<i>Phaseolus vulgaris</i> (Beans) + <i>Brassica oleracea</i> var. <i>capitata</i> (Cauliflower) + <i>Brassica juncea</i> (Mustard) + <i>Phaseolus vulgaris</i> (Rajmash)

2) Horticulture land use system

In horticulture land use system, the constituent fruit tree species were Apricot, Apple, Mulberry and Walnut. In this land use system the main fruit tree species was Apricot that was either managed as pure orchard (Table 13) or other fruit tree species – Apple and Walnut were also grown along with it by the farmers.

Table 13: System units and their constituent fruit trees in horticulture land use system practiced by farmers of Saspol block

Sr. No.	Fruit trees
1	<i>Prunus armeniaca</i> (Apricot)
2	<i>Prunus armeniaca</i> (Apricot) + <i>Malus domestica</i> (Apple)
3	<i>Prunus armeniaca</i> (Apricot) + <i>Malus domestica</i> (Apple) + <i>Juglans regia</i> (Walnut)

3) Agrisilviculture land use system

In agrisilviculture land use system, agriculture crops were cereals- Wheat and Barley; oil seed- Mustard; vegetables- Pea, Turnip, Beans, and Potato. It was recorded that in all the system units trees of *Populus nigra* and *Salix alba* were retained by farmers on the bunds of their field. The different combinations of the crops are given in Table 14.

Table 14: System units and their constituent agriculture crops and trees in agrisilviculture land use system practiced by farmers of Saspol block

Sr. No.	Agriculture crop	Fodder/Timber/Fuelwood
1	<i>Triticum aestivum</i> (Wheat)	<i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)
2	<i>Brassica rapa</i> (Turnip) + <i>Brassica juncea</i> (Mustard)	<i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)
3	<i>Triticum aestivum</i> (Wheat) + <i>Brassica rapa</i> (Turnip)	<i>Populus nigra</i> (Poplar)
4	<i>Pisum sativum</i> (Pea) + <i>Solanum tuberosum</i> (Potato) + <i>Phaseolus vulgaris</i> (Beans)	<i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)
5	<i>Triticum vulgare</i> (Barley)	<i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)

4) Agrihortisilviculture land use system

In agrihortisilviculture land use system, the farmers of Saspol block mainly farmed six main crops i.e. Wheat, Barley, Turnip, Potato, Beans and Pea. The tree species of *Populus nigra* and *Salix alba* were retained by farmers on the bunds of their field whereas tree species of Apricot, Apple and Mulberry were planted by the farmers across their agricultural fields. The different combination of agriculture crops with different tree species in agrihortisilviculture land use system is exhibited in Table 15.

Table 15: System units and their constituent agriculture crops and trees in agrihortisilviculture land use system practiced by farmers of Saspol block

Sr. No.	Agriculture crop	Fruit/Fodder/Timber/Fuelwood trees
1	<i>Triticum aestivum</i> (Wheat)	<i>Malus domestica</i> (Apple) + <i>Prunus armeniaca</i> (Apricot) + <i>Populus nigra</i> (Poplar)
2	<i>Triticum vulgare</i> (Barley)	<i>Prunus armeniaca</i> (Apricot) + <i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)
3	<i>Solanum tuberosum</i> (Potato) + <i>Pisum sativum</i> (Pea)	<i>Prunus armeniaca</i> (Apricot) + <i>Morus alba</i> (Mulberry) + <i>Populus nigra</i> (Poplar)
4	<i>Brassica rapa</i> (Turnip) + <i>Phaseolus vulgaris</i> (Beans)	<i>Prunus armeniaca</i> (Apricot) + <i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)

5) Silvipasture land use system

The tree components in this system were: *Populus nigra* and *Salix alba*. The pasture components consisted of *Medicago sativa*, *Medicago falcata* and *Iris lactea*. The different combinations of trees and pasture crops are presented in Table 16.

Table 16: System units and their constituent trees and grasses in silvipasture land use system practiced by farmers of Saspol block

Sr. No.	Fodder/Timber/Fuelwood trees	Grasses
1	<i>Populus nigra</i> (Poplar)	<i>Medicago sativa</i> (Alfalfa) + <i>Medicago falcata</i> (Alfalfa) + <i>Iris lactea</i> (Iris)
2	<i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)	<i>Medicago sativa</i> (Alfalfa) + <i>Medicago falcata</i> (Alfalfa)
3	<i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)	<i>Medicago sativa</i> (Alfalfa)

6) Hortisilvipasture land use system

The different tree species in hortisilvipasture land use system were *Prunus armeniaca*, *Malus domestica*, *Juglans regia*, *Populus nigra* and *Salix alba*, whereas, *Medicago sativa*, *Medicago falcata* and *Iris lactea* constituted the pasture component. The various combinations of trees and pasture crops are given in Table 17.

Table 17: System units and their constituent trees and grasses in hortisilvipasture land use system practiced by farmers of Saspol block

Sr. No.	Fodder/Timber/Fuelwood trees	Grasses
1	<i>Malus domestica</i> (Apple) + <i>Populus nigra</i> (Poplar)	<i>Medicago sativa</i> (Alfalfa) + <i>Medicago falcata</i> (Alfalfa)
2	<i>Prunus armeniaca</i> (Apricot) + <i>Malus domestica</i> (Apple) + <i>Populus nigra</i> (Poplar) + <i>Salix alba</i> (Willow)	<i>Medicago sativa</i> (Alfalfa) + <i>Iris lactea</i> (Iris)
3	<i>Prunus armeniaca</i> (Apricot) + <i>Juglans regia</i> (Walnut) + <i>Salix alba</i> (Willow)	<i>Medicago sativa</i> (Alfalfa)
4	<i>Prunus armeniaca</i> (Apricot) + <i>Salix alba</i> (Willow)	<i>Medicago falcata</i> (Alfalfa) + <i>Iris lactea</i> (Iris)

7) Agrihorticulture land use system

In agrihorticulture land use system, the farmers mainly raised six agriculture crops viz. Wheat, Potato, Pea, Beans, Turnip and Tomato. The tree component comprised of trees of Apricot, Apple and Mulberry. The various combinations of agriculture crops and fruit trees are given in the Table 18.

