PATTERN, COMPOSITION AND VEGETATION DYNAMICS OF AGROFORESTRY SYSTEMS IN GIRI CATCHMENT, HP

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COLLEGE OF FORESTRY

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This is to certify that the thesis entitled, **"Pattern, composition and vegetation dynamics of agroforestry systems in Giri catchment, Himachal Pradesh."** submitted in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY** in **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. Matber Singh (F-2009-01-D)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

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

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This is to certify that the entitled, **"Pattern, composition and vegetation dynamics of agroforestry systems in Giri catchment, Himachal Pradesh"**, submitted by **Mr. Matber Singh (F-2009-01-D)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY** in **AGROFORESTRY** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the external examiner.

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Chapter-1

INTRODUCTION

Himalaya is a vast mountain system covering partly/fully eight countries of South Asia including Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan. In India, Himachal Pradesh (HP) is a Himalayan state with geographical area of 55,673 km^2 bounded in between 30^o 22′ 44″ to 33^o 12′ 20″ N latitude and 75^o 45′ 55″ to 79^o 04′ 20″ E longitude. The climate of HP varies from sub-tropical through sub-temperate to temperate, that changes with altitude too, which extends from 350 to 6975 m above mean sea level (amsl). Physiographically, it is divided into five zones based on altitude and moisture regime which vary from wet/humid, sub-temperate to alpine highlands. Average annual rainfall in the state is about 720 mm. The state is drained by nine major river systems, Yamuna is one of them. Giri is a tributary to Yamuna river of the Indo-Gangetic plains.

The drainage of Giri river cover parts of Sirmour, Solan and Shimla district of Himachal Pradesh, known as Giri Ganga catchment (Gopal and Chauhan, 2007). It originates from Shiwalik ranges above Kotkhai at an elevation of 3626 m amsl. flows through Shimla hills and then covers south-east part of district Sirmour before joining Yamuna near Paonta Sahib. Giri catchment is one of the catchments which hold the economy of local inhabitants besides nurturing adjoining states. The area is fragile where, topography, availability of natural resources and land use pattern differ greatly and varies in short distance. It is mostly rainfed except Churpeak, which experiences snowfall in winter months. The entire catchment is sparsely populated and covered by forests from elevation 630 m to 3626 m amsl. The catchment harbours forests of Sal, Chir pine, Deodar, Oak, Kail, Fir and Spruce. Large area is covered by grasslands and unprotected lands. People in this catchment are agrarian by nature and depend on agriculture for their livelihoods.

In Himachal Pradesh, 80 percent of its total population lives in villages. Their economy is dependent on agriculture, horticulture and animal husbandry. The practice of pure agriculture in HP is sufficient for the inhabitants to sustain only their food requirements but, for other needs peoples are forced to exploit forests. The mounting population subsequently demands higher amount of forest products, thereby creating more stress on these ecosystems.

Various fodder, fuelwood and timber trees are deliberately retained on the bunds of agriculture fields where species composition varies depending on land holding and basic requirements of the farmers (Toky et al. 1989a). In the present context therefore, scientific management of agroforestry practices in vogue with innovations is the only viable alternative through which the pressure on existing forests can be reduced.

The art and science of cultivating trees (or other woody perennial plants) in association with crops or animals is christened as ‘Agroforestry’ for the last three decades and it has gained considerable attention in scientific community. Trees and shrubs have been traditionally managed and used on agricultural landscapes around the world for shelter, wood, browse, fruit or nuts and they continue to be essential for these purposes in many developing countries. Nair (1993) specified that agroforestry is a land use practice which combines woody perennials intentionally with crops and/or animals on the same land management and there are both ecological and economical interactions between different components. The World Agroforestry Centre defines agroforestry as "a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels." Current global overview displays several examples of agroforestry systems and practices in different ecological and geographical regions of the world that provide food, fiber, fodder, fruit and fuelwood.

At present, agroforestry is accepted as an integrated applied science that has the potential for addressing many of the land management and environmental problems found in both developing and industrialized nations. Many agroforestry systems lend themselves to the concept of ‘ecological engineering’, whereby the ecological processes are used to solve engineering problems in such a way that ecosystems are designed, constructed, and managed for both environmental and societal benefits.

Agroforestry systems of any region are characterized by specific plant composition environmental conditions and socioeconomic factors with distinct association of the components and their management. As far as estimating the area under agroforestry is concerned, a major difficulty is the lack of proper procedures for delineating the area influenced by trees in a mixed stand of trees and crops. The entire area occupied by multi-strata systems such as homegardens, shaded perennial systems and intensive tree-intercropping situations is listed as under agroforestry. An estimation reveals that 5% of the world's forests are managed as agroforests; given that the total area under forest is 4000 million ha, the area under agroforestry in forest lands is 200 million ha (FAO, 2007) in an another estimate. The total area under agroforestry in the world is 1023 million ha (Nair et al. 2009). Currently Forest Survey of India reported 1, 11, 554 sq km (3.39 per cent of country's geographical area) area under agroforestry (FSI, 2013).

Agroforestry helps through their ecological, social and economic benefits for sustainable development and livelihood improvement of local people (Pandey, 2007). Agroforestry practices can provide food security, enhance soil fertility, supply fodder and enable income generation by ensuring a diversity of outputs (Garity, 2004; Huxley, 1999; Jose, 2009; Nair, 2007) and provide ecosystem services that are defined as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (Daily, 1997). Intergovernmental Panel on Climate Change recognized agroforestry as potential carbon sequestering systems and considered them as part of climate change mitigation strategies (Watson et al., 2000).

Many diverse agroforestry systems are found in the tropics, partly because of their favorable climatic conditions and partly because of the socio-economic factors such as human population pressure, availability of labor, smaller land holding size, complex land tenure, and less proximity to markets (Zhaohua et al. 1991, Clarke and Thaman, 1993, Kumar, 2006; Nair, 2007; Nair et al. 2008). This practice is now recognized widely as an applied science that is instrumental in assuring food security, reducing poverty and enhancing ecosystem resilience at the scale of thousands of smallholder farmers. A rapid population growth in recent times has increased the pressure on the natural resources such as the available land for sustaining the livelihoods, and with over exploitation and extraction of the natural resources ecosystems are becoming unsustainable and fragile (Sundriyal & Sharma, 1996). Thus, ecosystem service trade-offs arise from management choices made by humans, which can change the type, magnitude, and relative mix of services provided by ecosystems (Rodriguez et al., 2006). Land degradation is among the major challenges confronting sustainable development. As a result, millions of people depending on forests and tree resources for their subsistence have become more vulnerable. Their vulnerability mostly affected by the biotic and abiotic pressure experienced on which the systems biomass productivity and carbon sequestration potential depends.

Agroforestry systems in India have diverse variations in their structural and functional components depending upon the temperature, elevation, soil structure and rainfall pattern (Combe, 1982: Tejwani, 1987: Nair and Dagar, 1991; Tiwari, 1995; Maikhuri et al., 2000; Pandey, 2007; Singh and Pandey, 2011). In Himachal Pradesh the diversity of agroforestry systems, their floristics, biomass production, carbon sequestration potential, soil amelioration etc. have been described by Khosla and Toky, (1996); Toky et al. (1989); Atul and Khosla (1990); Thakur (2002); Thakur et al. (2004) and Bijalwan (2012). Agroforestry system research and development has evolved dramatically with much emphasis on how they function, diversity from local, landscape to regional level, local knowledge systems, economic valuation and environmental services they provide (Beer et al., 2005).

Species composition in an agroforestry systems, their distribution in time and space is the measure of plant diversity, indicated by simple and easily interpretable indicator called species richness. High species richness frequently results in increased above and belowground productivity, which in turn is a measure of their success in the prevailing environment. Biomass is another important characteristic of any vegetation and is regarded as an important indicator of ecological and management processes in the vegetation. Plants that dominate a site in terms of biomass reflects that they are controlling the nutrient, water, and solar resources on the site. Therefore, biomass is often measured to assess the ecological status of a site. Measures of standing crop also reflect the amount of energy stored in the vegetation, which can indicate the potential productivity at the site. Many workers have given account on biomass production (aboveground and belowground), vegetation, forest floor, leaf longevity and forest structure along altitude (Singh et al. 1994; Tiwari et al., 2005; Kaur, 2007; Sharma et al., 2011; Sheikh et al. 2012; Farooq, 2012; Sharma, 2012).

Productivity studies often ends up with generating data about how much carbon is stored in the living biomass - roots, trunks, and leaves of plants - after tallying up carbon gains through photosynthesis and carbon losses through respiration. Forests are important for carbon sequestration besides playing very important role in the global carbon cycle. They store about 80% of all aboveground and 40% of all belowground terrestrial organic carbon (IPCC, 2001). During productive season, CO_2 from the atmosphere is taken up by the vegetation and stored as plant biomass (Losi et al., 2003). Disturbances in the forest due to natural and human influences lead to more carbon released into the atmosphere than the amount used by vegetation during photosynthesis (Brown, 2002). Carbon sequestration involves the net removal of CO_2 from atmosphere and its storage in long-lived pools such as aboveground plant biomass and belowground biomass (roots, soil microorganisms).

Agroforestry systems are believed to have a higher potential to sequester carbon than pastures or field crops. In addition to sequestering C in biomass and soil, these systems can contribute to both carbon conservation (conservation of carbon stocks in forests by alleviating the pressure) and carbon substitution (reducing fossil fuel burning by producing fuel wood). Pandey (2007) reported the C sequestration potential of agroforestry systems and recorded values of 12 to 228 Mg ha^{-1}. The potential varied from different regions and system to systems. Determination of carbon storage in different components of system (Crop, annual and perennial herbs, shrubs, palm, bamboo, trees and soil) is most important for reporting systems C sequestration potential. In temperate regions, agroforestry practices have been estimated to have the potential to store C in the range of 15 - 198 Mg C ha^{-1}. In the tropics, agroforestry systems are estimated to have helped to regain 35% of the original C stock of the cleared forest, compared to only 12% by croplands and pastures. It has also been estimated that an increase of 1 ton (Mg) of soil carbon pool of degraded cropland soils may increase crop yields by 20 - 40 kg ha^{-1} (Nair et al., 2008). In India, average sequestration potential in agroforestry has been estimated to be 25 tonnes carbon per ha over 96 million ha (Sathaye and Ravindranath, 1998), but there is a considerable variation in different regions depending upon the biomass production (Ram newaj et al., 2013; Ramnewaj and Dhyani, 2008; Dhyani et al., 2009).

Information on agroforestry interventions in Giri catchment on the above discussed parameters of vegetation is not adequate. Hence, the present investigation was aimed at to identify different agroforestry systems in this catchment and study spatial and temporal distribution of vegetation components in them with the following objectives:

1. To identify types of agroforestry systems and study their structural variations along the elevation.
2. To evaluate biomass production and carbon stock of agroforestry systems.
3. To assess the economic viability of agroforesry systems.

Chapter-2

REVIEW OF LITERATURE

Vegetation present in all the terrestrial ecosystems is beneficial for human being either it gives food, timber, other miner products, medicine, fodder for animals and/or environment amelioration through carbon sequestration. Trees and other vegetation plays major role in mitigating climate change through sequestration of atmospheric carbon in vegetation and soil as well, but in recent scenario trees are cut for construction of buildings and roads at alarming rate. To reduce the burden for food, fodder, timber, fuel wood on the forest it's time to instate trees in agricultural field to increase tree cover outside the forests. The incorporated trees enhance income of the farmer though diverse production, improve soil physico-chemical properties and, increase the accumulation of carbon in vegetation and soil. The pertinent relevant literature on economic return, plant diversity of different land use systems and carbon storage in trees and soil, has been reviewed under the following headings;

2.1 Socioeconomic analysis
2.2 Identification of agroforestry systems
2.3 Floristic composition and phytosociology
2.4 Biomass production
2.5 Carbon storage in vegetation and soil
2.6 Economic analysis

2.1. SOCIOECONOMIC ANALYSIS

Negi (1993) analyzed the pattern and potential of farm trees growing in farming systems of Himachal Pradesh. The focus was to determine the conditions that encourage or discourage tree growing in western Himalayan region. The study showed that forest trees are subsidiary component in these farming systems, particularly in the mid hills where farms were relatively closer to public forests. Low-hill farms, which have higher market and off-farm labour opportunities, maintain higher proportion of commercial and fast growing trees than mid-hill farms. Off-farm income and employment opportunities directly influence tree growing. This income effect was stronger in the low than in mid-hills. It was significant for small but not large farms. Increase in land-dependent household population inversely affects farm tree growing by putting additional food demands on farm resources. He concluded that understanding farmer's interests, capacities and opportunities were important for promoting farm tree growing.

Thangata (1996) studied socioeconomic characters that influence adoption of agroforestry systems in the highlands of south western Uganda (Ibid). He contended that the size of family labour force has a positive impact on adoption of agroforestry technology. Combining tree resources and food crops on the farm is labour demanding and families with low labour force may not be able to practice agroforestry. Further, household size also influenced practice of agroforestry and higher number of children in a household encouraged tree planting because the need of tree products are higher and also labour is available. He also reported that gender is also an important factor that influenced adoption of agroforestry practices and the probability of adoption was higher for men than women farmers.

Rao et al. (1988) studied the socioeconomic characteristics and natural resource development of Chinnatekur watershed of Kurnool in Andhra Pradesh by interviewing different farmers selected randomly and computed that the economy of the watershed is mostly dependent on agriculture affected by the literacy rate which is low that varied from 22 to 40 % amongst the surveyed farm families.

Shrestha (1995) revealed that planting trees on agriculture land or the practice of agroforestry can protect forest by providing easily the tree products such as firewood and fodder to the farmers. It will also restore fertility of land by decreasing soil erosion, adding nutrients through decomposition of leaf litter and nitrogen fixation, recycling leached-down nutrients and helping breakdown of nutrients in the subsoil by means of deep roots. She found that shortage of forest resources in mid-hills of Nepal have been reduced through retaining trees in farmlands despite having limited landholdings.

Sharma and Singh (1998) conducted a study on the costs and benefits of agroforestry systems using three commercial tree species namely Eucalyptus, Acacia and Populus planted on moderately alkaline soils in 20cm wide and 100-120cm deep holes dug out with tractor mounted post-hole digger. The trees were grown alone and in combination with different crop rotation, viz. rice-wheat, for four years followed by guinea grass and oats in the fifth year, rice-barseem for four years followed by cowpea-barseem. The study showed that the output from agroforestry systems can be diversified and higher economic returns and obtained by this land use pattern. None of the trees had significant adverse effects on crop yields during the first two years. However, the yields of cultivated field crop were adversely affected from the third year onwards under the agroforestry system. But the reported losses in agricultural production were typically offset by the benefits received from the trees.

Jain and Singh (2000) evaluated the performance of poplar based agroforestry system in terms of income, employment and environmental impact from the farmer's perspective in the northern region of India. They reported that poplar based agroforestry system was economically viable and more profitable than many of the crop rotations currently being followed in the study area. This land use system was capable to provide employment opportunities on the farms.

Khanduri et al. (2002) studied the socioeconomic status of people in three villages with respect to the forest composition at elevation of 1700 m (Makkumath), 1900 m (Krokhi) and 2100 m (Sari) in Kedarnath Forest Division, Garhwal Himalaya. The average fuel consumption per household ranged from 9.73 kg/day at Sari to 4.94 kg/day at Makkumath. Fodder consumption from forests per cattle was maximum at Makkumath (6.76 ± 0.46 kg/day) and minimum in Sari (5.74 ± 0.57 kg/day).

Shiferaw et al. (2002) worked upon socioeconomic characterization of the production systems and resource use and management patterns in Adarsha (in Telangana) and Lalatora (in Madhya Pradesh) watersheds on the basis of baseline data collected from there. As such, they could not give conclusions from analysis of data but contended that the results are expected to serve as a reference on major socioeconomic conditions of agriculture and natural resource management in the watersheds, and provide a foundation for further research, including an assessment of the livelihood and environmental impacts of watershed management interventions in the area. They also reported that soil and water degradation decrease the profitability from investments in new technologies, thereby making it unattractive for small farmers to adopt agricultural innovations.

Inhabitants around any natural resource are the prime factor of disturbance leading to changes in flora and fauna. Arunachalam et al. (2004) reported that several ethnic societies living in and around Namdapha nature reserve in the Eastern Himalaya (India) are posing threat to biodiversity in this reserve. They reported 25 villages and two unauthorized settlements with 1420 households and 9618 human population are dependent upon the reserve for timber, bamboo, roofing material, medicinal plants and NTFPs (non-timber forest products). They reported that villagers harvested 15.5 tonnes of roofing material, 975 tonnes of bamboo and 45.5 tonnes of vegetables and medicinal plants annually. They further contended that over exploitation of *Zalacca secunda* (stem less rattan palm), bamboo etc. over a period of time, may cause damage to overall diversity of the reserve.

Dwivedi et al. (2007) did socioeconomic diagnosis of traditional as well as commercial agroforestry practices followed by farmers in western Uttar Pradesh and testified that fuel wood (50.6%) was major driving force for agroforestry adoption followed by additional income (24.4%) and shade (17.5%) in traditional agroforestry region while, additional income (71.3%) was the major factor in commercial agroforestry region.

Parizanganeh et al. (2008) evaluated the socioeconomic and environmental impacts of the watershed management projects of Zanjar river in Iran. They reported that 92 per cent of the farmers agreed that the project has considerable economic impact. They further recorded that that due to projects area under cultivation has increased and the crops production has enhanced.

Chandra et al. (2008) studied the socioeconomic status of people in Arnigad watershed of Mussoorie hills (Uttarakhand) and reported that *Grewia optiva*, *Bauhinia vahlii*, *Bauhinia retusa*, *Quercus leucotrichophora*, *Flacourtia ramontchii*, *Ougenia oogeinensis*, *Celtis australis*, *Lantana camara*, *Woodfordia fruticosa*, *Mangifera indica*, *Butea monosperma* and *Syzigium cuminii* used for fuelwood, whereas *C. australis*, *B. vahlii*, *Q. leucotrichophora*, *W. fruticosa*, *Murraya koenigii*, *F. ramontchii*, *Chrysopogon fulvus* and *Apluda mutica* are used as a fodder resource for livestock. However, dense forest was the major source of fuel wood *i.e.* 44.44% followed by scrub forest 36.50%, degraded land 13.09% and cultivated land 5.95%. Fodder collection was most from dense forest (37.27%) followed by scrub forest (32.63%) and least from cultivated land (14.22%).

Lodha and Gosain (2008) assessed and quantified the livelihoods of people by using socioeconomic indicators to know impact of watershed management in Dudhi micro-watershed in Madhya Pradesh. They developed house-hold development index (HHDI) that represents the position of a particular household within a given population with respect to the indicators like, income, literacy, land holding and livestock holding. They also calculated Village Development Index (VDI) and then Watershed Development Index (WDI) that represent the general well-being of community inhabiting villages in the watershed. Their results estimated annual watershed growth rate 1.2%.

Moote and Kusel (2010) developed and evaluated measures and indicators for assessing socioeconomic attributes in three watersheds (Upper Merced River Watershed, Mariposa Stream Groups Watershed and Upper Chowchilla river Watershed) in California USA. They identified five socioeconomic conditions of watersheds viz., Watershed Character, Public Health, Income and Impoverishment, Economic viability and Capacity to address watershed condition and stressors. They identified various indicators and measures to assess each of these conditions.

Démurger and Fournier (2010) discussed determinants of firewood consumption in a poor township in rural northern China, with a special focus on the relationship between households' economic wealth and firewood consumption. They found strong support for the poverty-environment hypothesis since household economic wealth is a significant and negative determinant of firewood consumption. They concluded that firewood can be considered as an inferior good for the whole population in the rural area, although further evidence showed that at the top of the wealth distribution, there might be a floor effect in the decreasing firewood consumption. They further argued that increasing education is a key factor in energy consumption behaviour, especially when dealing with energy source switching behaviour.

Onoja and Idoko (2012) determined variables influencing fuelwood demand in rural areas of Kogi state in Nigeria and reported that most significant determinant of fuelwood consumption in the area is the price of fuelwood, kerosene price, household size and personal incomes of the household heads. They recommended that there should be reduction in kerosene prices beside investment in renewable energy, cooking gas and electricity for sustaining natural resources. They further suggested that agricultural agents should educate farmers on sustainable farming.

Damte et al. (2012) examined the coping mechanisms employed by rural households to deal with fuelwood scarcity in randomly selected rural households in Ethiopia. Their results of the empirical analysis showed that rural households in forest-degraded areas respond to fuelwood shortages by increasing their labor input for fuelwood collection.

However, for households in high forest cover regions, forest stock and forest access may be more important factors than scarcity of fuelwood in determining household‘s labor input to collect it. The also contended that there is limited evidence of substitution between fuelwood and dung, or fuelwood and crop residue. They suggested that supply-side strategies alone may not be effective in addressing the problem of forest degradation and biodiversity loss. Any policy on natural resource management, especially related to rural energy, should distinguish regions with different levels of forest degradation.

Philip et al. (2013) revealed that farmers' adoption of agro-silviculture system is significantly effected by the age, gender, farmers' level of education, contact with extension staff and level of awareness. Most of the farmers' sale tree products from their farms to get income to meet out their household needs. They indicated that farmers increase their resource base by adopting agro-silviculture to solve their livelihoods problems. Agroforestry trees were selected on the basis of their minimum effect on intervening crops and also, sold seedlings of trees to earn money.

2.2 IDENTIFICATION OF AGROFORESTRY SYSTEMS

Nair (1987) carried out diagnostic survey for preparing inventory of agroforestry systems. These inventories enable the researchers to bring out the enormous magnitude of a complexity and diversity of existing agroforestry systems which helps in evaluation of system and identifying the most common gaps in research.

Chauhan and Dhyani (1989) identified economically important tree species on hill slopes, farm boundaries, in homesteads of five agro-climatic zones of Meghalaya. They furnished a list of 80 tree species and described their zone of occurrence.

Zou and Sanford (1990) classified natural agroforestry systems in china on the basis of system type and system unit and reported 7 system types and 26 system units. They defined system type as homogenous group whose major components are closely related economically, socially and environmentally, while system unit was defined as a basic functional unit that reveals the specific biological relationship among the major components that require similar management strategies and techniques.

Singh et al. (1991) studied the three types of agroforestry systems in Sikkim, namely silvihorticulture, hortiagriculture and agrisilviculture. In silvihorticultural systems large cardamom was the major horticulture component grown under the shade of trees like, *Alnus nepalensis*, *Schima wallichii* etc. In hortiagricultural system Mandrin (*Citrus reticulata*) was the commercial fruit trees grown with pulses. In agrisilviculture maize, wheat, barley and vegetables were grown with fodder and fuel trees like, *Ficus* sp., *Machilus edulis*, *Celtis cinnamomea*, *Erythrina arborescens*. They also reported that forage crops are seldom cultivated here, the leaves of fodder trees are the chief source of feed to animals in winter.

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 revealed that the farmers showed greater interest for agrihorticulture followed by agrihortisilivculture system, combined with livestock components.

Rana (1995) identified four traditional agroforestry systems in mid-hill zone of Himachal Pradesh. agrisilviculture, agrisilvipartoral, agrisilvihortiprotoral and pasture were the most promising system. According to survey conducted by Mazumdar (1991) five agroforestry systems were identified at Nauni, Himachal Pradesh (H.P.) viz. agricultural system, hortiagriculture, hortisilviprtoral, grasslands and wastelands. While Kachru (1997) conducted a diagnostic survey and productivity appraisal of the agroforestry systems in sub-temperate and sub humid region of Himachal Pradesh and reported eight agroforestry system types viz, agri-silviculture, agri-horticulture, agri-silvihorticulture, pastoral-silviculture, pastoral-hortisilviculture, agri-hortisilviculture, pastoral-silviculture, and pasture.The diagnostic survey of agroforestry systems conducted in Balh valley of H.P. revealed that in uplands six agroforestry systems types viz., agri-silviculture, agri-silvihorticulture, pastoral-silviculture, pastoral-silvihorticulture, pastoral-horticulture and horti-pastoral were prevalent among farmers. Similarly, Upadhyaya (1997) identified, six agroforestry systems types namely, agri-siliviculture, agri-silvihorticulture, pastoral-silvihorticvultural, pastoral-hortisilviculture and silvipasture in lowlands of Himachal Pradesh.

Sharma et al. (1995) assessed the status of agroforestry systems in Bundelkhand, UP region found two trees per 100 m running length of field bunds. The prominent multipurpose tree species in the agroforestry systems were *Zizyphus mauritiana, Acacia nilotica, Leucaena leucocephala* and *Azadirachta indica*.

Sood et al (2000) listed the agroforestry systems of Arunachal Pradesh. The most prominent systems were agrisilvicultural, silvipastoral and agrisilvipastoral. The other agrforestry systems include agrisilvifishery, agrisilvisericulture. They also highlighted the common constraints of existing agrforestry land use of Arunachal Pradesh.

Mughal et al. (2000) conducted a diagnostic survey and identified agroforestry systems, namely agrisilviculture, hortisilviculture, hortisilvipasture, hortisilviagriculture kitchen gardens and boundary plantations, in rural Srinagar of Kashmir valley.

Thakur et al. (2002) studied structural components of three agroforestry systems viz, agri-silviculture, pastoral-silviculture and horti-silvipastoral systems in Kuthar and Arla-Kalyana village of Solan district in Himachal Pradesh. They found that horti-sivipastoral system was more diversified amongst the three systems with 12 tree, 4 shrub and 6 fruit trees. The dominant trees in these systems were *Acacia catechu*, *Grewia optiva*, *Celtis australis* and *Pyrus pashia*. The common shrub species were *Murraya koenigii*, *Lantana camara*, and *Berberis lycium* while *Lathyrus aphaca*, *Chrysopogon montanus*, and *Cyperus rotundus* were prominent herb species.

Kumari et al. 2008 identified traditional agroforestry systems of Lahaul and Kinnaur districts of Himachal Pradesh, India. In Lahaul area five agroforestry systems viz., agrihorticulture (Pea, Potato & Apple), agrisilviculture (Pea, Potato, Rajmash, Salix), agrisilvipastoral (Pea, Salix, Grasses), pastoralsilviculture (Grasses, Salix) and Pastoralhorticulture (Grasses, Apple). In Kinnaur the agroforestry systems and their components were same except for the absence of agrisilvipastoral system.

Sood and Mitchell., (2009) conducted the study in Himachal and found that a combination of biophysical and social factors including farm size, agroclimatic zone, soil fertility, mobility and importance of tree for future generations and use of indigenous knowledge of farmers are key factors, which may influence tree growing on farmer’s land.

Bijalwan, (2012) studied traditional agroforestry systems of mid-hill region of Garhwal Himalaya between the elevation of 1000 to 2000 masl. The study discloses that the majority of land-use fall in forest area adjacent to different villages followed by area under cultivation including traditional agroforestry practices. The traditional agroforestry systems in the area were recorded as agrisilviculture (AS), agrihortisilviculture (AHS), agrihorticulture (AH), agrisilvipasture (ASP), silvipasture (SP) and hortisilviculture (HS) etc. But, the predominant systems were agrisilviculture (AS), agrihortisilviculture (AHS) and agrihorticulture (AH). The major tree under agroforestry systems were *Grewia optiva*, *Celtis australis*, *Melia azedarach* and *Ficus roxburghii*. The average tree density in AS was recorded 620 trees ha-^{1}, in AHS 495 trees ha-^{1} and in AH 705 trees ha^{-1}.

2.3. FLORISTIC COMPOSITION AND PHYTOSOCIOLOGY

Ecosystems and their component species are important in sustaining human life and health of our planet, which is disappearing at an alarming rate. Consequently, the need for immediate action to design effective strategies to conserve biodiversity is receiving considerable attention worldwide. Agroforestry contributes to improve and conserve biota in the following ways: (1) preserve germplasm of sensitive species; (2) reduce the rates of degradation of systems; (3) provides connectivity by creating corridors between habitat remnants which may support the integrity of these remnants and the conservation of area-sensitive floral and faunal species; and (4) conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat. Agroforestry play an important roles in the battle to conserve global biodiversity is illustrated by various studies in the recent past. Shade coffee under agroforestry system shows great promise to enhance biodiversity compared to traditional agricultural practices (Moguel and Toledo, 1999).

Along the altitude of Indian Central Himalaya, the geographic and climatic conditions change sharply and, so the plant species. More number of species exists at low altitude to mid altitude corresponding to tropical/subtropical belt due to overlapping of climatic conditions but with further increase in altitude it decrease consistently (Kharkwal et al. 2005). In a study in Kumaon forest of Central Himalaya (India), a total of 19 tree communities and 17 ground vegetation communities were noted (Hussain et al.2008). The distribution of tree species indicated influence of altitudinal gradient as well as of canopy cover and shrub diversity.

Gairola et al. (2008), Timilsina et al. (2007) and Ahmed et al. (2010) contended that forest composition, community structure and diversity patterns are import ecological attributes are significantly correlated with environmental and anthropogenic variables. Himalayan forests are amongst the globe's most depleted forests (Duke, 1994; Schickhoff, 1995; Shaheen et al. 2011) and this has been attributed to the high population increase associated with land use changes, socioeconomic transformations and unsustainable exploitation of natural forest resources (Nayar and Sastry, 1990; Ghosh, 1994; Myers, 1986).

Kumar and Bhatt (2006) while studying floristic composition, diversity, dominance and abundance in two different forest sites of a tropical foot hill region of Garhwal Himalaya found that in tree layer, *Lannea coromendelica* (IVI 39.80) and *Anogeissus latifolia* (IVI 29.50) were the dominant species at site I and site II, respectively. They also reported that most of the species on both the sites were contagiously distributed except few species that were randomly distributed.

Sharma et a*l*. (2009) compared different forest associations along the altitudinal gradient in Himalayan temperate forest. They recorded significant negative correlation of density with altitude and slope and, suggested that species distribution with altitude and climatic factors are largely regulated by climatic factors.

Rana and Gairola. (2009) studied the effect of altitudinal variation on structure and composition of the vegetation in natural Himalaya forests of Parshuram Kund area in Lohit district of Arunachal Pradesh. Three altitudinal zones viz., upper zone (550-850 m amsl), middle zone (500-700 m amsl) and lower zone (350-450 m amsl) showed variation in species composition. At upper and middle altitude *Musa nagensium* was the dominant shrub species. At lower altitude *Piper peepuloides* was the dominant shrub species. In grasses at upper altitude, *Imperata cylindrica* was the dominant herb species followed by *Equisetum* spp. At lower altitude *Bidens pilosa* was the dominant herb.

Yadava and Singh (2010) studied the community structure and floristic diversity of tree stratum of deciduous forest of Achanakmar - Amarkantak biosphere reserve in Chattisgarh, India. They observed that density and basal area of trees in forest plots ranged from 240 (degraded forest) to 1270 (regeneration forest) stems per hectare and 23.65 (regeneration forest) to 37.57 (dense forest plot) m^2 ha^{-1}, respectively. Devlal and Sharma (2010) conducted a study on dominance, diversity and species richness of tree species along an altitudinal gradient of Mandakini catchment of Garhwal Himalaya. They recorded that density (trees/ha) and total basal area (m^2/ha) values of the selected stands ranged between 2084 and 600 trees/ha and 53.44 - 29.36 m^2/ha.

Calles et al. (2010) compared richness and diversity of native plant species among six sites each of agroforestry systems and forests in areas dominated by columnar cacti: (i) ‘‘chichipera’’ dominated by *Polaskiachichipe*; (ii) ‘‘jiotillal’’ dominated by *Escontriachiotilla;* and (iii) ‘‘garambullal’’ dominated by *Myrtillocactusschenckii*, in the semi-arid valley of Central Mexico. All the samples of the agroforestry systems studied maintained on average nearly 59% plant species and 94% genetic variation of dominant cacti occurring in the forests. They also reported that agroforestry systems are losing their capability to maintain vegetation cover, mainly because of (i) decreasing amount of land managed by households, determined by a progressive fragmentation of the land area given to new families, (ii) adoption of technologies to intensify agriculture, and (iii) governmental programs penalizing the presence of vegetation patches within agricultural lands since they are considered ‘‘useless’’ areas.

A phytosociological study of weed flora in three abandoned farm lands within Owo ‘local government area’ of Ondo State, Nigeria, was done by Ige et al. (2008) and they reported that *Chromolaena odorata, Tridaxprocumbens* and *Imperata cylindrica* were the dominant weeds there.

Sharma and Sharma (2013) in their investigation at western foot hill gaps of central Aravallis reported that response of herbaceous flora varied under different plantations of *Acacia tortilis, Acacia senegal* and *Eucalyptus camaldulensis* and concluded that many species which showed high value of frequency might not be dominants with respect to IVI. Grasses were common for all the sites of study, however, some species responded differentially and to some extent, dominance of a species under a particular tree plantation affected the soil properties and floor dynamics.

A study carried out by Hussain et al. (2010) to assess the phytosociology and structural characteristics of central Karakoram National Park (CKNP) of Pakistan, in which *Picea smithiana* and *Pinus wallichiana* formed a community in two sites, associated with *Juniperus excels*a. The pine tree species were distributed as pure stands in different sites with higher density and basal area. In pure stands, *Juniperus excels*a attained lowest density with highest basal area.

Indreica and Kelemen (2011) studied phytocenoses of sessile oak and spruce in acidophilus oak forests (*Luzulo luzuloidis - Quercetum petraeae*), but some of them resemble oak-hornbeam forests (*Carici pilosae - Carpinetum*), indicating a more recent change in stand structure and suggesting that not the soil, but the climate is the driving force of succession in forests with sessile oak (*Quercus petraea*) and Norway spruce (*Picea abies*) from south-eastern Transylvania.

The vegetation of the area of Kizildag (Isparta province, Turkey) was analysed using a 3-dimensional ordination technique based on the Braun-Blanquet method by Saglam (2013) in which 5 new plant associations were identified that belonged to forest, shrub, and steppe vegetation as 1. *Meliloto bicoloris* **-** *Quercetum cocciferae* 2. *Hyperico heterophylli* **-***Cistetum laurifolii* 3. *Atraphaxo billardieri - Amygdaletum orientalii* 4. *Veronico isauricae -Cedretum libani* and 5.*Centauro detonsae -Thymetum sipylei*.

Verma and Kapoor (2013) conducted a studied on floristic diversity along an altitudinal gradient at Kinnaur district of Himachal Pradesh. They reported 142 plant species belonging to 49 families and 105 genera. The prominent plant families of these species were Asteraceae, Polygonaceae, Ranunculaceae and Rosaceae. The number of shrub and herb species decreased as elevation increased. The distribution of species at different elevation was contiguous. *Populus nigra* was the dominant tree species at 3000- 3500 m asl and *Ephedra gerardiana* was dominant at 3000 to 4000 m asl.

2.4. BIOMASS PRODUCTION

Kumar (1996) studied bio-economic appraisal of agroforestry systems in Himachal Pradesh and revealed that the biomass productivity of different agorforestry systems followed the decreasing order of Agri-silviculture (AS) > Agri-horti-silviculture (AHS) > Agri-horticulture (AH) > sole cropping. In agri-silviculture (AS) system he recorded 1.1, 1.23 and 1.31 times higher biomass in maize - lentil cropping pattern and 1.09, 1.22 and 1.29 times in soybean - wheat cropping pattern than AHS, AH and sole cropping, respectively.

Samra et al. (1999) studied the biomass production of trees and grasses in a silvipasture system on marginal lands of Doon valley in Uttarakhand. They observed that the total biomass production was highest in inter cropping of *Bauhinia purpurea* with grass (2929 kg ha^{-1}) followed by *Grewia optiva* (2372 kg ha^{-1}) which appeared to be most suitable tree species along with *Eulaliopsis binata* for sustainable silvopasture development on the marginal land.

Maikhuri et al. (2000) studied ten locally valued multipurpose tree species, *viz.*, *Albizia lebbek*, *Alnus nepalensis*, *Boehmeria arugulosa*, *Celtis australis*, *Dalbergia sissoo*, *Ficus glomerata*, *Grewia optiva*, *Prunus cerasoides*, *Pyrus pashia* and *Sapium sebiferum*, as mixed plantations in a degraded community forest land site and an abandoned agricultural land site in a village at 1200 m altitude in district Chamoli, India and found that above-ground tree biomass accumulated at the abandoned agricultural land site was 3.9 t $ha^{-1}yr^{-1}$ compared with 1.1 t $ha^{-1}yr^{-1}$ at the degraded forest land site.

Sanneh (2007) reported that maximum aboveground biomass (308.96 t ha^{-1}), belowground biomass (62.09 t ha^{-1}) and total biomass (371.06 t ha^{-1}) was in the forest land use system. It was followed by silvi-pasture, agri-silvipasture, agri-horticulture, agriculture and grassland systems, respectively in wet temperate north - western Himalayas at different altitudinal gradients.The rate of biomass production (t ha-1) increased with increasing altitudinal ranges.

Swamy et al. (2008) carried out a study on variation in tree growth, above and below ground biomass and nutrient storage in *Gmelina arborea* planted at three densities (4m x 4m, 4m x 6m, and 4m x 8m) under agri-silvicultural systems at Raipur. After 5 years, total biomass ranged from 6.96 to 13.75 Mg/ha. It was highest in trees planted under 4m x4m, spacing and lowest in 4m x8m spacing.

Dossa et al. (2008) conducted an interaction study between mature coffee plantation and *Albizia* in south western Togo to determine carbon in shaded versus open grown coffee systems, they found above and belowground biomass estimates were respectively, 140 Mg ha^{-1} and 32 Mg ha^{-1} in the coffee–*Albizia* association, and 29.7 Mg ha^{-1} and 18.7 Mg ha^{-1} in the open-grown system. *Albizia* trees contributed 87% of total aboveground biomass and 55% of total root biomass in the shaded coffee system. Individual coffee bushes consistently had higher biomass in the open-grown than in the shaded coffee system.

Minj (2008) conducted a study in low and mid hills of Himachal Pradesh and reported that maximum mean aboveground biomass (188.60 t ha^{-1}), belowground biomass (49.04 t ha^{-1}) and total biomass (237.70 t ha^{-1}) was accumulated in pure poplar plantation, followed by agri-silviculture, silvi-pasture, pure agriculture, and pure grassland systems, respectively. The mean total biomass production of all the systems in Zone I and Zone II was (98.14 t ha^{-1}) and (46.99 t ha^{-1}), respectively.

Saravanan et al. (2009) studied biomass production under 4 year *Casuarina* based agroforestry system and reported that the dry matter production was 8314kg ha^{-1} of which 50% was contributed by stem, 27% by leaf and 23% by branch. Sharma (2009) studied distribution of biomass in different land uses along altitudinal gradient from 900 to 2100m of Solan Forest Division, Himachal Pradesh and revealed that out of 1.07 M t of total biomass in the division, the chir pine land use contributes 36.63%, ban oak 32.78%, other broadleaves 28.94%, deodar 1.15% and culturable land 0.48%. Along altitudinal gradient, it was 44.89% in 1500 – 1800 m, 42.38% in 1200 – 1500 m, 10.35% in 1800 – 2100 m and 2.36% in 900 - 1200 m elevation. He further reported that Dharampur Forest Range accounted for 31.60%, Parwanoo 27.38%, Solan 25.77%, Kandaghat 11.22% and Subathu 4.01% of the total biomass.