Table 18: System units and their constituent agriculture crops and trees in agrihorticulture land use system practiced by farmers of Saspol block

Sr. No.	Agriculture crop	Fruit trees
1	<i>Triticum aestivum</i> (Wheat)	<i>Prunus armeniaca</i> (Apricot) + <i>Malus domestica</i> (Apple)
2	<i>Solanum tuberosum</i> (Potato) + <i>Pisum sativum</i> (Pea) + <i>Phaseolus vulgaris</i> (Beans)	<i>Prunus armeniaca</i> (Apricot) + <i>Malus domestica</i> (Apple)
3	<i>Brassica rapa</i> (Turnip) + <i>Solanum lycopersicon</i> (Tomato)	<i>Prunus armeniaca</i> (Apricot) + <i>Morus alba</i> (Mulberry) + <i>Juglans regia</i> (Walnut)

Thus, the results revealed that farmers in Leh region practiced different land use systems viz. agriculture, horticulture, agrisilviculture, agrihortisilviculture, hortisilvipasture, silvipasture and agrihorticulture. The component diversity in these systems did not show significant variation in Khaltsi and Saspol block. The cereals, pulses and vegetable crops grown by farmers in the area are a result of their inherited experience ably supported by scientific output.

Many workers have worked upon different land use systems and reported similar results. In Ladakh region, traditional agroforestry system in the form of agrisilvicultural system existed since time immemorial. Agriculture fields usually had boundary plantations of

multipurpose trees of Willow (*Salix spp.*) and Poplar (*Populus spp.*). Silvipasture system consisting of Poplar and Salix trees along with Alfalfa was the dominant system. The major agroforestry systems identified by them were: Poplar + food crops/Potato/vegetables/ fodder crops; Salix + food crops/Potato/vegetable/fodder crops; Apricot/Apple/Walnut + food crops/Potato/vegetable/fodder crops; food crops/Potato/vegetable + fodder crops (Bhat *et al.*, 2015). Nayak *et al.*, (2011) identified and categorized five types of agroforestry systems in cold deserts of Lahaul and Spiti area. These identified systems were agrihorticulture, agrisilviculture, agrisilvipasture, silvipasture and hortipasture. The major tree species of the area were Willow, Poplar and Apple. Goswami (2008) reported five agroforestry systems viz., agrisilvihorticulture (Maize, Wheat, Black gram, *Grewia*, *Ficus* and Pear), agrihortisilviculture (Wheat, Rajmash, Tomato, Pomegranate and *Grewia*), agrisilviculture (Maize, Barley and *Ficus* and *Grewia*), agrihorticulture (Maize, Capsicum, Tomato, Plum and Pear) and silvipasture (*Pinus*, *Acacia* and grasses) in Kwaal khad watershed in district Solan, Himachal Pradesh. Rajput (2010) reported four agroforestry systems viz, agrihorticulture having Maize, Black gram, Cauliflower and Apple; agrisilviculture with Maize, Wheat, *Grewia* and *Celtis*; agrihorticulture with Maize, Wheat, Tomato, Apple and *Grewia* and silvipasture having *Grewia*, Chir pine, *Bauhinia* and grasses in Kullu valley of Himachal Pradesh.

4.2 FLORISTIC COMPOSITION OF DIFFERENT LAND USE SYSTEMS

Floristic composition is a measure of species diversity in a community. The degree of diversity is a function of adaptability of species to the particular microhabitat as well as various other biotic and abiotic factors. In the present investigation, the different species of trees, grasses and herbs present on the fields of farmers only were considered for studying the floristic composition.

Table 19: Floristic composition of the study area

Plant category	Floristic composition of Khaltsi block			Floristic composition of Saspol block		
	Family	Genus	Species	Family	Genus	Species
Trees	4	6	6	4	6	6
Grasses	2	2	3	2	2	3
Herbs	6	9	12	5	7	10
Total	12	17	21	11	15	19

In the study area, a total of 21 species were recorded in Khaltsi block out of which 6, 3 and 12 species are of trees, grasses and herbs, respectively. In case of Saspol block, a total of 19 species were recorded of which, 6, 3 and 10 are of trees, grasses and herbs, respectively (Table 19). The floristic composition of both the blocks were almost same except the absence of Buck wheat and Foxtail millet in Saspol block.

4.2.1 Distribution of different species among various land use systems of Khaltsi block

It is evident from the Table 20 and 21 that different species of trees, grasses and herbs were maintained by the farmers of Khaltsi block under different land use systems. The silviculture tree species *Populus nigra* and *Salix alba* were present in agrisilviculture, agrihortisilviculture, silvipasture and hortisilvipasture land use systems. The fruit tree species Mulberry and Walnut were present only in horticulture and hortisilvipasture land use systems whereas Apple and Apricot were present in horticulture, agrihortisilviculture, hortisilvipasture and agrihorticulture land use systems. Among agriculture crops Wheat, Barley, Buckwheat and Foxtail Millet were mainly present in agriculture and agrisilviculture land use systems. Wheat and Barley were also grown under agrihorticulture land use system. Rajmash was grown under agrihortisilviculture land use system whereas Beans and Tomato were grown in both agriculture and agrihorticulture land use systems. The pasture species of *Medicago sativa*, *Medicago falcata* and *Iris lactea* occurred in silvipasture and hortisilvipasture land use systems.

Table 20: Distribution of trees and grasses among various land use systems of Khaltsi block

Sr. no.	Scientific Name	Common Name	Land use systems						
			A	H	AS	AHS	SP	HSP	AH
Trees									
1	<i>Populus nigra</i>	Poplar	-	-	+	+	+	+	-
2	<i>Salix alba</i>	Willow	-	-	+	+	+	+	-
3	<i>Prunus armeniaca</i>	Apricot	-	+	-	+	-	+	+
4	<i>Malus domestica</i>	Apple	-	+	-	+	-	+	+
5	<i>Juglans regia</i>	Walnut	-	+	-	-	-	+	-
6	<i>Morus alba</i>	Mulberry	-	+	-	-	-	+	-
Grasses									
1	<i>Medicago sativa</i>	Alfalfa	-	-	-	-	+	+	-
2	<i>Medicago falcata</i>	Alfalfa	-	-	-	-	+	+	-
3	<i>Iris falcata</i>	Iris	-	-	-	-	+	+	-

Table 21: Distribution of agricultural crops in various land use systems of Khaltasi block

Sr. no.	Scientific Name	Common Name	Land use systems						
			A	H	AS	AHS	SP	HSP	AH
1	<i>Hordeum vulgare</i>	Barley	+	-	+	+	-	-	+
2	<i>Triticum aestivum</i>	Wheat	+	-	+	-	-	-	+
3	<i>Fagopyrum esculentum</i>	Buckwheat	+	-	+	-	-	-	-
4	<i>Setaria italica</i>	Foxtail millet	+	-	+	-	-	-	-
5	<i>Brassica juncea</i>	Mustard	-	-	+	-	-	-	-
6	<i>Brassica oleracea</i> var. <i>Botrytis</i>	Cauliflower	+	-	-	+	-	-	-
7	<i>Phaseolus vulgaris</i>	Rajmash	-	-	-	+	-	-	-
8	<i>Pisum sativum</i>	Pea	+	-	+	+	-	-	+
9	<i>Solanum tuberosum</i>	Potato	+	-	+	+	-	-	+
10	<i>Solanum lycopersicon</i>	Tomato	+	-	-	-	-	-	+
11	<i>Allium sepa</i>	Onion	+	-	-	-	-	-	-
12	<i>Brassica rapa</i>	Turnip	+	-	+	+	-	-	+
13	<i>Brassica oleracea</i> var. <i>Capitata</i>	Cabbage	+	-	-	+	-	-	-
14	<i>Phaseolus vulgaris</i>	Beans	+	-	-	-	-	-	+

4.2.2 Distribution of different species among various land use systems of Saspol block

Table 22 and 23 revealed that different species of trees, pastures and herbs were maintained by the farmers of Saspol block under different land use systems. The silviculture tree species of *Populus nigra* and *Salix alba* were present in agrisilviculture, agrihortisilviculture, silvipasture and hortisilvipasture land use system. The fruit tree species Mulberry and Walnut were present only in horticulture and hortisilvipasture land use system whereas Apple and Apricot were present in horticulture, agrihortisilviculture, hortisilvipasture and agrihorticulture land use system. Among agriculture crops Wheat and Barley were mainly present in agriculture, agrisilviculture, agrihortisilviculture and agrihorticulture land use system. In addition to agriculture land use system, Pea and Potato were also present in agrisilviculture and agrihortisilviculture land use systems. Rajmash was grown under agriculture and agrihorticulture land use systems whereas Beans and Turnip were grown in agriculture, agrihortisilviculture and agrihorticulture land use systems. The pasture species of *Medicago sativa*, *Medicago falcata* and *Iris lactea* occurred in silvipasture and hortisilvipasture land use systems.

The results revealed that the main silviculture tree species of the region are Poplar and Salix, whereas, the horticulture trees consisted of Apricot, Apple, Mulberry and Walnut. The agriculture crops grown by the farmers included Wheat, Barley, Buckwheat, Cabbage, Cauliflower, Beans, Pea, Potato etc. The pasture crop is made up by Alfalfa and Iris.

Many workers have studied the floristic composition of different land use systems of cold deserts and found similar results. Butola *et al.*, (2012) recorded that the traditional crops of the Leh region included Barley, Wheat, Pea, Potato, Mustard, Onion, Cabbage, Cauliflower etc. The traditional agroforestry system of the region exists in the form of agrisilviculture system that is the combination of agricultural crops with boundary plantation of Willow and Poplar. Many legumes like Alfalfa also act as valuable source of fodder and helps in enrichment of soil. Srivastava *et al.*, (2015) found that the main crops grown in Leh region were Wheat, Barley, vegetables, fodder and fruit crops. The vegetables grown by the farmers were Cabbage, Cauliflower, Pea, Potato, Tomato, Onion etc. Apple and Apricot were the main fruit crops. The other important crops were fodder, particularly Lucerne (Alfalfa) which is primarily used for livestock purposes. Takeda and Yamaguchi (2015) conducted a study in Domkhar village of Leh Ladakh and found that Barley and Wheat was the main agriculture crop cultivated by the farmers. In the lower region of the village, various cash crops viz. Turnip, Tomato, Cabbage, Cauliflower etc. were also cultivated by farmers mainly for self consumption. They found that the village was also suitable for growing fruit trees of Apple and Apricot along with its neighbour village Khaltsi. The other agriculture crops cultivated by the farmers consisted of Buck wheat, Foxtail millet, Mustard, Pea etc. The tree species of Poplar and Salix along with Alfalfa grass was also prevalent in the village.

Table 22: Distribution of trees and grasses in various land use systems in Saspol block

Sr. no.	Scientific Name	Common Name	Land use systems						
			A	H	AS	AHS	SP	HSP	AH
Trees									
1	<i>Populus nigra</i>	Poplar	-	-	+	+	+	+	-
2	<i>Salix alba</i>	Willow	-	-	+	+	+	+	-
3	<i>Prunus armeniaca</i>	Apricot	-	+	-	+	-	+	+
4	<i>Malus domestica</i>	Apple	-	+	-	+	-	+	+
5	<i>Juglans regia</i>	Walnut	-	+	-	-	-	+	-
6	<i>Morus alba</i>	Mulberry	-	+	-	-	-	+	-
Grasses									
1	<i>Medicago sativa</i>	Alfalfa	-	-	-	-	+	+	-
2	<i>Medicago falcata</i>	Alfalfa	-	-	-	-	+	+	-
3	<i>Iris falcata</i>	Iris	-	-	-	-	+	+	-

Table 23: Distribution of agricultural crops in various land use systems of Saspol block

Sr. no.	Scientific Name	Common Name	Land use systems						
			A	H	AS	AHS	SP	HSP	AH
1	<i>Hordeum vulgare</i>	Barley	+	-	+	+	-	-	-
2	<i>Triticum aestivum</i>	Wheat	+	-	+	+	-	-	+
3	<i>Brassica juncea</i>	Mustard	+	-	+	-	-	-	-
4	<i>Brassica oleracea</i> var. <i>Botrytis</i>	Cauliflower	+	-	-	-	-	-	-
5	<i>Phaseolus vulgaris</i>	Rajmash	+	-	-	-	-	-	+
6	<i>Pisum sativum</i>	Pea	+	-	+	+	-	-	+
7	<i>Solanum tuberosum</i>	Potato	+	-	+	+	-	-	+
8	<i>Solanum lycopersicon</i>	Tomato	+	-	-	-	-	-	+
9	<i>Allium sepa</i>	Onion	+	-	-	-	-	-	-
10	<i>Brassica rapa</i>	Turnip	+	-	+	+	-	-	+
11	<i>Brassica oleracea</i> var. <i>Capitata</i>	Cabbage	+	-	+	-	-	-	-
12	<i>Phaseolus vulgaris</i>	Beans	+	-	-	+	-	-	+

4.3 ABOVE GROUND, BELOW GROUND, TOTAL BIOMASS AND CARBON STORAGE OF DIFFERENT LAND USE SYSTEMS

Biomass production levels

The biomass production (above ground, below ground and total biomass) and carbon stock of different land use systems of Khaltsi block and Saspol block have been presented in Table 24.