Distribution pattern of aboveground biomass in natural and plantation forests of humid tropics in northeast India was studied by Baishya et al. (2009) and reported that the aboveground biomass (AGB) distribution was lower in natural forest (323.9 Mg ha^{-1}) than the plantation forest (406.4 Mg ha^{-1}). About 49% of the AGB was contributed by trees having dbh > 60 cm in the natural forest against 24% in the plantation forest.

Singh and Lodhiyal (2009) conducted a study with 8-year old *Populus deltoides* agroforestry plantation in tarai region of Central Himalaya. They observed that the total biomass of plantation was (202.59 t ha^{-1}) and the aboveground components contributed 78.68% and belowground contributed 21.32% biomass to the total biomass.

Yadava (2010) carried out a study on biomass in different agroforestry systems in Bagawala, Uttarakhand and reported that the biomass was influenced by structural composition of agroforestry system, number of woody perennial and management practices. Maximum total aboveground biomass was recorded in intercropping of *Populus deltoides* with wheat in block plantation (57.69 t ha^{-1}) followed by intercropping with lemon grass (56.38 t ha^{-1}).

A study undertaken in moist temperate Mandal - Chopta forest of Chamoli District, Garhwal Himalaya, Uttarakhand, India by Gairola et al. (2011) to assess live tree biomass and revealed that the total live tree biomass density varied from 215.5 to 468.2 Mg ha^{-1}.

Kumar et al. (2011) conducted a study to estimate the biomass and net primary productivity of different age grouped *Butea monosperma* forest ecosystems in western India and found that the tree biomass increased with age of forest stand. The tree biomass increased from 183.7 to 298.3 t $ha^{-1}$with age.

Gupta and Sharma (2012) studied the land use and vegetation distribution in Solan Forest Division of Himachal Pradesh in India. They reported that the biomass density (t/ha) increased along the altitude and estimated 38.39 t/ha, 30.77 t/ha, 65.69 t/ha, 111.43 t/ha, and 143.89 t/ha biomass density at 600–900 m, 900–1200 m, 1200–1500 m, 1500–1800 m and above 1800 m, respectively.

The assessment of biomass production in different tree based systems of Central Himalayan tarai region studied by Kanime et al. (2013) exhibited that highest above and belowground biomass in *Dalbergia sissoo* plantation as 9.48 Mg ha^{-1} and 16.90 Mg ha^{-1}, respectively. Lowest above and belowground biomass occurred in *Populus deltoides* boundary plantation (1.23 Mg ha^{-1}) and *Paulownia salicina* (0.30 Mg ha^{-1}), respectively.

2.5. CARBON STORAGE IN VEGETAION AND SOIL

Carbon sequestration involves the removal and storage of carbon from the atmosphere in carbon sinks (such as oceans, vegetation, or soils) through physical or biological processes. The incorporation of trees or shrubs in agroforestry systems can increase the amount of carbon sequestered compared to a monoculture field of crop plants or pasture (Kirby and Potvin, 2007).

According to the study conducted by Dixon (1995) carbon storage potential of agroforestry systems ranges from 12 to 228 t C ha^{-1}, with agroforestry systems in the humid tropics displaying the greatest carbon storage ability. In the context of global carbon cycle, agroforestry is an important land use system for two primary reasons; one, the tree component in agroforestry systems fixes carbon from the atmosphere and stores it until they are cut or die and secondly, it helps in reducing pressure on forest by supplementing some of the products obtained by natural forests (Pandey, 2002). He also reported that, agroforestry systems can sequester carbon to a tune of 0.2 to 3.1 C t ha^{-1} yr^{-1}, and they have the potential to sequester 7 Gt of carbon between 1995 and 2050 globally; however, better country-specific assessments are needed to refine this estimate.

For carbon estimation in trees first requirement is their volume estimation and then convert the volume of wood into biomass. The next step is to find out the carbon content in the biomass. The carbon content of the different part of the plant has been found to vary to a certain extent. But in general 50% of the biomass is taken as carbon content for all the carbon estimation (Mac Dicken, 1997).

Animon et al. (1999) studied soil organic carbon content under *Acacia auriculiformis* and *Eucalyptus tereticornis* plantations at three different soil depths *viz.,* 0 -10 cm, 10 – 30 cm and more than 30 cm and found that soil organic carbon content decreased under all the plantations with soil depth. Higher organic carbon content was noticed under *Acacia* soils, while the lower under *Eucalyptus tereticornis*, comparatively more organic carbon content under *Acacia* was attributed to higher accumulation of litter and its slow decomposition.

Kaur et al. (2000) conducted an investigation at Karnal to analyze the role of agroforestry systems in improving soil organic matter status on moderately alkaline soils. They selected some systems for study that were: rice-berseem crop rotation; agrisilvicultural systems of *Acacia, Eucalyptus* and *Populus* along with rice-berseem and single species tree plantations. They found that maximum build-up of organic carbon in soil occurred under *Acacia* based systems followed by *Populus* and *Eucalyptus* based systems. Averaged across the distance from the trees at 0–7.5 cm soil depth, carbon concentrations were found to be higher in the case of *Acacia* based systems (0.57 – 0.63% C) and *Populus* based systems (0.41 – 0.59% C) as compared to *Eucalyptus* based systems (0.38 – 0.54% C).

Sivakumar et al. (2000) studied the potential of rubber plantations in carbon sequestration and presented some economic models, which could form the basis for the smart partnership between of sustainable rubber cultivation. Carbon sequestration from one hectare 27 year old stand of rubber tree was 72.36 tonnes. The major portion was sequestered in the trunk and primary branch comprising of 21.6 and 18.9 tonnes, respectively. The result showed that sequestration capacity differed among organs, highest carbon sequestration of 88 per cent was found in the latex vessels; leaves and twigs had carbon content of 53.8 per cent. In litter it ranged from 45 to 46 per cent.

Dhand et al. (2003) estimated carbon content in some important forest tree species and reported that *Pinus roxburghii* stored maximum carbon (61.11%) in wood and 60.72% in leaf. In *Pterospermum acerifolium* 56.91% carbon was stored in wood and 41.72% leaf while in *Syzygium cuminii* 54.63% carbon resided in wood and 47.31% leaf. In *Dendrocalamus strictus* lowest amount of carbon was stored in wood (52.25%) and leaf (41.72%).

Zhao and Zhou (2006) evaluated the forest vegetation carbon storage from the Fourth Forest Inventory Data (FFID) in China using a modified volume-derived method. Results showed that total carbon storage and mean carbon density of forest vegetation in China was 3.8 Pg C (about 1.1% of the global vegetation carbon stock) and 41.32 Mg/ha, respectively.

Minj (2008) studied carbon stock and CO_2 sequestration in low & mid hills of Western Himalaya during year 2004-06 and estimated that mean biomass carbon stock & CO_2 sequestration in zone-I (sub montane low hills) was 2.09 times higher than zone-II (mid hills). Maximum mean total carbon stock (107.00 t ha^{-1}) was observed in pure plantations of Poplar at an average density of 1066 trees/hectare. It was 2.68 - 4.86 times higher than other perennial plant based system and about 12.40 - 22.57 times higher than annual crops or pure grasslands.

Chauhan et al. (2009) studied total above and belowground biomass and, carbon stock in different parts of agroforestry tree species (root, stem and leaf). They reported that carbon stock in aboveground biomass was more as compared to belowground biomass. Gupta *et al.* (2009) reported that poplar based agroforestry system improves aggregation of soil through input of huge amount of organic matter form leaves. The extent of improvement may be affected by the age of the Poplar trees and soil type. They analysed the surface and subsurface soil samples from agroforestry and adjoining non agroforestry sites with different years of Poplar plantation (1, 3 and 6 years) and varying soil textures (loamy and sandy clay) and found that soil carbon increased from 0.36 in sole crop to 0.66 % in agroforestry soils. Also, the soil organic carbon increased with increased in tree age. Further, they found that the soils under agroforestry had 2.9 - 4.8 Mg ha^{-1} higher soil organic carbon than in sole crop. They recorded that Poplar trees can sequester higher soil organic carbon in 0 - 30 cm profile during the first year of their plantation (6.07 Mg $ha^{-1}year^{-1}$) than the subsequent years (1.95 - 2.63 Mg ha^{-1} $year^{-1}$).

Homegardens sustainable agroforestry system is popular in tropics. Depth wise study of soil carbon stock under varying sizes and age class homegardens was conducted by (Saha et al., 2009) in Thrissur district, Kerala, India. The results so obtained revealed that the soil C stock was directly related to plant diversity of homegardens, those with higher species richness and tree density had higher soil carbon as compared to those with lower number of plant species. Overall, within 1.0 m profile, soil C content ranged from 101.5 to 127.4 Mg ha^{-1}. Soil C content especially below 50cm depth was higher in older homegardens.

Nair et al. (2009) showed that the carbon sequestration potential of the vegetation component (above and belowground) varied from 0.29 Mg ha^{-1} $year^{-1}$ in a fodder bank agroforestry system of West African Sahel to 15.21 Mg ha^{-1} $year^{-1}$ in mixed species stands of Puerto Rico. Soil carbon estimates ranged from 1.25 Mg ha^{-1} in a Canadian alley cropping system to 173 Mg ha^{-1} in an Atlantic coast silvopastoral system in Costa Rica. In general, agroforestry on arid, semiarid, and degraded sites had a lower carbon sequestration potential than those on fertile humid sites; and temperate agroforestry systems had relatively lower carbon sequestration rates as compared to tropical systems.

Zhu et al. (2010) estimated C stocks in vegetation, detritus, and soils of 22 forest plots along an altitudinal gradient from 700 - 2,000 m to quantify altitudinal changes in carbon storage of major forest ecosystems in Mt Changbai, Northeast China. Total ecosystem averaged C density was 237 t C ha^{-1} (ranging from 112 to 338 t C ha^{-1}) across all the forest stands, of which 153 t C ha^{-1} (52–245 t C ha^{-1}) was stored in vegetation biomass, 14 t C ha^{-1} (2.2–48 t C ha^{-1}) in forest detritus (including standing dead trees, fallen trees, and floor material), and 70 t C ha^{-1} (35–113 t C ha^{-1}) in soil organic matter (1m depth). Among all the forest types, the lowest total vegetation C density but the highest soil organic carbon (SOC) density occurred in *Betula ermanii* forest, whereas the highest detritus C density was observed in *Picea* and *Abies* forests. The C density of the three ecosystem components showed distinct altitudinal patterns: with increasing altitude, vegetation C density decreased significantly, detritus C density first increased and then decreased, and SOC density exhibited increasing but insignificant trends

Nakakaawa et al. (2010) analysed changes in carbon stocks and tree diversity on carbon and non-carbon farmers' plots in a pilot carbon offset project implemented by smallholder farmers in south-western Uganda. On carbon farmers plot's, results indicated a decline in carbon density on farmlands and an increase in grasslands. On non-carbon farmers' plots, there was an increase in both farmland and grassland carbon density. Carbon densities in farmland were significantly ($t = -2.38$; $P = 0.023$) higher than those in grasslands. There were strong positive correlations between carbon density and tree diversity.

Yadava (2010) conducted experiment on biomass production and carbon sequestration in different agroforestry system He reported that above ground biomass and carbon stock was more as compared to belowground biomass and carbon stock.

Fang et al. (2010) studied the effect of three poplar intercropping designs and two intercropping systems (wheat-corn and wheat-soybean cropping systems) on biomass production and C stocks in poplar intercropping systems at Suqian ecological demonstration garden of fast-growing poplar plantations in north western Jiangsu. Overall, total C stock in the poplar intercropping system was affected by configurations and cropping systems. They reported highest total C stock of 16.7t C ha^{-1} for the wheat–soybean cropping system and 18.9 t C ha^{-1} for the wheat–corn cropping system in a particular poplar intercropping system i.e, configuration-A. They also studied C concentration in poplar-biomass components and recorded highest value in stem wood and the lowest in fine roots, ranging from 459.9 to 526.7 g kg^{-1}.

Saha et al. (2010) examined soil C storage, an indicator of C sequestration potential, in homegardens (HGs), natural forest, and single-species stands of coconut (*Cocos nucifera*), rice (*Oryza sativa*), and rubber (*Hevea brasiliensis*) in Thrissur district of Kerala, India. Total C stock (Mg ha^{-1}) was highest in forests (176.6), followed by managed tree based systems, and lowest in rice-paddy field (55.6).

Chavan and Rasal (2011) studied the potential and status of carbon sequestration of *Eucalyptus* trees in Aurangabad. They observed that quantity of carbon stock sequestered in aboveground and belowground standing biomass of *Eucalyptus* sp. was 254.50 t ha^{-1} and 66.17t ha^{-1}, respectively while, total sequestered carbon of *Eucalyptus* sp. in 2847 hectares area was 320.67 t ha^{-1}.

Chauhan et al. (2011) assessed the carbon sequestration potential under one to six year block plantation of poplars. They reported the enrichment of the soil organic carbon through litter and roots in the surface layer of soil (0-15 cm) under poplar blocks as compared to open fields with wheat crop only. The carbon storage potential in agroforestry system was recorded very high in comparison to sole crop. The carbon storage in agroforestry system increased with the age of the plantation and the major contribution came from the timber, roots and litter.

Rizvi et al. (2011) noted that the poplar based agroforestry systems are prevalent among farmers of Saharanpur (UP) and Yamunanagar (Haryana) districts of northwestern India. They reported that a contribution of poplar plantations at a rotation period of 7 years to carbon storage was from 27–32 t ha^{-1} in boundary systems, whereas it was 66–8 t ha^{-1} in agri-silviculture systems.

A simulation study for potential carbon sequestration and soil organic carbon of agroforestry systems in indo-gangetic plains was conducted by Ajit *et al*. (2013). They estimated carbon sequestration of existing agroforestry systems to the tune of 0.111, 0.126 and 0.551 Mg C ha^{-1} $year^{-1}$ for Sultanpur, Dinajpur and Ludhiana districts, respectively. They further argued that carbon sequestration potential of agroforestry systems increased with increasing tree density per hectare. They found that soil organic carbon in the baseline ranged from 8.13 to 9.12 Mg C ha^{-1} and is expected to increase from 8.63 to 24.51 Mg C ha^{-1}.

The role of agroforestry in enhancing and maintaining long-term soil productivity and sustainability has been well documented. The incorporation of trees and crops that are able to biologically fix nitrogen is fairly common in tropical agroforestry systems. Non N-fixing trees can also enhance soil physical, chemical and biological properties by adding significant amount of above and belowground organic matter and releasing and recycling nutrients in agroforestry systems. The pH of the soils in *Acacia auriculiformis* plantations at different depths *viz.,* 0-20, 20-40 and 40-60cm indicated that the pH was decreased under plantation (4.7, 4.7 & 4.8) compared to adjacent fallow land (5.0, 4.9 and 4.9) at three different depth respectively (Sankran et al. 1993).

Seiter et al. (1995) demonstrated the use of N-fixing red alder (*Alnus rubra*) in a maize alley cropping system in Oregon. They observed, using an ^{15}N injection technique, that

32–58% of the total N in maize was obtained from N fixed by red alder and that nitrogen transfer increased with decreasing distance between the trees and crops.

Thomas et al. (2007) in their study on soil carbon in 2- row shelterbelt of red cedar (*Juniperus virginiana*) and scotch pine (*Pinus sylvestris*) in USA reported that the average soil organic carbon in 0-15 cm layer within the shelterbelt (3,994 g m^2) was significantly greater than in the cultivated fields (3,623 g m^2). The tree litter contained an additional amount carbon around 1300 g m^2.

Udawatta et al. (2008a) examined the role of agroforestry buffers in improving soil porosity by using high-resolution X-ray computed tomography in the mid-west region of the United States. They observed that average pore paths for grasses and agroforestry buffer strip soils were three and five times greater, respectively, than for soils under maize-soybean rotation. In a companion study, Udawatta et al. (2008b) further showed improved soil aggregates stability, soil carbon, soil nitrogen, and soil enzyme activity in soils under agroforestry buffers compared to row crops.

Ravindranath et al. (2008) assessed that if the current trend of afforestation and reforestation continues i.e. currently 67.83 m ha of area is under forest and is projected to reach 72 m ha by 2030, the forest carbon stock in India could increase from 8.79 Gt C in 2006 to 9.75 Gt C by 2030 - an increase of 11%.

Singh et al. (2010) evaluated the effect of pure stands of tree species and poplar-based agroforestry system on soil organic carbon (SOC) and available N, P and K contents. They observed that soil organic carbon and available nutrients were significantly higher in the surface soil depth (0-15 cm) than the lower depths, irrespective of tree species. Organic carbon and available nutrients were significantly more under all the tree species compared to control in the surface layer. Organic carbon increased by 90.3 per cent under Siris followed by Kikar (84.5%), Sissoo (82.2%) and Subabul (80.8%) over control. In poplar-based agroforestry system, the average contents of organic carbon, N, P and K were higher by 22.2, 10.2, 33.6 and 4.5 per cent respectively, than pure pearl millet-wheat rotation. However, the interaction effects of soil depths and cropping systems were significant only for organic carbon and available P.

Negi and Gupta (2010) investigated soil organic carbon (SOC) up to 30 cm in Giri catchment under different land uses viz., kail, deodar chir pine and sal forests, different orchards and agriculture land. They reported among forests maximum SOC store occurred in the soils of kail forests (93.47 t ha^{-}) and minimum in sal forests (47.29 t ha^{-}). The SOC in orchards and agriculture lands was to the tune of 53.96 t ha^{-1} and 53.62 t ha^{-1}, respectively. Altitudinally, SOC increased with increase in elevation with maximum SOC at altitude of 2500 m (91.37 t ha^{-1}) followed by 2000-2500 m (88.68 t ha^{-1}) and least at altitude below 1000 m (54.34 t ha^{-1}). They estimated that Girl catchment has 8.16 million tonnes SOC store in the forest areas and 3.16 million tonnes under agriculture land use.

Pal et al. (2013) studied the impact of five types of land use viz., natural forest of *Pinus roxburghii*, grassland, horticulture, agriculture and wasteland on Alfisol soil fertility at four depths i.e., 0 - 15, 15 - 30, 30 - 45 and 45 – 60 cm at Dharamshala in north-west Himalaya, India. The observed that OC content was higher in forest (3.01%), followed by grassland (2.16%) and was least (0.36%) in deeper layers of agriculture.

2.6. ECONOMIC RETURN OF DIFFERENT LAND USE SYSTEMS

Das et al. (1993) conducted a study on different land use system viz. annual cropping agrihorticulture and agrisilviculture on a semi-arid alfisol. He reported that the agri-horticultural system required more cash input but gave a benefit-cost ratio of 2.16 compare to 1.95 with annual cropping and 1.52 with agri-silviculture system.

Dyal et al. (1996) evaluated agri-silvi-horticulture system in Shivalik hills, India, whose components were *Leucaena leucocephala*, *Citrus aurantifolia*, *Carrica papaya* and *Curcuma longa*. They found that mean annual returns were Rs. 17,746 and Rs. 15, 092 under agri-silvi-horticulture as against Rs. 7,752 and Rs. 3,342/ha from agricultural cropping system (maize + black gram/wheat + mustard/maize + wheat) under irrigated and rain fed conditions, respectively.

Kumar (1996) conducted a study on bio economic appraisal of agroforestry systems in Himachal Pradesh and found that agri-horticulture system yielded the highest net returns followed by agri-horti-silviculture, agri-silviculture and minimum in sole cropping.