4.3.1 Above ground biomass (t ha^{-1})

A perusal of the data presented in the Table 24 reveals that different land use systems significantly influenced the above ground biomass. Among the different blocks, the maximum above ground biomass (15.78 t ha^{-1}) was exhibited by Khaltsi block. Among the different land use systems, hortisilvipasture exhibited the maximum above ground biomass (19.95 t ha^{-1}) whereas, agriculture land use system exhibited the lowest above ground biomass (6.52 t ha^{-1}).

4.3.2 Below ground biomass (t ha^{-1})

Below ground biomass production was significantly influenced by different land use systems (Table 24). The data presented in the table revealed that Khaltsi block exhibited the maximum below ground biomass (7.39 t ha^{-1}). Among the different land use systems, maximum below ground biomass (10.93 t ha^{-1}) was exhibited by hortisilvipasture land use system and the minimum below ground biomass (2.25 t ha^{-1}) was exhibited by agriculture land use system.

4.3.3 Total biomass (t ha^{-1})

Among the different blocks, the maximum total biomass (23.17 t ha^{-1}) production was exhibited by Khaltsi block (Table 24). The total biomass of different land use systems followed the order as hortisilvipasture > agrihortisilviculture > silvipasture > agrisilviculture > agrihorticulture > horticulture > agriculture. The hortisilvipasture land use system exhibited maximum total biomass (30.88 t ha^{-1}) and agriculture land use system exhibited minimum total biomass (8.76 t ha^{-1}).

4.3.4 Total carbon stock (t ha^{-1})

The total carbon stock was significantly influenced by different land use systems. The total carbon stock was higher (11.58 t ha^{-1}) in Khaltsi block as compared to Saspol block. The carbon stock of different land use systems followed the order as hortisilvipasture > agrihortisilviculture > silvipasture > agrisilviculture > agrihorticulture > horticulture > agriculture. Hortisilvipasture land use system exhibited the maximum (15.44 t ha^{-1}) carbon stock and the minimum (4.38 t ha^{-1}) carbon stock was exhibited by agriculture land use system.

The data presented in the in Table 24 revealed that above ground and below ground biomass in general followed the same trend as that of total biomass and total carbon stock of different land use systems. Further it is evident that different land use systems had significant effect on biomass production and carbon stock. It is influenced by the age of the components (annual or perennial), type of crop, structure of system, nature and number of woody components etc. The higher biomass production in hortisilvipasture land use system can be because of the higher density of trees as compare to other land uses. The hortisilvipasture land use system consisted of fruit and fodder trees and grasses.

Table 24: Above ground biomass, below ground biomass, total biomass and total carbon stock of various land use systems of the study area

Land use systems	Aboveground biomass (t ha ⁻¹)		Mean	Belowground biomass (t ha ⁻¹)		Mean	Total biomass (t ha ⁻¹)		Mean	Total carbon stock (t ha ⁻¹)		Mean
	Khaltsi Block	Saspol Block		Khaltsi Block	Saspol Block		Khaltsi Block	Saspol Block		Khaltsi Block	Saspol Block	
Agriculture	6.88	6.16	6.52	2.36	2.14	2.25	9.24	8.29	8.76	4.62	4.15	4.38
Horticulture	11.15	9.99	10.57	6.70	6.11	6.41	17.85	16.10	16.97	8.92	8.05	8.49
Agrisilviculture	17.72	16.50	17.11	6.28	5.79	6.03	23.10	22.29	23.14	11.10	11.15	11.57
Agrihortisilviculture	19.77	18.46	19.11	8.41	7.69	8.05	28.17	26.15	27.16	14.09	13.08	13.58
Silvipasture	17.44	16.39	16.91	9.62	9.41	9.51	27.06	25.79	26.43	13.53	12.90	13.21
Hortisilvipasture	20.73	19.17	19.95	11.22	10.65	10.93	31.95	29.81	30.88	15.98	14.91	15.44
Agrihorticulture	16.76	15.53	16.15	7.14	6.81	6.97	23.90	22.34	23.12	11.95	11.17	11.56
Mean	15.78	14.60		7.39	6.94		23.17	21.54		11.58	10.77	
C.D.(0.05)	System		0.78	System		0.47	System		0.80	System		0.40
	Block		0.42	Block		0.25	Block		0.43	Block		0.21
	(S X B)		NS	(S X B)		NS	(S X B)		NS	(S X B)		NS

Many workers have studied the biomass production and carbon stock of different land use systems and found similar trends. Montagini and Porras (1998) revealed that the mixed species have a greater capacity to produce high levels of biomass because of the difference in carbon fixing rates by species. Beer *et al.*, (1990) also revealed that higher biomass production depends on several factors including the age, the structure and the way the system is managed. Gupta and Singh (1981) revealed that the difference in productivity of agroforestry systems may be due to differences in soil conditions, phenology of dominant species. Deshmukh (1998) reported that management practices also affect the biomass production of trees grown under different agroforestry systems. The higher biomass production in hortisilvipasture land use system can be because of the higher density of trees as compare to other land uses.

4.4 SOIL NUTRIENT STATUS OF DIFFERENT LAND USE SYSTEMS

The soils of different land use systems were analyzed to check the pH, bulk density and to estimate EC, soil organic carbon, nitrogen, phosphorus, potassium, magnesium and calcium. The soil of this region is put under use for a minimum of six months (single cropping of kharif season), followed by grazing of the remaining aboveground and crop parts by the domestic animals and then left as such (fallow) during long winters.

4.4.1 SOIL pH

It is evident from Table 25 that the pH of soil of Khaltsi and Saspol block was almost same and alkaline in nature. The pH of different land use systems followed the order as agriculture > horticulture > agrisilviculture > agrihorticulture > silvipasture > hortisilvipasture > agrihortisilviculture. The pH was highest (8.01) in agriculture land use system and lowest (7.43) in agrihortisilviculture land use system. The amount of organic matter present in the soil significantly affects the pH of the soil. The decomposition of the organic matter produces acids such as follic acid and humic acid thereby lowering the pH of the soil. As the agriculture land use system contains less organic matter therefore, its pH is highest among all the land use systems.

The higher value of pH in agriculture land use system may be because of absence of trees as they add more organic matter into the soil and lowers the pH. Berhe *et al.*, (2013) reported higher soil pH outside the tree canopy of *Ficus thonningii* as compared to that of soil pH under tree canopy. This was attributed to several mechanisms that releases H⁺ ions such as soil base cation uptake, decomposition of organic matter to organic acids and CO₂, root

respiration and nitrification. Nakayama (1969) reported that under vegetation cover, the respiring roots raise the CO₂ concentration in soil atmosphere, which on dissolution in water produces carbonic acid (HCO₃). This acid would reduce the pH of the soil under vegetative cover. The alkaline nature of the soil of Ladakh region has also been reported by Dwivedi *et al.*, (2005), Sharma *et al.*, (2006), Tundup *et al.*, (2016) and Tundup *et al.*, (2018).

4.4.2 BULK DENSITY (g cm⁻³)

Data in table 25 revealed that the bulk density of soil of Khaltisi block was higher (0.76 g cm⁻³) than Saspol block. The bulk density of soil of different land use systems followed the order as agriculture > horticulture > agrisilviculture > agrihorticulture > silvipasture > hortisilvipasture > agrihortisilviculture. The bulk density was recorded highest (0.86 g cm⁻³) in agriculture land use system and lowest (0.64 g cm⁻³) in agrihortisilviculture land use system.

Table 25: pH, bulk density and electrical conductivity of soil of various land use systems of the study area

Land use systems	pH			Bulk density (g cm ⁻³)			Electrical conductivity (d S m ⁻¹)		
	Khaltisi block	Saspol block	Mean	Khaltisi block	Saspol block	mean	Khaltisi block	Saspol block	Mean
Agriculture	8.05	7.98	8.01	0.88	0.83	0.86	0.98	0.96	0.97
Horticulture	7.9	7.87	7.89	0.81	0.76	0.79	0.91	0.84	0.88
Agrisilviculture	7.79	7.73	7.76	0.79	0.75	0.77	0.85	0.80	0.83
Agrihortisilviculture	7.44	7.41	7.43	0.67	0.61	0.64	0.64	0.60	0.62
Silvipasture	7.5	7.45	7.48	0.72	0.67	0.70	0.67	0.63	0.65
Hortisilvipasture	7.49	7.44	7.46	0.71	0.66	0.68	0.71	0.68	0.70
Agrihorticulture	7.59	7.55	7.57	0.73	0.69	0.71	0.76	0.73	0.75
Mean	7.68	7.63		0.76	0.71		0.79	0.75	
C.D.(0.05)	System		NS	System		NS	System		NS
	Block		NS	Block		NS	Block		NS
	(SXB)		NS	(SXB)		NS	(S XB)		NS

From the finding it was observed that the land use system which is intensively managed had higher bulk density and it declined as the intensity of land management system reduced. The higher value of bulk density can also be ascribed to lower soil organic carbon

content. The agriculture crops such as Wheat, Barley and vegetables are uprooted during harvesting season and the land is kept bare for the whole winter season. This results in lower addition of organic carbon in this land uses as there is no material left for decomposition. These results are in the line with findings of Karan *et al.*, (1991) and Senneh (2007), who reported higher values of bulk density in cultivated soil in comparison to grasslands. Similar results were also found by Toppo (2012).

4.4.3 EC (d S m^{-1})

The EC of soil of Khaltasi block was higher (0.79 d S m^{-1}) than Saspol block (Table 25). The EC of different land use systems followed the order as agriculture > horticulture > agrisilviculture > agrihorticulture > hortisilvipasture > silvipasture > agrihortisilviculture. The EC was highest (0.97 d S m^{-1}) in agriculture land use system and lowest (0.62 d S m^{-1}) in agrihortisilviculture land use system.

The higher value of EC in agriculture land use system might be because of continuous addition of fertilizers which might have added salts. Berhe *et al.*, (2013) reported lower soil electrical conductivity under tree canopy and it is higher in area outside tree canopy. The results of EC are in line with the findings of Dwivedi *et al.*, (2005), Sharma *et al.*, (2006), Tundup *et al.*, (2016) and Tundup *et al.*, (2018).

4.4.4 Organic carbon (%)

The organic carbon content of soil of Khaltasi block was higher (0.54 %) than Saspol block. The organic carbon content of soil of different land use systems followed the order as agrihortisilviculture > hortisilvipasture > silvipasture > agrisilviculture > agrihorticulture > horticulture > agriculture. The organic carbon content was highest (0.61%) in agrihortisilviculture land use system and lowest (0.41%) in agriculture land use system (Table 26).

The increased organic carbon content in soils under tree based system may be ascribed to more leaf litter deposition and root turnover from trees (Zegeye, 1999). Soil organic carbon is formed by the decomposition of plant and animal residues, root exudates (Lal 1989; Blevins and Frye, 1993). The similar range of soil organic carbon was found by Dwivedi *et al.*, (2005), Tundup *et al.*, (2016) and Sharma *et al.*, (2006).