Singh et al. (1998) evaluated the productivity and economics of eight intercrops in four crop sequences and reported that the vegetable intercropping did not cause any adverse effect on the yield and income in *Eucalyptus*. However, yield of all intercrops reduced with increase in the age of the trees. Among the crops sequences faba bean - colocasia (Rs 51, 037) was the best followed by french bean - turmeric (Rs 39,121), potato -onion (Rs, 37,861) and tomato - cowpea (Rs 32,797), cropping systems.

Neupane and Thapa, (2001) studied practices that minimises soil degradation, increase in crop yields and raise income of farmers to sustain the agricultural productivity in the hills of Nepal. They said that farmlands are undergoing changes in response to increasing population pressure, deforestation and subsistence. They examined the impact of agroforestry systems on farm income and found that cost-benefit ratio of agroforestry systems was more profitable than conventional agriculture. In their opinion mulberry tree for sericulture could increase farm income. They further that agroforestry has great potential for enhancing food reduction and farmers income.

Tomar and Bhatt (2004) conducted a field experiment in a six year old plantation of guava (*Psidium guajava* cv. Allahabad safeda), Assam lemon (*Citrus* lemon cv. Local) and peach (*Prunus persica* cv. TA 170) during 2002 and 2003, on acid alfisol under rain fed condition in Umiam, Meghalaya, India to study the performance of upland rice cultivars as intercrops in the existing fruit plantation and to study the overall productivity of agri-horticulture systems. They found that on an average, the maximum net monetary benefit per hectare was recorded from peach intercropped with rice (Rs. 48,044), followed by guava (RS. 27,887) and Assam lemon (Rs. 20,991), irrespective of rice cultivars. Peach, guava and Assam lemon exhibited 5.09, 2.95 and 2.22 fold higher net return, respectively, compared to the control. Peach based agroforestry systems was found to be most promising for rain fed agricultural conditions in the north-eastern region of India in general and Meghalaya in particular.

Dwivedi et al. (2007) noted that the major motivating factors for adoption of commercial agroforestry systems in western Uttar Pradesh was assured income, whereas the availability of fuelwood was the prime reason for patronizing trees on farmlands under traditional agroforestry systems. Fuelwood (50%) was the major factor in commercial agroforestry adoption followed by additional income (24.4%) and shade (17.5%) in traditional agroforestry. The net return from tree produce ha^{-1} per annum in traditional systems was Rs. 989, 541 and 440 for marginal, small and medium farmers, respectively. In commercial region, B: C ratio was higher (3.00) for poplar-based agri-silviculture than poplar (2.84) and *Eucalyptus* (2.68) boundary plantation agroforestry systems.

Sharma et al. (2007) studied the role of traditional large cardamom agroforestry systems (*Amomum subulatum*) on enhancing the ecosystem services in the Eastern Himalayas. They contended that agroforestry systems are efficient management systems with output to input ratio of more than 13 as compared to rainfed agriculture with value of 1.85. Cost-benefit analysis showed that the cardamom agroforestry is 5.7 times more profitable to farmers as compared to the rainfed agriculture.

Sharma et al. (2008) studied the economics of kinnow based agroforestry system with wheat and gobhi - sarson in Himachal Pradesh. Average yields (q/ha) of wheat (18.68) and gobhi - sarson (10.34) under kinnow plants were less in comparison to that of wheat (22.34) and gobhi - sarson (12.00) grown in open. However, overall return from agrihorticulture system was higher in comparison to sole crops. Cultivation of gobhi - sarson with kinnow was observed to be more profitable than wheat. The maximum returns per hectare (Rs. 56407.55) were realized under kinnow - gobhi - sarson combination.

Rajput (2010) in his study on bio-economic appraisals of different land use systems in Kullu district (HP) of temperate north-west Himalaya observed that orchard (apple) + vegetable land use system at 1600-1900 m earned a net profit of Rs 10,23,430 ha^{-1} yr^{-1} while, agri-horticulture land use system at 1700-2000 m earned a net profit of Rs. 9,69,194 ha^{-1} yr^{-1}. He calculated that total benefits (net profit + carbon credits) at 1600-2000 m were maximum in orchard (apple) + vegetable based cropping system and at 1700-2000 m in fruit based agri-horticulture system.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled **"Pattern, composition and vegetation dynamics of traditional agroforestry systems in Giri catchment, Himachal Pradesh."** was conducted during the years 2011 and 2012. The details of the study area, sampling sites, methodology adopted and materials used for the investigation are described as under:

3. 1 STUDY AREA

The present study was carried out in Giri catchment, a component of Giri river in Himachal Pradesh, located between 30° 33′ 48″ and 31° 16′ 08″ N latitude and 77° 02′ 32″ to 77° 38′ 22″ E longitude. It has an area of about 2389 km^2 (Rao et al. 1989). Catchment is distributed in Shimla, Sirmour and Solan districts of Himachal Pradesh that includes 135 sub-watersheds. The present investigation focused on traditional food and fodder resources in chir pine zone of Giri catchment, located in Solan and Sirmour districts of Himachal Pradesh.

Giri river is an important tributary of the Yamuna river and drains a part of south-eastern Himachal Pradesh. The Giri River originates at the altitude of 3358 m at Kupar Tibba on Kupar Dhar just near Jubbal village and flows down in the south-eastern direction and courses through the hills of Kot-Khai and Tatesh parts of Shimla district, and enters Sirmour district on its south-west side. The water from the Giri river passes through a tunnel to the power house of Giri nagar that leads it into river Bata. At village Mandoplasa of Sirmour district Giri river debouches into Yamuna river at Rampur Ghat below Mohkampur. Around sixty four percent of the Giri catchment area falls under high altitude hills from 1500 m to 3000 m. The area under mid altitude hills ranges from 1000 m – 1500 m and low altitude hills less than 1000 m are 30 and 5 per cent, respectively. Almost the whole catchment contains steep to very steep slopes.

3.1.1 Vegetation

In Giri catchment, the forest covers about 17 % of its geographical area in which lower areas are covered by scrubs and as the altitude increase corresponding to the sub-tropical climate chir pine (*Pinus roxburghii*) is the most prominent species, while oak

(*Quercus leucotrichophora*) mixed with conifers like Kail (*Pinus wallichiana*) and Deodar (*Cedrus deodara*) dominate the higher temperate zone. Fir (*Picea smithiana*) and Spruce (*Abies pindrow*) occur in the extreme north at higher altitude. The forest types found in this catchment are: (a) Northern mixed deciduous forest (700 - 1200 m) with main species as *Acacia catechu*, (b) upper Himalayan chir pine forest (1200 - 1700 m) with the main species as *Pinus roxburghii* (c) Himalayan moist temperate ban oak forest (1800 - 2000 m) with main speices as *Quercus leucotrichophora*, (d) Himalayan moist Moru oak forest (1900 - 2400 m) with main species as *Quercus dilatata* (e) Western mixed coniferous forest (2200 - 2800 m) with main species as *Abies pindrow*, and (f) Sal forest (700 - 860 m) with main species as *Shorea robusta*.

The dominant grassland type in the catchment in chir pine zone is *Themeda – Arundinella* and in upper temperate areas it is Temperate-Alpine type (Dabaghao and Shankaranarayan, 1973). In tropical and sub-tropical areas of this catchment scattered trees and bushes are found in grasslands and barren areas. The important grasses in these grasslands are: *Heteropogon*, *Chrysopogon*, *Arundinella*, *Apluda*, *Imperata*, *Themeda*, *Dicanthium*, and *Cymbopogon* species. The grasslands in temperate region, above 1800 m altitude bear steep slope, and have grasses like *Agropyron*, *Dactylis*, *Poa*, *Bromus* and *Festuca* species with significant occurrence of sedges and herbs and, abundant medicinal plants.

3.1.2 CLIMATE

Climate in this catchment varies with altitude, it is sub-humid and sub-tropical in lower part of the track lying in the Shivaliks to wet-temperate in the upper part in north-west Himalaya. The annual precipitation in the catchment varies from around 800 mm at Kot-Khai to 1950 mm at Sarahan. The mean annual precipitation in the catchment is around 1250 mm. The snow fall is a normal feature in areas above 1800 m. The droughts occur both in pre and post monsoon periods with March, April, May, October and November being generally dry months. The region has distinct seasons of summer (April to mid-June), monsoon (mid-June to September), autumn (October-November) and winter (December-March). At the source of Giri river in Kot-Khai tehsil of Shimla district, rainfall is less but in lower reaches of the catchment, rainfall is more and its major proportion is received during the monsoon months (June to September). Solan, in Giri catchment, is located in the chir pine zone. The meteorological record of Nauni in Solan, a part of the chir pine zone, for the years 2000 to

2012 revealed that mean annual maximum air temperature in this area varied between 25.43 to 25.51 °C and mean minimum annual air temperature fluctuated between 10.42 to 10.92 °C (Fig. 1). Mean annual air temperature in this area during 2000 - 2012 varied between 17.92 to 19.60 °C. The annual rainfall in the area ranged from 520.60 to 1788.90 mm and the mean annual relative humidity fluctuated between 54.17 to 64.13 %. However, during the years of study i.e., 2011 and 2012, mean annual maximum air temperature in this area was 25.43 and 25.51 °C, mean annual minimum air temperature was 10.42 and 10.92 °C and mean annual air temperature was 17.92 and 18.21 °C, respectively. The annual rainfall received in the area in these years was 520.60 mm in 2011 and 747.60 mm in 2012. It was recorded that 71 % and 80 % of the annual rainfall was received in rainy season (June to September) in the years 2011 and 2012, respectively. The mean relative humidity during the year 2011 was 57.16% and during the year 2012 it was 60.42 % (Fig 1).

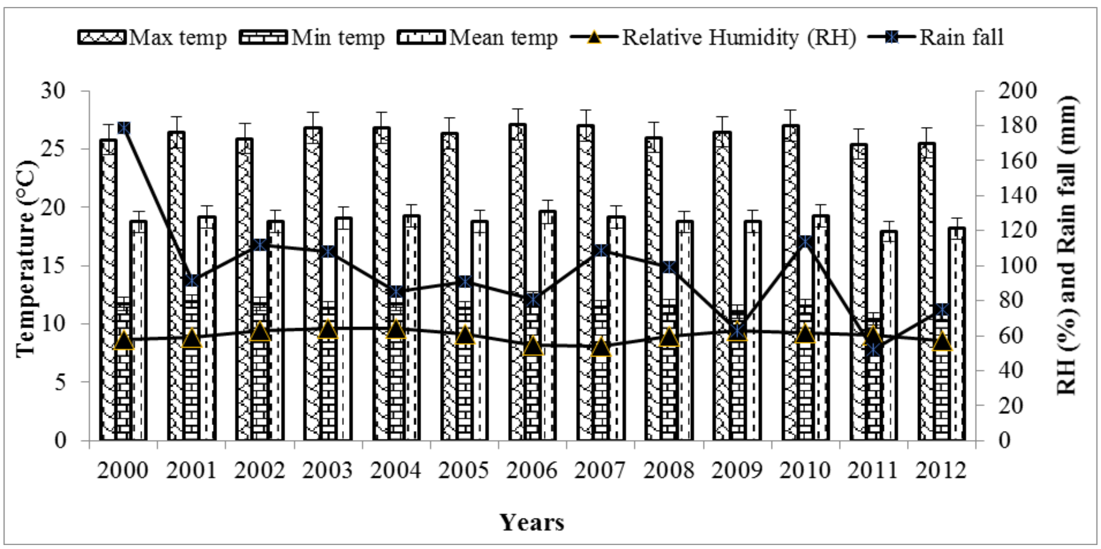

Fig.1 Meteorological record for Nauni area during the years from 2000 to 2012

3.1.3 Selection of representative sub-watersheds in the Giri catchment for socio-economic/vegetation sampling:

Out of the 135 sub-watersheds in Giri catchment, 13 sub-watersheds viz., SW_1 to SW_{13} were randomly selected to study socio-economic status and vegetation composition in them. The respective nomenclature given to each sub-watershed by Soil and Water Conservation Board of India, New Delhi is: SW_1 = Ga_3b, SW_2 = Ga_3c, SW_3 = Ga_3d, SW_4 = Ga_1j, SW_5 = Ga_2k, SW_6 = Gc_1a, SW_7 = Gc_1c, SW_8 = Gc_1f, SW_9 = Gd_1c, SW_{10} = Gd_1f, SW_{11} = Ga_1p, SW_{12} = Ga1n and SW_{13} = Gd_3a (Fig. 2). Each selected sub-watershed was delineated into three elevations for further investigations viz., elevation E_1 (900-1300 m), E_2 (1301-1700 m) and E_3 (1701 - 2100 m).

Thus, the total numbers of experimental sites (treatments) available from which the observations were taken was:

Number of sub-watersheds	:	13
Number of elevations in each sub-watershed	:	03
Total number of experimental sites (treatments)	:	13 x 3 = 39

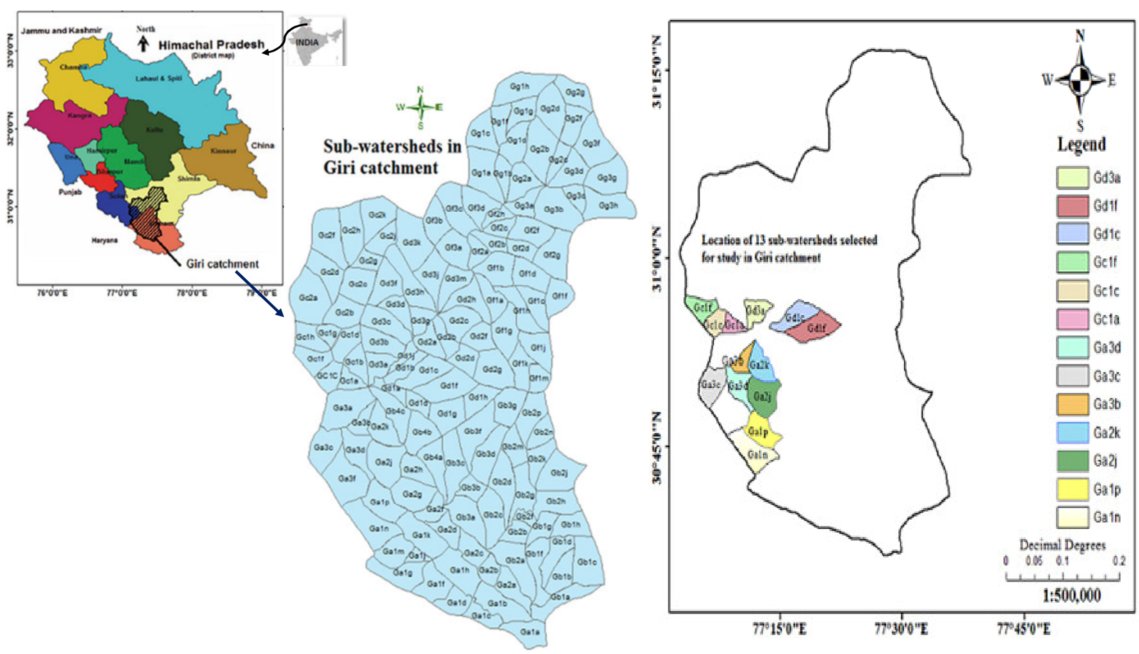

Fig.2 Location of the Giri catchment and sub-watersheds in it

3.2 PROCESS OF SOCIO-ECONOMIC SURVEY

At every elevation in the selected sub-watersheds, total number of villages were counted. The number of villages at any elevation did not exceed 10. Hence, one representative village was selected at every elevation in the selected sub-watersheds for socio-economic analysis. The number of households in a village fluctuated from 51 to 53. Out of the total households, 5 household heads were selected for personal interview through pre-tested schedule as given in Appendix - I to gather information on the following parameters:

i) Socio economic parameters

a) Land holding

i) Land holding size

ii) Land use: A) Forest, B) Horticulture, C) Agriculture , D) Grassland/pasture,
E) Cultivated land, F) Barren land and G) Fallow land

b) Demography: A) Family size, B) Number of males and females in a family and
C) Education level of family members

c) House hold activities

A) Animal numbers and their types B) Fuel wood consumption and C) Fodder consumption

3.3 VEGETATION ANALYSIS

3.3.1 Identification of existing agroforestry system:

Agroforestry systems prevalent in the study area were classified on the basis of structure (nature and arrangement) and function (role of output) of components (Nair, 1985). Stratified classification of agroforestry practices as given by Zou and Sanford (1990) was used to indicate the system types and their system units. A system type was named by considering the major components whereas, system unit was termed on the basis of major functional unit in combination with specific tree species or other related components. Hence, functional units like food grains, vegetable and pulses in agriculture; specific fruit trees in horticulture, grasses in grasslands and trees/grass species in silvipasture were considered to identify systems and system units. The different components of agroforestry systems were identified as below:

a) Primary components

The components occupying the larger area of the total unit area and serving the major function i.e. production of primary output needed by the farmers was termed as primary component.

b) Secondary components

The component occupying relatively lesser area of the total unit area compared to area under primary component and yielding secondary needs of the farmers, was termed as secondary component.

In present study, the land uses on which the agrarian people of the catchment are predominantly dependent were considered for further vegetation analysis. Thus, Cultivable, Chir pine based forests and grasslands land uses were selected for study. Using above mentioned frame-work for identifying agroforestry systems, four distinct types of agroforestry systems existing in the catchment were taken for study in which different system units were identified. Thus, in all, six systems were explored for vegetation analysis at each elevation in selected sub-watersheds, which are as follows:

a) S_1 = Agrisilviculture system (AS)
b) S_2 = Agrihorticulture system (AH)
c) S_3 = Agrihortisilviculture system (AHS)
d) S_4 = Agrisilvihorticulture system (ASH)
e) S_5 = Silvipasture system (SP)
d) S_6 = Grassland (GS)

3.3.2 Vegetation analysis

The species composition of herbaceous vegetation, agriculture crops, shrubs and trees (for timber, fruit and fodder) were recorded in standard sample plots. In agroforestry systems, the agriculture crop was sampled from plot size of 1 m x 1 m, while varying plot sizes (less than 20 m x 20 m) were used to measure tree parameters in agroforestry systems depending upon the field area. In silvipasture and grassland, standard sample plot of size 0.1 ha was laid out at each elevation in the selected sub-watersheds for taking observations on herbs, shrubs and trees as described below:

a) Herbs

Herbage sampling was done in 6 quadrates, each of size 50 cm x 50 cm (standardized through species area curve method) in all 39 sample plots. The herbage was harvested at ground level at the time of peak growth in the month of September. The grasses sedges, legumes and forbs were segregated into species in each quadrat. The tillers of each species were counted and their basal area was determined at ground level. Their relative density, relative basal area, relative frequency and Importance Value Index (IVI) were determined following Mishra (1968):

$$\text{Relative density} = \frac{\text{Density of individual species in a quadrat}}{\text{Total density of all species in a quadrat}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Basal area of individual species in a quadrat}}{\text{Total basal area of all species in a quadrat}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Frequency of individual species in a quadrat}}{\text{Total frequency of species in a quadrat}} \times 100$$

IVI = Relative density + Relative dominance + Relative frequency

b) Shrubs

In each sample plot, two sub-plots of size 10 m x 10 m were marked to study shrubs. Plants of shrub species in each sample plot were counted to determine shrub density. Stratified sampling was done to segregate large, medium and small shrub plants, based on size and number of stems in each plant. Proportionate sampling was done in different size of shrub plants. In each plant stem diameter was taken at ground level with vernier caliper. Total basal area of a shrub plant was calculated by adding basal area of constituting stems.

c) Trees

In each sample plot, the numbers of trees were counted to calculate tree density. The dbh (diameter at breast height) of individual trees species was measured by tree caliper and its height was determined by Ravi multimeter.