Table 26: Organic carbon, calcium and magnesium content in soils of various land use systems of the study area

	Organic carbon (%)			Calcium (C mol (P ⁺)Kg ⁻¹)			Magnesium (C mol (P ⁺)Kg ⁻¹)		
Land use system	Khaltsi block	Saspol block	Mean	Khaltsi block	Saspol block	Mean	Khaltsi block	Saspol block	Mean
Agriculture	0.44	0.38	0.41	1.10	0.99	1.04	0.09	0.07	0.08
Horticulture	0.49	0.43	0.46	1.14	0.96	1.05	0.13	0.10	0.12
Agrisilviculture	0.54	0.49	0.51	1.15	0.99	1.07	0.14	0.11	0.13
Agrihortisilviculture	0.63	0.6	0.61	1.21	1.08	1.15	0.23	0.32	0.27
Silvipasture	0.56	0.53	0.54	1.16	1.07	1.12	0.16	0.14	0.15
Hortisilvipasture	0.60	0.54	0.57	1.16	1.09	1.13	0.19	0.16	0.17
Agrihorticulture	0.52	0.48	0.50	1.14	1.08	1.08	0.15	0.13	0.14
Mean	0.54	0.49		1.15	1.03		0.16	0.15	
C.D.(0.05)	System	NS		System	NS		System	NS	
	Block	NS		Block	NS		Block	NS	
	(S X B)	NS		(S X B)	NS		(S X B)	NS	

4.4.5 MAGNESIUM AND CALCIUM

It is evident from the Table 26 that the mean calcium (1.15 C mol (P⁺) kg⁻¹) and magnesium (0.16 C mol (P⁺) kg⁻¹) content in soil of khaltsi block was higher than mean calcium (1.03 C mol (P⁺) kg⁻¹) and magnesium (0.15 C mol (P⁺) kg⁻¹) content of Saspol block. The calcium and magnesium content in soil of different land use systems followed the order as agrihortisilviculture > hortisilvipasture > silvipasture > agrihorticulture > agrisilviculture > horticulture > agriculture. The calcium content of agrihortisilviculture was highest (1.15 C mol (P⁺) kg⁻¹). Similarly magnesium in the same system was highest (0.27 C mol (P⁺) kg⁻¹). The minimum value of calcium and magnesium were respectively 1.04 C mol (P⁺) kg⁻¹ and 0.08 C mol (P⁺) kg⁻¹ in agriculture land use system.

Nair (1989) suggested that agroforestry and other trees based land use systems are commonly credited with more efficient nutrient cycling and in turn, a greater potential to improve soil fertility than many other systems because of the presence of woody perennials in the system and their suggested beneficial effects on soil. Kellman (1979) revealed that in addition to translocation of nutrients from soil layers beyond the reach of annual crops, enhancement of nutrient status beneath tree canopies is attributed to canopy capture of precipitation.

4.4.6 NITROGEN

The data from Table 27 revealed that mean nitrogen ($344.29 \text{ kg ha}^{-1}$) content in soil of khaltsi block was higher than mean nitrogen ($342.69 \text{ kg ha}^{-1}$) content of Saspol block. The nitrogen content of soil of different land use systems followed the order as agrihortisilviculture > hortisilvipasture > silvipasture > agrihorticulture > agrisilviculture > horticulture > agriculture.

Among the different land use systems, nitrogen content was highest ($352.08 \text{ kg ha}^{-1}$) in agrihortisilviculture land use system which was statistically at par with hortisilvipasture land use system. The minimum ($330.84 \text{ kg ha}^{-1}$) nitrogen content was found in agriculture land use system. The maximum nitrogen content in agrihortisilviculture land use system could be because of presence of nitrogen fixing agriculture crop such as Pea, Bean and Rajmash. Nitrogen is essential for crop production as it is an important constituent of proteins, nucleic acids and alkaloids. Soil organic matter acts as a store house and supplier of nitrogen to plant roots and microorganism, almost 95 per cent of the total soil nitrogen is closely associated with soil organic matter. The variation in available nitrogen may be attributed to variation in soil organic matter and total nitrogen contents (Korikanthmath, 1994). Atta *et al.*, (2013) also reported higher available nitrogen under tree canopy of *Acacia* species as compared to that of available nitrogen outside the tree canopy. The value range of nitrogen content in the study area is also in line with the findings of Tundup *et al.*, (2018).

4.4.7 PHOSPHORUS

It is evident from Table 27 that the mean phosphorus (8.25 kg ha^{-1}) content in soil of khaltsi block was higher than mean phosphorus (7.77 kg ha^{-1}) content of Saspol block. The phosphorus content of soil of different land use systems followed the order as agrihortisilviculture > hortisilvipasture > silvipasture > agrihorticulture > agrisilviculture > horticulture > agriculture. The phosphorus content of agrihortisilviculture was highest (9.99 kg ha^{-1}) among all the land use systems and the minimum (7.28 kg ha^{-1}) was recorded in agriculture land use system.

Tanga *et al.*, (2014) also reported higher available phosphorus under tree canopy to that of available phosphorus outside the tree canopy. This was ascribed to leaf litter deposition and release at mineralization, higher microbial population stimulated by organic matter input. The range of the result of phosphorus content in the soils of this region is at par with the results of Dwivedi *et al.*, (2005) and Sharma *et al.*, (2006).

4.4.8 POTASSIUM

A perusal of Table 27 revealed that the mean potassium ($355.21 \text{ kg ha}^{-1}$) content in soil of khaltsi block was higher than mean potassium ($353.51 \text{ kg ha}^{-1}$) content of Saspol block. The potassium content of soil of different land use systems followed the order as agrihortisilviculture > hortisilvipasture > silvipasture > agrihorticulture > agrisilviculture > horticulture > agriculture. The potassium content of agrihortisilviculture was highest ($360.81 \text{ kg ha}^{-1}$) among all the land use systems and the minimum ($344.30 \text{ kg ha}^{-1}$) was recorded in agriculture land use system.

Table 27: Nitrogen, Phosphorus and Potassium content in soils of various land use systems of the study area

Land use system	Nitrogen (Kg ha^{-1})			Potassium (Kg ha^{-1})			Phosphorus (Kg ha^{-1})		
	Khaltsi block	Saspol block	Mean	Khaltsi block	Saspol block	Mean	Khaltsi block	Saspol block	Mean
Agriculture	331.55	330.12	330.84	345.1	343.51	344.30	7.51	7.23	7.28
Horticulture	338.09	336.59	337.34	351.64	350.03	350.83	7.52	7.05	7.37
Agrisilviculture	343.72	341.88	342.8	354.44	352.64	353.54	7.58	7.19	7.38
Agrihortisilviculture	353.01	351.15	352.08	361.78	359.85	360.81	10.34	9.65	9.99
Silvipasture	347.37	345.88	346.63	357.76	356.11	356.93	8.18	7.8	7.99
Hortisilvipasture	351.62	349.74	350.68	358.9	357.1	358.00	8.76	8.31	8.53
Agrihorticulture	344.66	343.46	344.06	356.89	355.3	356.09	7.84	7.17	7.5
Mean	344.29	342.69		355.21	353.51		8.25	7.77	
C.D.(0.05)	System	1.48		System	0.68		System	0.15	
	Block	0.79		Block	0.37		Block	NS	
	(S X B)	NS		(S X B)	NS		(S X B)	NS	

The higher potassium contents in agroforestry systems as compared to agriculture can be ascribed to leaf litter deposition and release at mineralization, higher microbial population stimulated by organic matter input. Atta *et al.*, (2013) also reported higher available potassium under tree canopy of *Acacia* species as compared to that of outside the tree canopy. Tanga *et al.*, (2014) also reported higher available potassium under tree canopy to that of available potassium outside the tree canopy and available potassium decreased with increasing distance from tree trunk. Sileshi (2016) reported increased potassium under the tree canopy as compared to that outside the tree canopy. The results are also in line with the findings of Dwivedi *et al.*, (2005) and Sharma *et al.*, (2006).

Chapter 5

SUMMARY AND CONCLUSION

The present study entitled “**Floral spectrum and productivity of different land uses in Leh region of Himalayan cold desert**” was conducted in two blocks of Leh district of Jammu and Kashmir that lies between 34°10' N latitude and 77°35' E longitude. The present study was conducted to identify different land use systems present in the area; to study the floral spectrum of different land use systems; to study the biomass production and carbon storage potential of different land use systems and to estimate the nutrient status of soils of different land use systems.

5.1 Summary

5.1.1 Identification of different land use systems:

The land use systems were identified and studied in the fields of marginal (< 1ha land holding), small (1-2 ha land holding) and medium (>2 ha land holding) farmers. In Khaltasi block, among the marginal farmers, 4 land use systems viz. agriculture (A), agrisilviculture (AS), agrihortisilviculture (AHS) and hortisilvipasture (HSP) were identified. In case of small and medium farmers, 7 land use systems viz. agriculture (A), horticulture (H), agrisilviculture (AS), agrihortisilviculture (AHS), silvipasture (SP), hortisilvipasture (HSP) and agrihorticulture (AH) were identified. In case of Saspol block, among the marginal farmers, 4 land use systems viz. agriculture (A), agrisilviculture (AS), agrihortisilviculture (AHS) and hortisilvipasture (HSP) were identified. Among small farmers, the land use systems identified were 5 i.e. agriculture (A), agrisilviculture (AS), agrihortisilviculture (AHS), silvipasture (SP) and hortisilvipasture (HSP). Among medium farmers of Saspol block, 7 land use systems viz. agriculture (A), horticulture (H), agrisilviculture (AS), agrihortisilviculture (AHS), silvipasture (SP), hortisilvipasture (HSP) and agrihorticulture (AH) were identified (Table 4).

5.1.2 Floral spectrum of different land use systems:

In the study area, a total of 21 species were recorded in Khaltasi block out of which 6, 3 and 12 species were of trees, grasses and herbs, respectively. In case of

Saspol block, a total of 19 species were recorded of which, 6, 3 and 10 are of trees, grasses and herbs, respectively (Table 19). The floristic composition of both the blocks were almost same except the absence of buck wheat and foxtail millet in Saspol block.

5.1.3 Biomass production and carbon stock of different land use system:

The total biomass was significantly influenced by different land use systems. Among the blocks, total biomass and carbon stock was higher (23.17 t ha^{-1}) in Khaltsi block as compared to Saspol (21.54 t ha^{-1}) block. The total biomass and carbon stock of different land use systems followed the order as hortisilvipasture > agrihortisilviculture > silvipasture > agrisilviculture > agrihorticulture > horticulture > agriculture. The total biomass were 8.76 t ha^{-1} in agriculture, 16.97 t ha^{-1} in horticulture, 23.14 t ha^{-1} in agrisilviculture, 27.16 t ha^{-1} in agrihortisilviculture, 26.43 t ha^{-1} in silvipasture, 30.88 t ha^{-1} in hortisilvipasture and 23.12 t ha^{-1} in agrihorticulture land use system. Likewise, the carbon stock of different land use systems were 4.38 t ha^{-1} in agriculture, 8.49 t ha^{-1} in horticulture, 11.57 t ha^{-1} in agrisilviculture, 13.58 t ha^{-1} in agrihortisilviculture, 13.21 t ha^{-1} in silvipasture, 15.44 t ha^{-1} in hortisilvipasture and 11.56 t ha^{-1} in agrihorticulture land use system (Table 24).

5.1.4 Nutrient status of different land use systems:

Soil nutrient analysis revealed that soil pH, organic carbon, bulk density, electrical conductivity, nitrogen, phosphorus, potassium, calcium and magnesium differs significantly due to different land use systems.

The pH of the soil of the study area was alkaline in nature. The highest (8.01) pH was recorded in agriculture land use system and lowest (7.43) in agrihortisilviculture land use system. The electrical conductivity was highest (0.97 d S m^{-1}) in case of agriculture land use system and lowest (0.62 d S m^{-1}) in case of agrihortisilviculture. The nitrogen content was highest ($352.08 \text{ kg ha}^{-1}$) in case of agrihortisilviculture and the lowest ($330.84 \text{ kg ha}^{-1}$) was found in agriculture land use system. The calcium content was highest ($1.15 \text{ C mol (P}^+) \text{ kg}^{-1}$) in agrihortisilviculture while the lowest ($1.04 \text{ C mol (P}^+) \text{ kg}^{-1}$) was found in agriculture land use system. The magnesium was recorded highest ($0.27 \text{ C mol (P}^+) \text{ kg}^{-1}$) agrihortisilviculture land use system and the lowest ($0.08 \text{ C mol (P}^+) \text{ kg}^{-1}$) in agriculture land use system. The organic carbon content was highest (0.61 %) in case of agrihortisilviculture land use

system and the lowest (0.41 %) was recorded in case of agriculture land use system. Bulk density of the agriculture land use system was recorded highest (0.86 g cm^{-3}) whereas; agrihortisilviculture land use was recorded with lowest (0.64 g cm^{-3}) bulk density. The potassium was recorded highest ($360.81 \text{ kg ha}^{-1}$) in agrihortisilviculture and the lowest ($344.30 \text{ kg ha}^{-1}$) potassium was recorded in agriculture land use system. The phosphorus content of the agrihortisilviculture land use system was highest (9.99 kg ha^{-1}) among all the land use systems. Agriculture land use system was recorded with lowest (7.28 kg ha^{-1}) phosphorus content.