3.3.3 Biomass estimations

a) Herbs

The aerial portions of species segregated from harvested quadrates for phytosociological analysis were stored in separate paper bags for determining the aboveground biomass. The below ground biomass in each quadrat was estimated by digging 25 cm x 25 cm x 25 cm monolith from each quadrat. The soil was gently removed by tapping. Roots of different species were segregated and stored in different paper bags. All plant samples were oven dried at 70^{o}C till a constant weight was achieved. The dried samples of root and shoot of each species were weighed to determine aboveground and belowground biomass of each species.

b) Shrubs

Aboveground biomass of each shrub selected for phytosociological studies was determined by collecting its stem, branch and leaf samples. Their fresh weight was taken in field and stored in separate paper bags. The roots were extracted from the soil, washed in running water and stored in paper bags. Plants samples dried in oven at 72^{o}C till the constant weight was obtained and were weighed to determine their dry weight.

c) Trees

Volume equations developed for specific tree species for this region were used to calculate volume of stem of trees (FSI, 1996). The stem biomass was calculated by multiplying volume of the stem by its specific gravity.

Stem biomass (t/ha) = VOB x WD

Where, VOB = volume over bark

WD = volume weighted average wood density

The aboveground biomass of a tree (stem + leaves + branches) was calculated by multiplying biomass of stem with a biomass expansion factor as calculated by IPCC (2006).

Aboveground biomass (t/ha) = Stem biomass (t/ha) x BEF

BEF = biomass expansion factor (Appendix-V)

Belowground biomass of a tree was calculated by multiplying its aboveground with a standard factor of 0.20 (IPCC, 1996). The sum of aboveground and belowground was taken as total biomass of tree.

d) Agriculture crop biomass

The biomass production in cultivated land was determined by taking random samples of Kharif and Rabi crops in the farmers' field from 1 m x 1 m quadrates.

Belowground biomass of agriculture crops were calculated by multiplying aboveground biomass with a factor of root: shoot ratio of particular crops.

3.3.4 Carbon stock estimation

Above and belowground biomass carbon stock in vegetation was determined by multiplying vegetation biomass with default value of 0.5 (IPCC, 1996). Total carbon stock was determined by adding aboveground and belowground biomass carbon.

3.4 SOIL

3.4.1 Collection of soil samples

Composite soil samples from depth 0-30 cm were collected from various land uses. They were air dried, crushed and passed through 2 mm sieve and stored in cloth bags.

3.4.2 Soil analysis

Bulk density of each sample of soil was determined by weighing bottle method (Singh, 1980) and organic carbon by following Walkley and Black, (1934).

3.4.3 Carbon stock

The carbon stock in the soil was computed by using the formula given by the Nelson and Sommers, (1996) as follows:

C (t/ha) = [Soil bulk density (g/cm^3) x 0.30 cm x C (%)] x 100

3.5 ECONOMIC YIELD

The economic yield in different agroforestry systems was calculated by determining the following:

i) Production cost (Input)

Cost of cultivation is the total amount of expenditure (variable and fixed cost) done on producing yield.

ii) Gross return

The utilizable biomass of each functional unit in a system was given the current market value for estimating total return from a system.

iii) Net returns

Net Return = Gross return – Production cost

3.6 STATISTICAL ANALYSIS

The data obtained were subjected to statistical analysis as per the procedure suggested by Gomez and Gomez (1984). Wherever, the effects exhibited a significance of 5 per cent level of probability, the critical difference (CD) was calculated. Analysis was carried out by using statistical package "STATISTICS".

Chapter-4

EXPERIMENTAL RESULTS

4.1 SOCIO ECONOMICS OF STUDY AREA

The study on socio-economics and demography of households in an area gives an idea on types of prevailing agroforestry systems and their level of management. The demographic and socio-economic features of the 65 households sampled in the present study are presented in Tables 1-4 and described as under:

4.1.1 Villages and their demographic features

The number of villages in sub-watersheds selected for study varied from 5 to 10 at elevation E_1, 4 to 12 at elevation E_2, and 4 to 8 at elevation E_3. The average number of villages at elevations E_1, E_2 and E_3 was 6, 8 and 5, respectively (Table 1). The average number of households in villages at elevations E_1, E_2 and E_3 was 52, 54 and 51, respectively. Family size represented the total individuals in a household comprising of male and female persons (Table 1). It was recorded that the average family size of sampled households was 6.85, 6.97 and 7.09 persons/household at elevations E_1, E_2 and E_3, respectively. The male population at elevation E_3 was 51.84 per cent, which was more than female population of 48.16 per cent with sex ratio of 941 females to 1000 males. At elevation E_2, highest sex ratio, 971 females to 1000 males was recorded. The lowest sex ratio existed at elevation E_1 with 929 females to 1000 males (Table 1).

Table: 1. Number of villages, households, family size and sex ratio at different elevations in Giri catchment of HP

Elevation \ Character	Average number of villages in a sub-watershed	Average number of households (families) in a village	Average family size in a village	Male persons	Female persons	Sex ratio
E_1 (900 – 1300 m)	6	52	6.85	231 (51.84)	211 (48.16)	929
E_2 (1301 – 1700 m)	8	54	6.97	230 (50.77)	223 (49.23)	971
E_3 (1701 - 2100 m)	5	51	7.09	239 (51.84)	222 (48.16)	941
Mean	6.33	52.33	6.97	233.33	218.67	947

Note: -Number of households (families) sampled at each elevation was 65.
-Values in parenthesis are the percentages.

4.1.2 Qualification of inhabitants

Education is an important ingradient in the development process and it has positive bearing on the managerial skills and decision-making ability of the farmers. The qualification (primary, middle, matric, intermediate, graduate and post graduate) of the members of 65 households at each elevation showed that on an average 87.24% persons were literate at elevation E_2, closely followed by 85.70% at elevation E_3, and 85.91% at elevation E_1 (Table 2).

Table: 2. Qualification and literacy rate of people in Giri catchment of H.P.

Qualification / Elevation	Number of people and their qualification							Literacy (%)
	Primary	Middle	Matric	Intermediate	Graduate	Post graduate	Illiterate	
E_1(900-1300m)	88 (19.90)	88 (19.76)	94 (21.28)	64 (14.59)	38 (8.32)	6 (1.41)	64 (14.74)	85.91
E_2(1301-1700m)	86 (18.26)	117 (25.73)	105(23.50)	53(12.51)	26(5.86)	5(1.38)	59(12.76)	87.24
E_3(1701m-2100m)	69 (15.03)	115 (25.00)	108(24.09)	71(15.34)	31(6.86)	6(1.41)	61(13.14)	85.70

Note: - Number of people asked for their qualification at elevation E_1 was 442, at elevation E_2 was 453 and at elevation, E_3 was 461.
-Values in parenthesis are the percentages

4.1.3 Land use pattern

Land is a basic resource in the agrarian economy. Size of the land holding is an important variable that directly affects the household income, consumption and savings. A perusal of data in Table 3 reveals that the land holding per household in the selected sub-watersheds at elevation E_3, was higher (1.23 ha) as compared to elevation E_1, (1.09 ha) and E_2 (0.99 ha). It was recorded that at elevation E_1, 79.32% households cultivated land holding for meeting out their food requirements where as at elevation E_2, 78.30% and at elevation E_3, 77.13% households cultivated their land holdings. Orchards occupied, 4.50% of land holding of a farmer at elevation E_3, in comparison of 3.83% at elevation E_2, and 1.28% elevation E_1.

Fodder requirements are met out from pastures and fallow lands that occupied less than 25% land of a household. The area under pasture and fallow land constituted 12.05 per cent and 6.35 per cent of operational land holding at elevation E_1; 8.49 per cent and 9.37 per cent at elevation E_2 and 7.10 per cent and 11.27 per cent at elevation E_3.

Table: 3. Land utilization pattern at different elevations in Giri catchment of H.P.

Land use	Land holding (ha)		
	Elevation E_1 (900 - 1300 m)	Elevation E_2 (1301 - 1700 m)	Elevation E_3 (1701 - 2100 m)
1. Cultivated land	0.82 (79.32)	0.75 (78.30)	0.95 (77.13)
2. Orchards	0.04 (1.28)	0.05 (3.83)	0.06 (4.50)
3. Pasture	0.14 (13.05)	0.09 (8.49)	0.09 (7.10)
4. Fallow Land	0.10 (6.35)	0.09 (9.37)	0.14 (11.27)
Operational landholding size	1.09 (100.00)	0.99 (100.00)	1.23 (100.00)

Note: -Number of families sampled at each elevation was 65
-Values in parenthesis are the percentages of operational land holding

4.1.4 Livestock, fuel and fodder consumption

Livestock rearing is an integral part of farming system in the hilly states. They not only provide milk, meat, wool and manure but also serve as main source of energy for ploughing and transport. The productivity of the crops is enhanced by the use of Farm Yard Manure (FYM).

Table: 4. Livestock number, fuelwood and fodder consumption of households at different elevations in Giri catchment of H.P.

Elevation	Average livestock number per household						Fodder (kg/day/ household)	Fuelwood (kg/day /household)
	Hiefer	Cow	Bullock	Goat	Sheep	Buffaloes		
E_1 (900 - 1300m)	2.23	3.77	2.24	3.36	1.00	0.91	49.34 ± 2.00	22.77 ± 1.02
E_2 (1301 - 1700m)	2.71	5.67	2.40	3.24	1.23	1.08	56.78 ± 1.40	25.63 ± 2.15
E_3 (1701 - 2100m)	3.06	6.51	2.35	4.22	1.77	0.55	60.20 ± 1.54	30.92 ± 2.08

It was recorded that number of heifers, cows, goats and sheep per household was highest at elevation E_3 (Table 4). Buffaloes were higher in number at elevation E_2 (1.08/household). The average number of cows per household at elevations E_1, E_2 and E_3 was: 3.77, 5.67 and 6.51, respectively. Likewise, the number of goats per household at elevations E_1, E_2 and E_3 was: 3.36, 3.24 and 4.22, respectively.Cows and goats accounted for the majority of livestock in a household.

In Giri catchment, the fodder consumption was highest at elevation E_3 (60.20 ± 1.54 kg/household/day) followed by elevation E_2 (56.78 ± 1.40 kg/household/day) and elevation E_1 (49.34 ± 2.00 kg/household/day). The common tree species used for fodder in sub-watersheds are *Grewia optiva*, *Celtis australis*, *Ficus palmata*, *Bauhinia variegata*, *Quercus leucotrichophora, Morus alba* and *Toona ciliata.*

The consumption of fuelwood was recorded highest at elevation E_3 i.e. 30.92 kg/household/day while it was 25.65 kg/household/day at elevation E_2 and 22.77 kg/household/day at each elevation E_1. The common plant species used for fuel wood in Giri catchment are *Grewia optiva*, *Pinus roxburghii, Toona ciliata, Woodfordia fruticosa, Acacia catechu* and *Pyrus pashia.*

4.2 IDENTIFICATION OF LAND USE SYSTEM

Six types of vegetation systems are prevalent in Giri catchment viz., a) Agrisilviculture (AS), b) Agrihorticulture (AH), c) Agrihortisilviculture (AHS), d) Agrisilvihorticulture (ASH), e) Silvipasture (SP) and f) Grasslands (Gr). The structural components of each system is detailed for different elevations and is given as under:

4.2.1 Elevation E_1 (900 - 1300 m)

a) Agrisilviculture system (AS)

At elevation (E_1), in agrisilviculture system, twenty-six system units of different agricultural crops and trees combinations were recorded in Giri catchment. In rabi season, wheat was grown with mustard, pea or cabbage, whereas pea was also grown with barley and cabbage. In kharif season, maize was grown with blackgram, rajmah, capsicum, bean and tomato. The various fodder, fuel and timber trees viz., *Grewia*, *Morus*, *Bauhinia*, *Ficus*, *Melia* and *Prunus* were deliberately retained on the bunds of agriculture fields. Their number and distribution around the fields varied from place to place (Table 5).

b) Agrihorticulture (AH)

In agrihorticulture system, seventeen system units of varying agricultural crops and fruit trees were recorded (Table 5). In rabi season, wheat was grown with pea, cabbage, mustard and beans, whereas as pea was also grown with garlic, barley, beans and cabbage. In kharif season maize was the major cereal crop which was cultivated with tomato, capsicum and blackgram.

The various fruit trees viz. peach, pear, plum and apricot were recorded in different combinations. Fruit trees were planted at standard spacing within the fields. The agricultural crops were grown in interspaces of fruit trees.

Table: 5. Plant components of vegetation systems at elevation E_1 (900-1300 m) in Giri catchment of HP

Vegetation Systems	Cropping Season		Tree components
	Rabi	Kharif	Trees
Agrisiliviculture	Wheat, Mustard	Maize, Blackgram/ Maize, Capsicum Maize, Rajmah Maize, Tomato/bean	Grewia +Morus/ Bauhinia+ Morus/ Bauhinia+ Ficus /Grewia /Melia+Grewia/Prunus+Grewia Bauhinia +Ficus / Morus Bauhinia +Morus / Prunus + Grewia Grewia + Morus/ Bauhinia + Morus
	Barley, Pea	Maize, Blackgram Maize, Rajmah Maize, Tomato	Grewia+Toona Grewia+ Ficus /Grewia Celtis + Ficus
	Wheat, Mustard, Pea	Maize, Blackgram	Grewia +Bauhinia
	Mustard, Pea	Maize, Blackgram /Rajmah	Grewia+ Albizia/ Gewia+Ficus
	Wheat, Pea	Maize,Tomato Maize, Blackgram Maize, Capsicum Maize, Rajmah	Grewia +Bauhinia/Prunus + Grewia Celtis +Toona / Grewia +Toona Toona + Celtis Toona + Celtis
	Wheat, Cabbage	Maize, Tomato	Celtis + Grewia
Agrihorticulture	Wheat, Pea	Maize, Tomato	Pear + peach/Apricot +Plum
	Garlic, Pea	Tomato, Capsicum	Pear + Apricot
	Wheat, Cabbage	Maize, Tomato	Peach + Pear/Plum +Pear/Plum
	Barley, Pea	Maize, Tomato	Peach + Plum
	Wheat, Barley	Tomato, Blackgram	Pear + Plum
	Mustard, Pea	Tomato, Capsicum	Pear + Plum
	Pea, Beans	Tomato, Maize	Pear + Peach
	Cabbage, Pea	Tomato, Capsicum	Peach + Peach/Pear
	Barley, Pea	Maize, Tomato	Pear + Peach
	Wheat, Mustard	Tomato, Capsicum	Pear + Plum
	Wheat, Beans	Maize , Blackgram	Pear + Apricot
	Garlic, Cabbage	Tomato, Blackgram	Pear + Apricot
	Barley, Mustard	Maize, Blackgram	Pear + Plum
Agrisilvihorticulture	Wheat, Mustard, Pea	Maize, Capsicum	Grewia + Bauhinia + Pear
	Wheat, Pea	Maize, Tomato Maize, Capsicum Tomato, Capsicum	Grewia +Toona + Pear/ Morus + Pear/Grewia + Morus + Pear
	Wheat, Cabbage	Maize, Tomato Maize, Blackgram Maize, Capsium	Grewia + Pear Morus + Pear Celtis + Grewia + Pear
	Barley, Mustard	Maize, Blackgram	Grewia + Ficus + Pear
	Wheat, Mustard	Maize, Blackgram Maize, Rajmah	Grewia + Celtis + Pear/Grewia + Siris + Pear Celtis + Morus + Pear
Agrihortisilviculture	Wheat, Pea	Tomato, maize Capsicum, maize Tomato, Beans Maize, Beans Maize, Rajmah	Pear + Grewia Pear + Grewia Pea r + Grewia Peach + Toona Pear + Grewia
	Wheat, Mustard	Maize, Capsicum Maize, Blackgram	Pear + Celtis Pear + Celtis/Pear + Grewia
	Barley, Pea	Maize, capsicum Maize, tomato Maize, Blackgram	Pear + Grewia Plum + Grewia Pear + Grewia
Silvipasture	Natural grasses viz,*Arundinella, Chrysopogon, Themeda, Heteropogon, Alpuda,Dicanthium, Panicum, Ischaemum, Chloris, Imperata* and *Cymbopogon*		Pine + Acacia + Quercus + Siris + Toona + Bombax
Grassland	Natural grasses viz *Arundinella, Chrysopogon, Themeda, Heteropogon, Alpuda, Dicanthium, Panicum, Ischaemum* and *Cymbopogon*		,

'+' = denotes that the species were growing simultanepously
'/' = denotes the spatial difference in the presence of species
',' = denotes the temporal difference in the presence of species

c) Agrihortisilviculture (AHS)

In this agroforestry system, eleven system units having different agricultural crops and trees combinations were recorded at elevation (E_1), in Giri catchment (Table 5). In rabi season, wheat, barley and pea was cultivated by farmers. Wheat was also grown with pea, mustard and barley. In some places barley was cultivated with pea. In kharif season, the major crop was maize which was grown with capsicum, tomato, blackgram and beans.

Various fodder and fuel trees of *Grewia*, *Toona*, *Morus*, and *Celtis* were deliberately grown on the bunds of terraces and fruit trees of pear were planted at standard spacing within the fields.

d) Agrisilvihorticulture system (ASH)

In this agroforestry system, eleven system units of different agricultural crops and tree components were recorded (Table 5). In rabi season, wheat was main cereal crop which was cultivated with mustard, pea, barley and cabbage. Barley was also grown with mustard. In some places, wheat was cultivated with mustard and pea. In kharif season, maize was cultivated with tomato, capsicum, blackgram and rajmah. Various fodder, fuel and fruit trees were deliberately grown on the bund of terraces and fruit trees were planted at standard spacing within the fields. Major tree components were *Grewia*, *Toona*, *Morus*, and *Celtis*, whereas pear was the only fruit-tree component.

e) Silvipasture (SP)

In the study area, the dominating vegetation system was silvipasture (Table 5). The major timber, fuel and fodder tree component in this system were: *Pinus*, *Quercus*, *Albizzia*, *Toona* and *Bombax*.

Arundinella, Chrysopogon,Themeda, Heteropogon, Alpuda, Dicanthium, Panicum and *Cymbopogon* were the dominating grasses present in silvipasture systems. In forbs, segdes and legumes, *Ageratum, Artemisia, Bidens, Euphorbia, Micromeria, Dicliptera, Eriophorum, Cassia* and *Lespedeza* were present in this system. Among shrubs species: *Adhathoda*, *Berberis, Lantana, Leptodermis, Rabdosia, Meriandra* and *Murraya* were recorded.

f) Grasslands (Gr)

Natural grasses dominated this system (Table 5). Prominent grass species recorded in this system were *Arundinella, Chrysopogon, Themeda, Heteropogon, Alpuda, Dicanthium, Panicum, Ischaemum, Chloris, Imperata* and *Cymbopogon*. In forbs and legumes, *Artemisia, Bidens, Euphorbia, Micromeria, Dicliptera, Cassia* and *Lespedeza* were present in this system. Among shrubs *Berberis, Lantana, Carissa, Rabdosia, Meriandra, Adhathoda* and *Murraya* were recorded.

4.2.2 Elevation E_2 (1301 - 1700 m)

a) Agrisilviculture system (AS)

In agrisilviculture system at elevation (E_2), nine system units of agricultural crops and trees combinations were recorded (Table 6). In rabi season, wheat crop was grown with mustard and pea whereas, barley was cultivated with mustard in some places. In kharif season, maize was the main cereal crop cultivated with pulses like blackgram and rajmah. Vegetables viz., capsicum and beans were also grown by farmers.

Various fodder, fuel and timber trees viz; *Grewia*, *Toona*, *Morus*, *Celits*, *Albizzia* and *Bauhinia* were deliberately retained on the bunds of terraces.

b) Agrihorticulture system (AH)

In agrihorticulture system, twelve system units of different agricultural crops and fruit trees combinations were recorded at elevation E_2 (Table 6). In rabi season, wheat was cultivated along with pea and mustard, whereas barley was cultivated with mustard and pea. In kharif season, maize was major cereal crop which was cultivated along blackgram, rajmah, capsicum, tomato and beans. Agriculture crops for cereals and pulses, and vegetables were grown in interspaces of the fruit trees which were planted at standard spacing inside the fields. In this system the fruit trees of peach, plum and pear were recorded.

c) Agrisilvihorticulture system (ASH)

Under this agroforestry system, nine system units of varying agricultural crops, fodder, fuel, timber and fruit trees components were recorded at elevation E_2 (Table 6). In rabi season wheat was grown with mustard, pea and barley, whereas in kharif season maize was major cereal crop which was cultivated with pulses and vegetable crops like blackgram, rajmah, tomato and beans.

Table: 6. Plant components of vegetation systems in Giri catchment at elevation E_2 (1301-1700 m)

Vegetation Systems	Cropping Season		Tree components
	Rabi	**Kharif**	**Trees**
Agrisiliviculture	Wheat, Mustard, Pea	Maize, Capsicum	Grewia + Toona/Grewia + Morus
	Wheat, Pea	Maize, Blackgram	Grewia + Toona + Celtis
	Wheat, Mustard	Maize, Blackgram	Albizzia + Grewia/ Toona + Celtis/Grewia + Bauhinia
	Barley, Mustard	Maize, Blackgram Maize, Rajmah	Grewia + Celtis Toona + Morus
	Wheat, Cabbage	Maize, Bean	Grewia + Celtis
Agrihorticulture	Wheat, Pea	Maize, Tomato Maize, Capsicum Maize, Rajmah Maize, Bean	Plum + Pear Pear + Peach Peach + Pear Pear + Plum
	Barley, Mustard	Maize, Blackgram	Pear + Peach
	Barley, pea	Maize, Beans	Pear + Plum
	Wheat, Mustard	Maize,Tomato Maize, Blackgram Maize, Capsicum Maize, Rajmah Maize, Beans	Pear + Plum Pear + Peach/Peach Pear + Peach Peach + Plum Pear + Peach
Agrisilvihorticulture	Wheat, Mustard	Maize, Blackgram Maize, Rajmah	Grewia + Toona + Pear + Peach /Grewia + Celtis + Pear /Grewia + Morus + Pear Grewia + Toona + Pear + Plum
	Wheat, Mustard, Pea	Maize, Blackgram,Tomato	Grewia + Bauhinia + Pear + Apricot/Grewia + Pear
	Wheat, Pea	Maize, Rajmah Maize, Beans	Morus + Grewia + Pear Morus + Grewia + Pear
	Wheat, Cabbage, Pea	Maize, Tomato, Beans	Ficus + Celtis + Pear
Agrihortisilviculture	Wheat, Mustard	Maize, Rajmah	Grewia + Ficus + Apricot + Pear
	Wheat, Mustard, Pea	Maize, Blackgram,Tomato	Grewia + Celtis + Pear + Plum
	Barley, Mustard	Maize,Tomato	Bauhinia + Celtis + Pear + Plum
	Wheat, Pea	Maize, Blackgram	Grewia + Pear
Silvipasture	Natural Grasses viz, *Heteropogon, Themeda, Apluda Chrysopogon* and *Dicanthium,*		Pinus + Bauhinia + Quercus + Toona + Siris
Grassland	Natural grasses viz, *Heteropogon,Themeda,Apluda, Chrysopogon* and *Panicum,*		-

'+' = denotes that the species were growing simultanepously
'/' = denotes the spatial difference in the presence of species
',' = denotes the temporal difference in the presence of species

The tree components were: *Grewia*, *Toona*, *Morus*, *Celtis*, *Ficus* and *Bauhinia* which were retained on the bunds of agriculture fields. Major fruit trees were pear and plum, which were planted at standard spacing inside the agriculture fields.

d) Agrihortisilviculture (AHS)

In this agroforestry system**,** four system units of crops, fruit, fodder, fuel and timber trees were recorded at elevation E_2 (Table 6). In rabi season, wheat was cultivated with mustard and pea whereas, barley was cultivated with mustard only. In kharif season, maize was major cereal crop, which was grown in combination with rajmah and blackgram. In some places, maize and tomato were cultivated by farmers.

The major fodder, fuel and timber trees in agrihortisilviculture system viz., *Grewia*, *Ficus* and *Celtis* were retained on the bunds of agriculture fields whereas fruit plants of pear and plum were planted inside the agriculture fields at standard distances.

e) Silvipasture system (SP)

The major timber, fuel and fodder tree components in this system were *Pinus*, *Bauhinia*, *Ficus*, *Toona* and *Bombax* (Table 6). The grasses in this system were *Chrysopogon, Arundinella, Themeda, Heteropogon, Alpuda, Panicum, Ischaemum, Cymbopogon, Chloris* and *Dicanthium*. Forbs were: *Micromeria, Dicliptera, Cristella*, *Artemisia* and *Bidens* whereas legumes were: *Rhynchosia, Cassia* and *Lespedeza*. Among shrub species *Berberis, Lantana, Leptodermis, Rabdosia, Meriandra, Adhathoda* and *Murraya* were recorded.

f) Grasslands (Gr)

The natural grasses were dominating in this system like, *Arundinella, Chrysopogon, Themeda, Heteropogon, Alpuda, Dicanthium, Panicum, Ischaemum, Chloris, Imperata* and *Cymbopogon*. Forbs and legumes like, *Artemisia, Bidens, Euphorbia, Micromeria, Dicliptera, Cassia* and *Lespedeza* were recorded. Among shrubs viz., *Berberis, Carissa, Lantana, Leptodermis, Myrsine, Rabdosia, Meriandra, Adhathoda* and *Murraya* were recorded (Table 6).

4.2.3 Elevation E_3 (1701-2100m)

a) Agrisilviculture system (AS)

In agrisilviculture system, eleven system units of different agricultural crops and tree components were recorded (Table 7). In rabi season, wheat was major cereal

Table: 7. Plant components of vegetation systems in Giri catchment at elevation E_3 (1701-2100 m)

Vegetation system	Cropping Season		Tree components
	Rabi	Kharif	Trees
Agrisiliviculture	Wheat, Mustard, Pea	Maize, Blackgram, Tomato Maize, Rajmah, Bean	Grewia + Toona + Bauhinia Morus + Celtis + Grewia
	Wheat, Mustard	Maize, Blackgram Maize, Rajmah, Tomato Maize, Tomato, Capsicum	Grewia + Celtis/Grewia + Morus Grewia + Celtis Grewia + Celtis
	Wheat, Pea	Maize, Rajmah Maize, Blackgram	Toona + Grewia Morus + Toona/Grewia + Morus
	Barley, Mustard	Maize, Blackgram	Grewia + Celtis + Toona
	Wheat, Mustard, Cabbage	Maize, Blackgram, Tomato	Grewia + Toona
Agrihorticulture	Wheat, Mustard, Pea	Maize, Blackgram, Capsicum	Pear+Peach
	Wheat, Mustard	Maize,Tomato Maize, Capsicum	Pear + Peach Pear + Peach
	Wheat, Pea	Maize,Tomato/ Capsicum/Beans Maize, Blackgram Maize, Rajnmah	Pear + Plum, Pear/Apricot
	Barley, Mustard	Maize, Tomato	Pear + Apricot/Pear/Peach
Agrihortisilviculture	Wheat, Mustard	Maize, Blackgram Maize, Capsicum Maize, Rajmah	Pear + Grewia + Prunus Peach + Morus + Grewia Pear + Grewia +Toona
	Wheat, Mustard, Pea	Maize, Blackgram	Pear + Peach + Grewia + Celtis
	Wheat, Pea	Bean, Capsicum Maize, Blackgram	Pear + Ficus+ Celtis Apricot + Grewia +Toona
	Barley, Mustard	Maize, Blackgram	Pear + Morus + Toona
Agrihortisilviculture	Wheat, Pea	Maize, Rajmah Maize, Tomato	Grewia + Morus +Apricot Celtis + Grewia + Peach + Pear
	Wheat, Mustard	Maize, Capsicum	Grewia + Celtis + Plum + Pear
	Barley, Mustard	Maize, Tomato, Blackgram	Morus + Grewia + Pear
	Wheat, Mustard, Pea	Maize, Rajmah, Blackgram	Grewia + Celtis + Pear
Silvipasture	Natural Grasses viz; *Arundinella, Heteropogon,Themeda, Apluda* and *Chrysopogon*		Pinus + Siris + Bombax + Toona + Quercus
Grassland	Natural Grasses viz; *Heteropogon,Themeda, Apluda* and *Chrysopogon*		-

'+' = denotes that the species were growing simultanepously
'/' = denotes the spatial difference in the presence of species
',' = denotes the temporal difference in the presence of species

crop which was cultivated with oil seeds and vegetable crops like mustard, cabbage and pea. In some places barley was grown with pea. In kharif season, maize was major cereal crop which was cultivated with blackgram, rajmah, tomato, capsicum and beans.

b) Agrihorticulture (AH)

In agrihorticulture systems, eight system units of different crops and fruit trees combination were recorded (Table 7). In rabi season, wheat was grown along with pea, cabbage, mustard and beans. However, pea was also grown with garlic, barley, beans and cabbage. In kharif season maize was major cereal crop which was cultivated with tomato, capsicum and blackgram.

The fruit trees viz., peach, pear, plum and apricot were planted at standard spacing within the agricultural fields. The annual crops were grown in the interspaces of fruit trees.

c) Agrisilvihorticulture systems (ASH)

In this agroforestry system, seven system units of varying agricultural crops, fodder and fruit trees were recorded (Table 7). In rabi season, wheat and barley were the main cereal crops which were cultivated along with vegetables and oilseed crops viz., mustard and pea. Whereas, in some places barley and mustard were also cultivated by farmers. In kharif season, maize was main cereal crop which was cultivated with pulses like blackgram and rajmah. Maize was also grown in combination with vegetable crops like tomato and capsicum.

Various fodder trees viz., *Grewia*, *Prunus*, *Ficus*, *Toona*, *Morus* and *Celtis* were deliberately retained on the bund of terraces whereas fruit trees of pear, peach and apricot were planted at standard spacing within the fields.

d) Agrihortisilviculture (AHS)

In this system, five system units were recorded (Table 7). In rabi season, wheat was major cereal crop which was grown along with pea, mustard and barley. In some places barley was cultivated along with pea. In kharif season, the major cereal crop was maize. Vegetable crops of tomato and capsicum were also grown with pulses like blackgram and beans.

The fruit trees of pear and plum were planted at standard spacing within the agriculture fields and fodder, fuel and timber trees viz., *Grewia*, *Toona* and *Celtis* were retained on the bund of fields.

e) Silvipasture (SP)

Silvipasture system was the dominating system in the study area (Table 7). The major fodder, fuel and timber tree component in this system were: *Pinus*, *Quercus*, *Albizzia*, *Toona* and *Bombax*.

Chrysopogon, Themeda, Heteropogon, Alpuda, Dicanthium, Panicum and *Cymbopogon* were the dominating grasses. In forbs and legumes, *Artemisia, Bidens, Micromeria, Dicliptera, Cassia* and *Lespedeza* were present in this system. Among shrubs viz, *Princepia, Berberis, Myrsine, Leptodermis, Rabdosia, Meriandra*, *Rubus* and *Rosa* were present.

f) Grasslands (Gr)

The natural grasses were dominating plant category in this system (Table 7). The grass species recorded in this system were: *Arundinella, Chrysopogon, Themeda, Heteropogon, Alpuda*, *Dicanthium, Panicum, Ischaemum, Chloris, Imperata* and *Cymbopogon*. In forbs and legumes, *Artemisia, Bidens, Euphorbia, Micromeria, Dicliptera, Cassia* and *Lespedeza* were recorded. Among shrubs, *Myrsine*, *Berberis, Lantana, Leptodermis, Rabdosia, Meriandra, Adhathoda* and *Murraya* were recorded.

4.3 FLORISTIC COMPOSITION

Comprehensive floristic composition studies were carried out in silvipasture and grassland ecosystems. The tree, shrub, grass, sedge, legume and forb species existing in these systems were recorded and is described below:

Silvipasture systems in the sub-watersheds selected for study had plants of 88 genera with 93 species and in grasslands, 86 genera with 94 species were recorded.

The number of species of grasses, sedges, forbs, legumes, shrubs and trees in silvipasture systems were 20, 4, 31, 4, 27 and 7, respectively whereas in grasslands they were 22, 4, 36, 5, 27 and 0, respectively.

There was one family from Gymnosperms i.e., Pinaceae while angiosperms were represented from 37 families viz., Acanthaceae, Adiantaceae, Amaranthaceae, Anacardiaceae, Apiaceae, Apocynaceae, Asteraceae, Asparagaceae, Berberidaceae, Commelinaceae, Convolvulaceae, Cyperaceae, Eleagnaceae, Euphorbiaceae, Fabaceae, Fagaceae, Geraniaceae, Hypericaceae, Lamiaceae, Linaceae, Lythraceae, Malvaceae, Meliaceae, Myrisinaceae, Poaceae, Polygalaceae, Ranunculaceae, Rosaceae, Rubiaceae, Rutaceae, Santalaceae, Smilacaceae, Thelypteridaceae, Ulmaceae, Verbenaceae, Violaceae and Tiliaceae

4.3.1 Silvipasture system (SP)

In silivipasture system, 20 species belonged to family Poaceae, 12 species to Asteraceae, 9 species to Fabaceae and Lamiaceae, 5 species to Acanthaceae and 4 species each to Cperaceae and Rosaceae. Other plant families had 1-4 species (Tables 8 and 9).

Grass species recorded in silvipasture systems of the selected subwatersheds were: *Apluda mutica*, *Arudinella nepalensis*, *Chloris barbata*, *Chrysopogon montanus, Cymbopogon martinii*, *Dicanthium annulatum*, *Heteropogon contortus*, *Imperata cylindrica, Ischaemum aristatum, Oplismenus burmanii, Paspalum coloratum, Panicum maximum, Themeda anathera* and *Urochloa panicoides*. Sedge species present in this system were: *Cyperus rotundus, Cyperus esculentus, Eriophorum comosum and Fimbrstylis rigidula* whereas, forb species were: *Ageratum conyzoides, Andrachne cordifolia, Artemisia roxbughiana, Bidens pilosa, Cheitanthus farinosa, Commelina bengalensis, Dicliptera bupleuriodes, Euphorbia heterophylla, Evolvulus alsinoides, Leucus lanata, Micromeria biflora, Origanum vulgare, Platystemma violoides, Reinwardtia indica, Rhus cotinus, Sonchus arvensis, Thalictrum foliosum, Tricholepsis elongata* and *Viola serpens.* The legume species recorded in silvipasture systems of the sub-watersheds selected for study were: *Cassia mimmosides, Lespedeza gerardiana* and *Rhynchosia* *himalensis*. The shrub species present in silvipasture were: *Adhathoda vasica, Asparagus adscendens, Berberis lycium, Carissa carandus, Colebrookia oppositifolia, Eleaegnus umbellata, Hamiltonia suaveolens, Hypericum oblongifolium, Indigofera pulchella, Inula cappa, Lantana camara, Leptodermis*

Table: 8. Plant families, genera and species in silvipasture and grassland systems of Giri catchment in H.P.

Sr. No.	Family	Silvipasture		Grasslands	
		No. of Genus	No. of Species	No. of Genus	No. of Species
1	Acanthaceae	5	5	4	4
2	Adiantaceae	1	1	1	1
3	Amaranthaceae	1	1	1	1
4	Anacardiaceae	1	1	1	1
5	Apiaceae	1	1	1	1
6	Apocynaceae	1	1	1	1
7	Asteraceae	11	12	12	13
8	Asparagaceae	1	1	1	1
9	Berberidaceae	1	1	1	1
10	Commelinaceae	1	1	1	1
11	Convolvulaceae	1	1	1	1
12	Cyperaceae	3	4	3	4
13	Eleagnaceae	1	1	1	1
14	Euphorbiaceae	1	1	1	2
15	Fabaceae	9	9	6	7
16	Fagaceae	1	1	-	-
17	Geraniaceae	1	1	2	2
18	Hypericaceae	1	1	1	1
19	Labiateae	-	-	1	1
20	Lamiaceae	9	9	8	8
21	Linaceae	1	1	1	1
22	Lythraceae	1	1	1	1
23	Malvaceae	1	1	-	-
24	Meliaceae	1	1	-	-
25	Myrisinaceae	1	1	1	1
26	Pinaceae	1	1	-	-
27	Poaceae	17	20	19	22
28	Polygalaceae	-	-	1	1
29	Ranunculaceae	1	1	1	1
30	Rosaceae	4	4	4	4
31	Rubiaceae	3	3	4	4
32	Rutaceae	1	1	1	1
33	Santalaceae	1	1	1	1
34	Smilacaceae	1	1	1	1
35	Thelypteridaceae	1	1	1	1
36	Verbenaceae	1	1	1	1
37	Violaceae	1	1	1	2
	Total	**88**	**93**	**86**	**94**

lanceolanta, Meriandra storbilifera, Myrsine africana, Osyris arborea, Prinsepia utilis, Rabdosia ragosa, Rosa moschata, Rubus ellipticus, Smilex aspera, Woodfordia fruticosa and *Zanthoxylum armatum* (Table 9).

4.3.2 Grasslands

In grasslands, 22 species were recorded from family poaceae, 13 species from Asteraceae, 8 species from Lamiaceae and 7 from Fabaceae. Other plant families were represented by 1-4 species (Tables 8 and 10).

The various grass species recorded in grasslands of selected subwatersheds of Giri catchment were: *Apluda mutica*, *Arudinella nepalensis*, *Chloris barbata*, *Chrysopogon montanus, Cymbopogan martinii*, *Dicanthium annulatun*, *Heteropogon contartus*, *Imperata cylindrica, Ischaemum aristatum, Oplismenus burmanii, Panicum coloratum, Panicum maximum, Themeda anathera* and *Urochloa panicoides*. The sedge species in grasslands were: *Cyperus rotundus, Cyperus esculentus, Eriophorum comosum* and *Fimbrstylis rigidula* whereas, forbs species in the grassland systems were: *Achyranthus aspera,Ageratum conyzoides, Andrachne cordofolia, Artemisia roxburghiana,Barleria strigosa, Bidens pilosa,Conyza stricta, Cheitanthus farinosa, Commelina bengalensis, Dicliptera bupleuriodes, Euphorbia heterophylla, Evolvulus alsinoides,Geranium nepalensis,Gerbera gossypina,Justicia simplex, Leucus lanata, Micromeria biflora, Origanum vulgare, Platystemma violoides,Plectranthus sericea, Reinwardtia indica, Rhus continus, Swertia angustifolia, Thalictrum foliosum, Tricholepsis elongata,Viola indica, Viola serpens* and *Xanthium indicum.* The legume species recorded in grasslands were: *Cassia mimosides, Lespedeza gerardiana* and *Rhynchosia himalensis.* Likewise, the shrub species that were present in grassland systems of the selected sub-watersheds of Giri catchment were: *Adhathoda vasica, Asparagus adscendens, Berberis lycium, Carissa carandus, Colebrookia oppositifolia, Elaegnus umbellata, Hamiltonia suaveolens, Hypericum oblongifolium, Indigofera pulchella, Inula cappa, Lantana camara, Leptodermis lanceolanta, Meriandra storbilifera, Myrsine africana, Osyris arborea, Principia utilis, Rabdosia rugosa, Rosa moschata, Rubus ellipticus, Smilex aspera, Woodfordia fruticosa* and *Zanthoxylum armatum* (Table 10).