5.2 CONCLUSIONS

1. A total of 7 land use systems viz. Agriculture, Horticulture, Agrisilviculture, Agrihortisilviculture, Silviculture, Hortisilvipasture and Agrihorticulture have been identified.
2. A total number of 21 species of trees, grasses and agriculture crops have been found in the different land use systems.
3. The total productivity and carbon stock has been recorded maximum in hortisilvipasture land use system.
4. Nitrogen, Potassium, Phosphorus, Calcium, Magnesium and Organic Carbon have been found highest in agrihortisilviculture land use system. Whereas, Electrical Conductivity and Bulk Density have been found highest in agriculture land use system.

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APPENDIX-I

Equations used for volume estimation of different woody tree species

Sr. no.	Botanical name	Volume equation	Reference
1	<i>Populus nigra</i>	$V=0.193297-2.267002D+10.679492D^2$	FSI, 1996
2	<i>Salix alba</i>	$V=0.3846-3.4559D+10.9878D^2$	FSI, 1996
3	<i>Prunus armeniaca</i>	$V/D^2=0.007602/D^2-0.033037/D+1.868567+4.483454D$	FSI, 1996
4	<i>Malus domestica</i>	$V/D^2=0.007602/D^2-0.033037/D+1.868567+4.483454D$	FSI, 1996
5	<i>Juglans regia</i>	$\sqrt{V}= -0.207299+3.254007D$	FSI, 1996

APPENDIX- II

Specific gravity of different woody tree species

Sr. no.	Botanical name	Specific gravity	Reference
1	<i>Populus nigra</i>	0.40	Kumar, 1998
2	<i>Salix alba</i>	0.48	Rajput et al (1985)
3	<i>Prunus armeniaca</i>	0.63	Anonymous, 1996
4	<i>Malus domestica</i>	0.70	Anonymous, 1996
5	<i>Juglans regia</i>	0.47	Rajput et al (1985)

APPENDIX- III

Biomass expansion factor of different woody tree species

Sr. no.	Botanical name	Expansion factor	Reference
1	<i>Populus nigra</i>	1.58	Kaul and Sharma, (1983)
2	<i>Salix alba</i>	1.50	IPCC, 2003
3	<i>Prunus armeniaca</i>	1.43	IPCC, 2003
4	<i>Malus domestica</i>	1.50	IPCC, 2003
5	<i>Juglans regia</i>	1.40	IPCC, 2003

APPENDIX- IV

Root: Shoot of different woody tree species

Sr. no.	Botanical name	Root: Shoot	Reference
1	<i>Populus nigra</i>	0.19	Kaul and Sharma, 1983
2	<i>Salix alba</i>	0.25	IPCC, 2003
3	<i>Prunus armeniaca</i>	0.25	IPCC, 2003
4	<i>Malus domestica</i>	0.27	IPCC, 2003
5	<i>Juglans regia</i>	0.27	IPCC, 2003

APPENDIX –V

Trees, grasses and agricultural crops present in the existing land use systems in Leh region of Himalayan cold desert

Local name/ English	Botanical name	Family
Forest trees		
Yulad/poplar	<i>Populus nigra</i>	Salicaceae
Willow/Malchang	<i>Salix alba</i>	Salicaceae
Fruit trees		
Chuli/Apricot	<i>Prunus aremeniaca</i>	Rosaceae
Kushu/Apple	<i>Malus domestica</i>	Rosaceae
Starga/Walnut	<i>Juglans regia</i>	Juglandaceae
Osay/mulberry	<i>Morus alba</i>	Moraceae
Grasses		
Aul/Alfalfa	<i>Medicago sativa</i>	Fabaceae
Aul/Alfalfa	<i>Medicago falcata</i>	Fabaceae
Tesma/Iris	<i>Iris lactea</i>	Iridaceae
Agricultural Crops		
Tro/Wheat	<i>Triticum aestivum</i>	Poaceae
Knas/Barley	<i>Hordeum vulgare</i>	Poaceae
Chah/Foxtail millet	<i>Setaria italica</i>	Poaceae
Dro/ Buck wheat	<i>Fagopyrum esculentum</i>	Polygonaceae
Mustard, Sarson	<i>Brassica nigra</i>	Brassicaceae
Phool gobi/Cauliflower	<i>Brassica oleracea</i> var. <i>Botrytis</i>	Brassicaceae
Bandh gobhi/Cabbage	<i>Brassica oleracea</i> var. <i>Capitata</i>	Brassicaceae
Nyungma/Turnip	<i>Brassica rapa</i>	Brassicaceae
Beans	<i>Phaseolas vulgaris</i>	Fabaceae
Rajmah/Red bean	<i>Phaseolas vulgaris</i>	Fabaceae
Matar/Pea	<i>Pisum sativa</i>	Fabaceae
Aloo/Potato	<i>Solanum tubersum</i>	Solanaceae
Tomato	<i>Solanum lycopersicon</i>	Solanaceae
Tsong/Onion	<i>Allium sepa</i>	Amaryllidaceae

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ABSTRACT

The present study entitled **“Floral spectrum and productivity of different land uses in Leh region of Himalayan cold desert”** was conducted in two blocks of Leh district of Jammu and Kashmir that lies between 34°10' N latitude and 77°35' E longitude. The present study was conducted to identify different land use systems present in the area; to study the floral spectrum of different land use systems; to study the total biomass production and carbon storage potential of different land use systems and to estimate the nutrient status of soils of different land use systems. The systems identified are agriculture, horticulture, agrisilviculture, agrihortisilviculture, silvipasture, hortisilvipasture and agrihorticulture. A total of 21 and 19 species of trees, grasses and agricultural crops were recorded from the fields of different farmers of Khaltsi and Saspol block respectively. The maximum total biomass production was recorded in hortisilvipasture (30.88 t ha⁻¹) and minimum in agriculture (8.76 t ha⁻¹) land use system. The maximum total carbon stock was recorded in hortisilvipasture (15.44 t ha⁻¹) and minimum in agriculture (4.38 t ha⁻¹) land use system. The soil of the study area was found to be alkaline in nature ranging from 7.43-8.01. Nitrogen, potassium, phosphorus, calcium, magnesium and organic carbon was highest in agrihortisilviculture land use system whereas, electrical conductivity and bulk density was highest in agriculture land use system.

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