Table: 9. Floral composition in silvipasture systems at elevations E_1 (900-1300 m), E_2 (1301-1700 m) and E_3 (1701-2100 m) of Giri catchment in HP

Species /Categories	Plant family	SUB-WATERSHEDS																																						
		SW_1			SW_2			SW_3			SW_4			SW_5			SW_6			SW_7			SW_8			SW_9			SW_{10}			SW_{11}			SW_{12}			SW_{13}		
		E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
GRASSES																																								
Apluda mutica Linn.	Poaceae	-	-	+	-	-	+	+	+	+	-	-	+	+	-	+	-	+	-	+	+	+	+	+	-	+	-	+	+	+	+	+	-	-	-	+	+	-	-	-
Arundinella nepalensis Trin.	Poaceae	+	+	+	-	+	+	+	+	+	-	+	+	+	-	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+
Avena fatua Linn	Poaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloris barbata S.W.	Poaceae	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	+	-	+	-	+	-	+
Chrysopogon fulvus (Spreng.)Chiov.	Poaceae	-	+	-	-	-	-	-	-	+	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Chrysopogon montanus Trin.	Poaceae	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cymbopogon martinii (Roxb.)Wats.	Poaceae	-	-	-	-	-	-	+	+	-	+	-	-	+	-	-	+	-	-	-	-	-	+	-	+	-	+	+	+	-	-	-	-	+	-	-	-	+	-	-
Dicanthium annulatum (Forsk)Stapf	Poaceae	+	+	+	-	-	-	+	-	+	+	+	-	+	+	+	+	-	+	+	+	-	+	-	-	-	+	+	-	+	-	+	+	-	-	+	+	-	+	-
Digiteria stricta Linn.	Poaceae	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Heteropogon contortus (Linn) P.Beav.exRoem& Shult	Poaceae	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	+	+	+	+	+	+	+	+
Imperata cylindrica (Linn) P. Beauv.	Poaceae	-	-	-	-	+		-	-	+	-	-	-	-	+	-	-	-	+	+	-	-	+	+	-	+	-	-	+	-	-	-	-	-	-	-	+	-	-	-
Ischaemum aristatum. Linn.	Poaceae	-	-	-	+	-	-	-	+	-	+	-	-	+	-	-	+	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	+	+	-	+	+	+	-	-
Oplismenus burmannii (Retz)P.	Poaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	+	-	-	-	-
Panicum coloratum Linn.	Poaceae	-	-		-	-	-	+	+	-	+	-	-	+	-	-	+	+	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Panicum maximum Jacq.	Poaceae	-	-	+	+	-	+	-	+	-	-	-	-	-	-	-	+	+	-	+	+	-	+	+	+	-	-	+	-	-	-	+	+	+	-	+	-	+	-	+
Paspalum notatum Flugge	Poaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Setaria glauca (Linn) P. Beauv.	Poaceae	-	-	-	-	+		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda anathera (Nees) Hack	Poaceae	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	+	+	+
Themeda quadrivalvis Roxb.	Poaceae	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+		-	-	-	-	-	-	-	+	
Urochloa panicoides P.Beav.	Poaceae	+	-	-	-	+	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	+	+	-	+	+	-	-	-	-	-	-	-	+
Total number of grasses		**6**	**7**	**7**	**5**	**8**	**7**	**8**	**9**	**9**	**8**	**5**	**5**	**9**	**6**	**6**	**9**	**8**	**7**	**8**	**8**	**6**	**9**	**9**	**7**	**8**	**8**	**8**	**9**	**7**	**6**	**8**	**7**	**8**	**4**	**10**	**8**	**8**	**8**	**7**
SEDGES																																								
Cyprus esculantus Linn.	Cyperaceae	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyperus rotundus Linn.	Cyperaceae	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	+	-	+	-	-	-	-	+	+	-	-	-	-	-	+	+	-	+	+	+	-	+
Eriophorum comosum Wall.	Cyperaceae	-	-	+	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	+	-	-	+	-	-	-	-	-
Fimbristylis rigidula Vahl.	Cyperaceae	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	+
Total number of sedges		**1**	**-**	**1**	**1**	**2**	**1**	**1**	**-**	**-**	**1**	**-**	**-**	**-**	**-**	**1**	**1**	**-**	**2**	**-**	**1**	**1**	**-**	**1**	**-**	**1**	**1**	**-**	**1**	**-**	**-**	**2**	**1**	**1**	**2**	**1**	**1**	**1**	**-**	**2**
FORBS																																								
Achyranthes aspera Linn.	Amaranthaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-
Ageratum conyzoides Linn	Asteraceae	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Andrachne cordifoliea Linn	Asteraceae	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Artemisia roxburghiana Bess.	Asteraceae	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	+	-	-	-	-	-	-	-	-

Continued.....

Species /Categories	Plant family	SUB-WATERSHEDS																																						
		SW_1			SW_2			SW_3			SW_4			SW_5			SW_6			SW_7			SW_8			SW_9			SW_{10}			SW_{11}			SW_{12}			SW_{13}		
		E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
Barleria strigosa Willd.	Acanthaceae	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bidens pilosa Linn.	Asteraceae	-	+	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	+	-
Bidens tripartita Linn	Asteraceae	-	-	-	-	+	-	-	-	-	+	+	-	+	-	-	+	+	-	-	-	-	-	-	+	-	-	+	+	+	+	-	-	+	-	-	+	+	-	+
Cissanpetous pariera Linn	Asteraceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Cheilathes farinosa (Forssk.) Brownesey & Jermy	Adiantaceae	-	+	-	+	+	-	-		-	-	-	+	-	-	-	-	-	-	-		-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-
Commelina benghalensis Linn.	Commenlinaceae	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-
Conyza stricta Willd.	Asteraceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Cristella dentatata Lev.Emend.Holt.	Thelypteridaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dicliptera bupleuroides Nees.	Acanthaceae	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	+	-	-	+	-	+
Erigeron annus Pers.	Asteraceae	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euphorbia heterophylla Linn.	Euphorbiaceae	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	
Evolvulus alsinoides Linn.	Convolvluaceae	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Geranium nepalensis Sweet.	Geraniaceae	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Gerbera gossypinna (Royle) Beauv.	Asteraceae	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Justicea simplex D. Don.	Acanthaceae	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-
Leucus lanata Benth.	Lamiaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	+	-	-	-	-	-
Micromeria biflora Benth.	Lamiaceae	-	+	+	+	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	+	+	-	+	-	-	-	+	-	-	+	+	-	+	+	+	+
Origanum vulgare Linn.	Lamiaceae	-	+	+	+	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	+	-	+	+	-	-
Pimpinella diversifolia DC.	Apiaceae	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Platystemmsa violoides Wall.	Lamiaceae	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Plectranthus sericea Linn.	Lamiaceae	-	-	-	-	-	-	-	+	+	-	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Reinwardtia indica Dum.	Linaceae	-	+	+	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Rhus cotinus Linn.	Anacardiaceae	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Sonchus arvensis Linn.	Asteraceae	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Thalictrum foliosum DC.	Ranunculaceae	-	+	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Tricholepis elongata DC.	Asteraceae	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	+	-	-	-	-
Viola serpens Wall.	Voilaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Total number of forbs		**6**	**6**	**4**	**8**	**9**	**4**	**2**	**3**	**1**	**1**	**6**	**5**	**3**	**4**	**5**	**2**	**4**	**2**	**1**	**2**	**3**	**1**	**1**	**4**	**3**	**3**	**5**	**6**	**3**	**4**	**2**	**4**	**3**	**6**	**2**	**4**	**4**	**5**	**4**
LEGUMES																																								
Cassia mimosoides Linn.	Fabaceae	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-
Desmodium trifolirum DC.	Fabaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Lespedeza gerardiana Michx.	Fabaceae	-	+	-	-	-	-	+	-	+	-	-	+	-	+	-	-	-	-	+	-	+	-	-	-	-	+	-	+	+	-	+	-	-	-	-	-	-	-	-
Rhynchosia himalensis Benth.	Fabaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total number of legumes		**0**	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**2**	**1**	**2**	**2**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**

Continued .....

Species /Categories	Plant family	SUB-WATERSHEDS																																						
		SW_1			SW_2			SW_3			SW_4			SW_5			SW_6			SW_7			SW_8			SW_9			SW_{10}			SW_{11}			SW_{12}			SW_{13}		
		E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
SHRUBS																																								
Adhathoda vasica (Linn.) Nees	Acanthaceae	-	-	+	-	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Aechmanthera gossypina Nees	Acanthaceae	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Asparagus adscendens Roxb.	Asparagaceae	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	+	+	-	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Berberis lycium Royle	Berberidaceae	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+
Carissa carandas Linn.	Apocynaceae	+	+	-	+	+	-	+	+	+	-	+	+	+	-	-	+	-	-	+	-	-	-	-	-	+	+	-	-	-	-	-	+	-	-	+	-	+	+	-
Caryopteris wallichiana Schauer.	Lamiaceae	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-		-	-
Colebrookea oppositifolia Smith	Lamiaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	+	-	-
Elaeagnus umbellata Thunb.	Elaeagnaceae	-	-	-	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
Hamiltonia suaveolens Roxb.	Rubiaceae	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Hypericum oblongifolium Wall.	Hypericaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indigofera pulchella Wall.ex Baker	Fabaceae	-	-	-	-	-	-	-	-	-	+	+	-	-	+	-	+	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Inula cuspidata (DC.) C. B. Clarke	Asteraceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
Lantana camara Linn.	Verbenaceae	+	+	-	+	-	-	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-
Leptodermis lanceolata Wall.	Rubiaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
Meriandra strobilifera Benth.	Lamiaceae	+	-	+	-	-	-	-	+	+	+	+	+	+	-	+	-	+	-	+	-	-	-	+	-	-	+	-	+	+	+	-	+	+	-	-	-	-	-	-
Mimosa rubicaulis Lamarck.	Fabaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
Myrsine africana Linn.	Myrsinaceae	-	-	-	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+	+	+	+	+	+	-	-	-	-	+	-	+	-	-	+	+	-	+	-	-
Osyris arborea Wall. ex DC.	Santalaceae	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	+	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prinsepia utilis Royle	Rosaceae	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Prunus cerasoides D.Don	Rosaceae	-	-	+	-	-	-	+	+	-	+	-	-	-	-	-	+	-	+	+	-	-	-	-	-	+	-	-	-	-	-	+	-	+	+	-	+	+	-	-
Rabdosia rugosa Wall. ex Benth.	Lamiaceae	-	+	-	-	-	-	-	+	-	-	-	-	+	+	-	-	+	-	+	+	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	+	+
Randia tetrasperma (Roxb.) Benth. & Hook. f.	Rubiaceae	-	-	+	-	-	-	+	+	+	-	-	+	-	-	+	+	+	+	+	+	-	+	+	+	-	-	+	-	+	+	-	-	-	-	-	+	-	-	-
Rosa moschata HerRm.	Rosaceae	-	-	-	-	-	+	-	+	-	-	-	+	-	-	-	-	-	-	-	+	-	+	-	-	-	-	+	-		+	-	-	+	-	-	+	-	-	-
Rubus ellipticus Smith	Rosaceae	+	+	-	+	+		+	+	-	+	+	+	-	+	-	-	-	+	+	+	-	+	+	+	+	-	-	+	+	-	+	+		+	+	-	+	+	-
Smilax aspera Linn.	Smilacaceae	-	-	+	-	-	+	-	-	-	-	-	+	-	-	+	-	-	+	-	-	-	+	+	+	-	-	+	-	-	+	-	-	-	-	-	+	-	-	+
Woodfordia fruticosa (Linn.) Kurtz.	Lythraceae	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Zanthoxylum armatum DC.	Rutaceae	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	+	-	+	+	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-
Total number of shrubs		**5**	**5**	**6**	**5**	**4**	**4**	**7**	**11**	**7**	**8**	**10**	**9**	**8**	**9**	**4**	**8**	**7**	**9**	**11**	**11**	**6**	**9**	**8**	**6**	**6**	**5**	**5**	**5**	**6**	**5**	**4**	**7**	**4**	**7**	**4**	**5**	**6**	**4**	**4**
TREES																																								
Acacia catechu (L. f.) Willd.	Fabaceae	+	-	-	+	-	-	+	-	-	+	-	-	+	-	-	+	-	-	+	-	-	+	-	-	+	-	-	+	-	-	-	+	-	+	-	-	+	-	-
Albizia lebbeck Benth.	Fabaceae	+	+	-	+	+	-	+	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	+	+	+	+		+	-	+	+
Bauhinia variegate L.	Fabaceae	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	-	+	+	-	+	-	+	-	+	+	+	+	+	-	+
Bombax ceiba L.	Malvaceae	+	+		+	+	+	+	-	+	-	-	+	+	-	+	+	+	+	+		+	+	+	+		-	+	-	+	-	+	+	+	+		+	+	+	+
Pinus roxburghii Sarg.	Pinaceae	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Toona ciliate M. Roemer	Meliaceae	+	+	+	+	+	-	-	-	+	+	+	-	+	+	+	+	+	-	+	+	-	+	+	+	+	-	+	+	-	-	+	+	+	+	-	+	+	+	+
Quercus leucotrichophora A. Camus ex Bahadur	Fagaceae	-	-	+	-	+	+	-	-	-	+	+	+	+	+	+	+	-	-	-	-	+	+	+	+	-	+	+	+	-	-	-	+	+	+	+	-	-	+	+
Total number of trees		**6**	**5**	**4**	**6**	**6**	**4**	**4**	**3**	**4**	**6**	**4**	**5**	**6**	**5**	**5**	**7**	**4**	**4**	**5**	**4**	**4**	**5**	**4**	**6**	**3**	**4**	**5**	**5**	**3**	**2**	**5**	**6**	**6**	**7**	**3**	**5**	**5**	**5**	**6**
Total number of plant species		**24**	**24**	**23**	**24**	**30**	**22**	**23**	**25**	**22**	**24**	**25**	**25**	**26**	**25**	**21**	**29**	**23**	**24**	**26**	**26**	**20**	**25**	**24**	**24**	**20**	**23**	**23**	**28**	**23**	**19**	**28**	**25**	**22**	**26**	**20**	**23**	**24**	**22**	**23**

Where: **+** = present and - = absent

Table: 10. Floral composition in grasslands at elevations E_1 (900-1300 m), E_2 (1301-1700 m) and E_3 (1701-2100 m) of Giri catchment in HP

Species /Categories	Plant family	SUB-WATERSHEDS																																						
		SW_1			SW_2			SW_3			SW_4			SW_5			SW_6			SW_7			SW_8			SW_9			SW_{10}			SW_{11}			SW_{12}			SW_{13}		
		E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
GRASSES																																								
Apluda mutica Linn	Poaceae	+	+	+	+	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+	+	+	+	+	+	+	-	+	+
Arundinella nepalensis Trin	Poaceae	+	+	+	+	+	+	+	+	-	-	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	-	-	+	-	-	+	+	+	+	+	-	+	+	-
Avena fatua Linn.	Poaceae	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bothriocholoa pertusa Linn	Poaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Cenchrus ciliaris Linn	Poaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+
Chloris barbata S.W.	Poaceae	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-
Chrysopogon fulvus (spreng) Chiov	Poaceae	-	+	+	+	+	-	-	-	-	+	-	+	+	+	+	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-
Chrysopogon montanus Trin	Poaceae	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-
Cymbopogon martinii (roxb) Wats	Poaceae	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	-	+	-	-	+	-	+	-	-	+	+	+	+	-	-	-	+	+	-	-	+	-	+	-
Dicanthium annulatum (forsk) Stapf	Poaceae	-	+	+	-	-	-	+	+	+	+	+	-	+	+	+	+	+	-	+	+	-	+	-	-	-	+	+	-	+	-	+	+	-	+	+	-	-	-	+
Digitera stricta Linn	Poaceae	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+
Heteropogon contortus (Linn) P. Beauv.ex Roem & Shult	Poaceae	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+
Imperata cylindrica (Linn) P. Beauv	Poaceae	+	-	-	+	+	+	-	-	-	-	+	-	+	+	+	-	-	-	+	+	-	+	+	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Ischaemum aristatum. Linn	Poaceae	+	-	-	+	-	-	-	+	-	+	-	-	+	-	-	-	-	-	-	-	-	+	+	-	+	+	-	+	-	-	-	+	+	+	-	-	+	+	-
Oplismenus burmannii (Retz)	Poaceae	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Panicum coloratum Linn	Poaceae	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-
Panicum maximum Jacq	Poaceae	-	-	+	-	-	+	-	+	-	+	+	-	-	-	-	-	-	-	+	+	+	+	+	+	-	+	+	-	-	+	+	-	+	+	+	-	-	+	+
Paspalum notatum Flugge	Poaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Setaria glauca (Linn) P. Beauv	Poaceae	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	+	+	-	-	-	-	+	-	-	-	-	+
Themeda anathera (Nees) Hack	Poaceae	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	-	+	+
Themeda quadrivalvis Roxb	Poaceae	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	+	-	-
Urochloa panicoides P. Beauv.	Poaceae	+	-	-	+	+	-	-	-	+	+	-	-	-	+	-	+	+	+	-	-	+	-	+	+	-	-	+	-	+	-	+	+	+	+	+	+	-	+	+
Total number of grasses		**8**	**8**	**8**	**11**	**8**	**9**	**7**	**10**	**8**	**8**	**9**	**7**	**9**	**7**	**8**	**7**	**11**	**7**	**9**	**9**	**7**	**11**	**10**	**9**	**11**	**9**	**8**	**9**	**8**	**5**	**8**	**9**	**11**	**10**	**8**	**6**	**6**	**11**	**10**
SEDGES																																								
Cyperus esculantus Linn	Cyperaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Cyperus rotundus. Linn	Cyperaceae	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	+	+	+	-	-	-	-
Eriophorum comosum Wall	Cyperaceae	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	+	-	-	+	+	-	-
Fimbristylis rigidula Vahl	Cyperaceae	+	-	-	-	+	+	-	+	-	-	-	+	-	-	-	-	-	+	-	-	+	+	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Total number of sedges		**1**	**0**	**1**	**0**	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**0**	**1**
FORBS																																								
Achyranthes aspera Linn.	Amaranthaceae	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-
Ageratum conyzoides Linn	Asteraceae	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-

Continued .....

Species /Categories	Plant family	SUB-WATERSHEDS																																						
		SW_1			SW_2			SW_3			SW_4			SW_5			SW_6			SW_7			SW_8			SW_9			SW_{10}			SW_{11}			SW_{12}			SW_{13}		
		E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
Andrachne cordifolia Wall	Rubiaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Artemisia roxburghiana Bess	Asteraceae	-	+	-	+	-	+	-	-	-	-	-	-	-	-	+	+	+	+	+	-	+	-	-	+	-	+	-	-	-	-	+	-	-	+	+	+	-	+	+
Barleria strigosa Willd	Asteraceae	+	+	-	-	-	+	-	-	+	+	+	+	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	+	-	-	-	-
Bidens pilosa Linn	Asteraceae	-	-	+	+	+	+	-	-	+	-	-	-	+	-	+	-	+	-	-	-	+	-	-	+	-	-	-	-	+	+	-	-	+	-	+	+	-	+	-
Bidens tripartita Linn	Asteraceae	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	+	-	-	+	+	-	-	-	-	-	-	-	+	+	-
Cheilathes farinosa *(forsk) Brownesey & Jermy*	Adiantaceae	+	+	-	-	-	+	-	-	-	-	-	+	-	-	-	+	-	-	+	-	-	+	+	+	+	-	+	+	-	-	-	+	-	+	-	-	-	-	-
Cristella dentata lav. Emend holt	Commenlinaceae	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Commelina benghalensis Linn	Asteraceae	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	-
Conyza stricta Willd	Thelypteridaceae	-	-	-	-	-	-	-	-	-	-	+	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Dicliptera bupleuroides Nees.	Acanthaceae	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	+	-	-
Dryopteris panda Linn	Asteraceae	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Erigeron annus Pers	Asteraceae	-	-	+	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euphorbia heterophylla Linn	Euphorbiaceae	-	-	-	+	+	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	+	+	+	1	-	-	-	+	-	-	-	-	-
Euphorbia hirta. Orteg	Euphorbiaceae	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	+	+	+	-	-
Evolvulus alsinoides Linn	Convolvluaceae	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	+	-	+	-	+	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-
Geranium nepalense Sweet	Geraniaceae	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+
Gerbera gossypina (Royle) P. Beauv	Asteraceae	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Justicia simplex D.Don	Geraniaceae	-	-	-	+	-	+	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	+	+	-	+	-	-	+	+	-	-	-
Leucus lanata Benth	Asteraceae	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	+	+	+	-	+	-	-	+	-	-	-	-	-	-
Micromeria biflora Benth	Acanthaceae	+	+	+	-	-	-	-	-	+	-	-	-	+	+	+	-	-	-	-	-	+	-	-	+	-	-	+	+	-	-	-	-	+	+	-	-	-	+	+
Origanum vulgare Linn	Lamiaceae	-	-	+	-	-	-	-	-	+	+	-	-	-	-	+	-	-	+	+	-	+	-	-	+	-	+	-	-	-	-	+	-	+	-	-	-	-	-	+
Parthenium hysterophorus Linn.	Asteraceae	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-
Platystemma violoides Wall.	Lamiaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plectranthus sericea Linn	Lamiaceae	-	-	-	-	-	-	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polgala crotalariodes Buch	Polygalaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Reinwardtia indica Dum	Apiaceae	-	-	+	-	-	+	+	+	-	-	-	+	-	+	+	+	-	-	-	-	-	-	-	-	-	-	+	-	-	+	+	-	-	-	-	+	-	-	-
Rhus cotinus Linn.	Lamiaceae	+	+	-	-	-	-	+	+	+	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+	-	-
Salvia lanata Roxb.	Labiateae	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Swertia angustifolia Linn.	Linaceae	-	+	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+
Thalictrum foliosum.DC.	Anacardiaceae	-	+	-	-	-	+	-	-	+	+	+	-	-	-	-	+	-	-	-	+	-	+	-	-	-	-	+	-	-	-	+	-	-	+	-	-	-	-	-
Tricholepis elongata DC.	Asteraceae	-	-	-	+	+	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	+	+	-
Viola indica (L) DC	Violaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Viola serpens Wall.	Violaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Xanthium Indicum Koenig ex Roxb.	Ranunculaceae	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	+	-	-
Total number of forbs		**4**	**9**	**5**	**9**	**9**	**9**	**4**	**6**	**9**	**6**	**6**	**8**	**7**	**5**	**8**	**11**	**12**	**4**	**4**	**1**	**5**	**3**	**2**	**7**	**9**	**7**	**6**	**12**	**11**	**10**	**6**	**4**	**5**	**5**	**11**	**9**	**6**	**6**	**8**

Continued .....

Species /Categories	Plant family	SUB-WATERSHEDS																																						
		SW_1			SW_2			SW_3			SW_4			SW_5			SW_6			SW_7			SW_8			SW_9			SW_{10}			SW_{11}			SW_{12}			SW_{13}		
		E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
LEGUME																																								
Cassia absus Linn	Fabaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-
Cassia mimosoide Linn	Fabaceae	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	+	+	-	+	-
Desmodium triflorum DC	Fabaceae	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Lespedeza gerardiana Michx	Fabaceae	+	+	-	-	+	-	+	-	+	+	+	+	+	+	-	+	+	-	+	-	+	+	-	-	-	+	-	+	-	-	+	+	-	-	+	+	+	-	+
Rhynchosia himalensis benth	Fabaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total number of legumes		**1**	**2**	**0**	**1**	**2**	**0**	**1**	**0**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**2**	**4**	**0**	**2**	**1**	**1**	**2**	**1**	**0**	**1**	**2**	**1**	**3**	**2**	**0**	**1**	**1**	**0**	**0**	**3**	**2**	**1**	**1**	**1**
SHRUBS																																								
Adhatoda vasica (Linn.) Nees	Acanthaceae	-	-	+	-	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Aechmanthera gossypina Nees	Acanthaceae	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Asparagus adscendens Roxb.	Asparagaceae	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	+	+	-	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Berberis lycium Royle	Berberidaceae	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+
Carissa carandas Linn.Hook.f.	Apocynaceae	+	+	-	+	+	-	+	+	+	-	+	+	+	-	-	+	-	-	+	-	-	-	-	-	+	+	-	-	-	-	-	+	-	-	+	-	+	+	-
Caryopteris wallichiana Schauer.	Lamiaceae	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Colebrookea oppositifolia Smith	Lamiaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	+	-	-
Elaeagnus umbellata Thunb.	Elaeagnaceae	-	-	-	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
Hamiltonia suaveolens Roxb.	Rubiaceae	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Hypericum oblongifolium Wall.	Hypericaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indigofera pulchella Wall.ex Baker	Fabaceae	-	-	-	-	-	-	-	-	-	+	+	-	-	+	-	+	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Inula cuspidata (DC.) C. B. Clarke	Asteraceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
Lantana camara Linn.	Verbenaceae	+	+	-	+	-	-	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-
Leptodermis lanceolata Wall.	Rubiaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
Meriandra strobilifera Benth.	Lamiaceae	+	-	+	-	-	-	-	+	+	+	+	+	+	-	+	-	+	-	+	-	-	-	+	-	-	+	-	+	+	+	-	+	+	-	-	-	-	-	-
Mimosa rubicaulis Lamarck.	Fabaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
Myrsine africana Linn.	Myrsinaceae	-	-	-	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+	+	+	+	+	+	-	-	-	-	+	-	+	-	-	+	+	-	+	-	-
Osyris arborea Wall. ex DC.	Santalaceae	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	+	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prinsepia utilis Royle	Rosaceae	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Prunus cerasoides D.Don	Rosaceae	-	-	+	-	-	-	+	+	-	+	-	-	-	-	-	+	-	+	+	-	-	-	-	-	+	-	-	-	-	-	+	-	+	+	-	+	+	-	-
Rabdosia rugosa Wall. ex Benth.	Lamiaceae	-	+	-	-	-	-	-	+	-	-	-	-	+	+	-	-	+	-	+	+	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	+	+
Randia tetrasperma (Roxb.) Benth. & Hook. f.	Rubiaceae	-	-	+	-	-	-	+	+	+	-	-	+	-	-	+	+	+	+	+	+	-	+	+	+	-	-	+	-	+	+	-	-	-	-	-	+	-	-	-
Rosa moschata Herrm.	Rosaceae	-	-	-	-	-	+	-	+	-	-	-	+	-	-	-	-	-	-	-	+	-	+	-	-	-	-	+	-		+	-	-	+	-	-	+	-	-	-
Rubus ellipticus Smith	Rosaceae	+	+	-	+	+		+	+	-	+	+	+	-	+	-	-	-	+	+	+	-	+	+	+	+	-	-	+	+	-	+	+		+	+	-	+	+	-
Smilax aspera Linn.	Smilacaceae	-	-	+	-	-	+	-	-	-	-	-	+	-	-	+	-	-	+	-	-	-	+	+	+	-	-	+	-	-	+	-	-	-	-	-	+	-	-	+
Woodfordia fruticosa (Linn.) Kurtz.	Lythraceae	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Zanthoxylum armatum DC.	Rutaceae	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	+	-	+	+	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-
Total number of shrubs		**5**	**5**	**6**	**5**	**4**	**4**	**7**	**11**	**7**	**8**	**10**	**9**	**8**	**9**	**4**	**8**	**7**	**9**	**11**	**11**	**6**	**9**	**8**	**6**	**6**	**5**	**5**	**5**	**6**	**5**	**4**	**7**	**4**	**7**	**4**	**5**	**6**	**4**	**4**
Total number of plant species		**19**	**24**	**20**	**26**	**24**	**23**	**19**	**28**	**26**	**24**	**27**	**26**	**25**	**22**	**22**	**28**	**34**	**21**	**26**	**22**	**20**	**26**	**22**	**23**	**27**	**24**	**20**	**29**	**27**	**21**	**20**	**22**	**22**	**23**	**27**	**23**	**20**	**22**	**24**

Where: '+' = present and '-' = absent

4.4 PHYTOSOCIOLOGY OF VEGETATION

The phytosociological study of herbaceous vegetation in silvipasture systems and grasslands at elevations E_1 (900-1300 m), E_2 (1301-1700 m) and E_3 (1701-2100 m) was done in thirteen sub-watersheds selected for study. The density, basal area, frequency and Importance Value Index (IVI) of constituent species were determined by using standard methodology. The results so obtained are described as under:

4.4.1 Silvipasture system (SP) - Herbacious Vegetation

4.4.1.1 DENSITY (tiller/m^2)

At elevation E_1 of sub-watersheds, in silvipasture systems, density (tillers/m^2) of herbage vegetation ranged from 657.73 (SW_2) to 984.67 (SW_1). The percent contributions of plant categories to the total density of herbage in different sub-watersheds exhibited that 60.30 % to 98.76 % of total density accounted for grasses, 0.41 % to 2.90 % for sedges, 0.69 % to 26.33 % for forbs and 0.11 % to 3.28 % for legumes (Table 11).

It was noted that among different herb species *Chrysopogon montanus*, *Themeda anathera* and *Heteropogon contortus* were the major contributors to the total density of herbage vegetation and their contributions to herbage density in different sub-watersheds varied from 112.67 ± 5.08 (SW_8) to 343.33 ± 22.69 (SW_{10}), 20.33 ± 5.00 (SW_2) to 505.33 ± 14.05 (SW_1) and 24.64 ± 4.75 (SW_5 & SW_3) to 355.33 ± 23.05 (SW_6) tillers/m^2, respectively.

The contribution of sedges to the total density of herbage in the sub-watersheds, where they were recorded, remained very low. Their total density varied from 2.67 (SW_2) to 42.00 (SW_1) tillers/m^2. The forbs contribution to the total density of herbage in sub-watersheds was also very less as compared to grasses and their total density ranged from 1.33 (SW_8) to 145.33 (SW_{12}) tillers/m^2. Likewise, the contributions from legumes in sub-watersheds, in which they were present, to the total density of herbage fluctuated between 0.67 (SW_3) to 26.67 (SW_{10}) tillers/m^2 (Table 11).

Table: 11. Density (tillers/m^2) of herbage species in silvipasture systems at elevation E_1 (900-1300m) in Giri catchment of HP

Plant species/ Plant categories	SUB-WATERSHEDS												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
DENSITY OF GRASSES													
Apluda mutica	-	-	15.33 ± 2.51	-	16.00 _ 2.65	-	48.00 ± 8.90	26.67 ± 6.67	29.33 ± 4.98	56.00 ± 6.93	66.67 ± 8.48	-	-
Arundinella nepalensis	21.33 ± 5.33	-	194.00±35.02	-	158.67 ±24.15	-	193.33 ±11.59	138.00 ± 9.42	148.00 ±12.48	2.17 ± 0.56	105.33 ±11.03	26.67 ± 4.29	108.00 ± 1.73
Chloris barbata	-	-	-	-	-	-	-	± -	-	-	-	-	15.33 ± 2.71
Chrysopogon montanus	140.00 ±20.90	262.67±17.19	218.67±18.86	173.33 ±16.18	240 ± 17.17	150 ± 18.00	242.00 ±10.15	112.67 ± 5.08	157.33 ±14.36	343.33 ±22.69	242.67 ±18.71	230.67 ±4.74	315.33 ±22.65
Cymbopogon martinii	-	-	37.33 ± 6.79	14.67 ± 3.67	37.33 ± 6.79	8.00 ± 2.00	-	7.33 ± 1.83	-	18.67 ± 3.46	-	-	64.00 ± 4.35
Dicanthium annulatum	10 .00± 2.50	-	22.67 ± 2.62	43.33 ± 5.78	6.00 ± 1.50	9.33 ± 2.33	65.33 ± 7.84	24.00 ± 6.00	-	-	27.27 ± 6.82	-	-
Heteropogon contortus	124.67 ±12.95	114.00 ± 8.80	24.67 ± 4.75	48.00 ± 4.49	24.67 ± 4.75	355.33 ±23.05	98.67 ± 11.00	194.67 ±16.77	88.67 ± 11.51	61.33 ± 7.82	279.33 ±18.09	129.32±10.87	126.00 ±12.41
Imperata cylindrica	-	-	-	-	-	-	22.67 ± 5.67	1.33 ± 0.33	7.33 ± 1.83	35.20 ± 5.22	-	-	-
Ischaemum aristatum.	-	7.33 ± 1.83	-	34.00 ± 5.56	16.00 ± 3.11	8.00 ± 1.63	-	-	42.67 ± 9.16	-	-	-	36.00 ± 1.61
Oplismenus burmannii	-	-	-	-	-	-	-	-	15.33 ± 2.59	-	-	-	-
Panicum coloratum	-	-	17.33 ± 4.33	68.00 ± 11.71	17.33 ± 4.33	20.67 ± 4.09	-	-	-	-	-	-	-
Panicum maximum	-	98.67 ± 12.44	-	-	-	34.67 ± 4.32	40.00 ± 10.00	174.67 ±22.52	-	-	25.33 ± 4.21	-	356.67 ±13.50
Themeda anathera	505.33 ±14.05	20.33 ±5.00	112.67±10.74	302.00 ±13.12	186.00 ± 9.40	112.67 ±10.13	298.40 ± 7.83	201.33 ±14.80	285.33 ±13.22	230.67 ± 8.77	54.00 ± 13.60	117.33 ±11.00	113.60 ± 6.60
Themeda quadrivalvis	-	-	-	-	-	-	-	-	-	3.33 ± 0.83	-	-	-
Urochloa panicoides	124.67 ±18.65	-	-	4.67 ± 1.17	-	8.67 ± 2.17	-	-	-	4.67 ± 1.17	9.33 ± 1.67	-	-
Total density of grasses	925.33	532.67	596.00	688.00	702.00	707.33	946.00	880.67	774.00	755.20	909.93	366.00	853.33
DENSITY OF SEDGES													
Cyperus rotundus	7.33 ± 1.83	-	-	4.00 ± 0.58	-	32.67 ± 5.02	-	-	14.00 ± 3.12	-	-	-	6.00 ± 0.96
Eriophorum comosum	-	-	10.00 ± 2.50	-	-	-	-	-	-	9.33 ± 2.33	16.67 ± 4.17	24.67 ± 2.54	-
Fimbristylis rigidula	-	2.67 ± 0.67	-	-	-	-	-	-	-	-	25.33 ± 6.33	16.00 ± 1.65	-
Total density of sedges	7.33	2.67	10.00	3.33	-	32.67	-	-	14.00	9.33	42.00	40.67	6.00
DENSITY OF FORBS													
Ageratum conyzoides	-	-	-	-	-	-	-	-	-	0.28 ± 0.02	-	-	-
Andrachne cordifolia	2.00 ± 0.50	-	-	-	-	-	-	-	-	-	-	-	-

Continued ….

Plant species/ Plant categories	SUB-WATERSHEDS												
	SW$_1$	**SW$_2$**	**SW$_3$**	**SW$_4$**	**SW$_5$**	**SW$_6$**	**SW$_7$**	**SW$_8$**	**SW$_9$**	**SW$_{10}$**	**SW$_{11}$**	**SW$_{12}$**	**SW$_{13}$**
DENSITY OF FORBS													
Artemisia roxburghiana	2.00 ± 0.50	-	-	-	-	-	-	-	7.33 ± 0.98	0.67 ± 0.17	2.40 ± 0.55	-	-
Barleria strigosa	-	12.00 ±3.00	-	-	-	-	-	-	-	-	-	-	-
Bidens pilosa	-	12.00 ± 1.55	-	-	-	-	-	-	5.33 ± 1.15	-	-	3.33 ± 0.54	-
Bidens tripartita	-	-	-	5.33 ± 0.99	2.00 ± 0.50	5.33 ± 1.33	-	-	-	4.00 ± 1.00	-	-	2.67 ± 0.67
Cheilathes farinosa	-	11.33 ±2.64	-	-	-	-	-	-	-	-	-	-	-
Commelina benghalensis	0.67 ± 0.17	-	-	-	-	-	-	-	-	6.00 ± 0.96	-	4.67 ±0.54	-
Dicliptera bupleuroides	-	13.33 ±3.33	-	-	-	-	-	-	-	-	-	10.00±0.54	1.33 ± 0.33
Euphorbia heterophylla	2.67 ± 0.67	-	-	-	-	-	-	-	13.33 ± 2.17	-	-	-	-
Evolvulus alsinoides	52.80 ± 8.15	-	-	-	-	-	12.00 ± 2.74	-	-	-	-	-	-
Leucus lanata	-	-	-	-	-	-	-	-	-	-	-	19.33 ± 2.71	-
Micromeria biflora	-	3.33 ± 0.54	-	-	-	28.00 ± 6.39	-	-	-	-	-	26.00 ± 5.23	12.00 ± 2.29
Origanum vulgare	-	14.00 ±2.50	-	-	-	-	-	-	-	-	-	21.33 ± 3.37	2.00 ± 0.50
Platystemmsa violoides		-	-	-	8.67 ± 2.17	-	-	-	-	-	-	-	-
Reinwardtia indica	-	-	10.67 ± 1.71	-	-	-	-	-	-	-	-	-	-
Rhus cotinus	-	-	8.80 ± 1.59	-	-	-	-	-	-	-	-	-	-
Sonchus arvensis	-	-	-	-	2.67 ± 0.67	-	-	-	-	-	-	14.00 ± 3.50	-
Thalictrum foliosum	-	45.60 ±3.84						1.33+0.33					
Tricholepis elongata	-	18.00 ±4.50	-	-	-	-	-	-	-	5.60 ± 1.28	-	4.67 ± 0.83	-
Viola serpens	-	-	-	-	-	-	-	-	6.00 ± 1.15	3.33 ± 0.83	-	-	-
Total density of forbs	**52.00**	**122.00**	**18.00**	**5.33**	**13.33**	**28.67**	**10.00**	**1.33**	**31.33**	**20.67**	**6.67**	**145.33**	**18.00**
DENSITY OF LEGUMES													
Cassia mimosoides	-	-	-	-	-	-	-	-	-	2.67 ± 0.67	-	-	-
Lespedeza gerardiana	-	-	0.67 + 0.17	-	-	-	15.33 + 3.83	-	-	24.00 + 3.93	6.00 + 1.50	-	-
Rhynchosia himalensis	-	-	-	-	-	-	-	24.00 + 3.36	-	-	-	-	-
Total density of legume	-	-	0.67	-	-	-	15.33	24.00	-	26.67	6.00	-	0.00
Total density of herbage	**984.67**	**657.33**	**671.33**	**696.70**	**715.33**	**768.33**	**971.33**	**906.00**	**819.33**	**806.00**	**964.00**	**746.00**	**877.33**

'-' = not present in sub-watershed

At elevation E_2, in silvipasture systems of different sub-watersheds, total density of herbage vegetation varied from 513.33 (SW_6) to 947.33 (SW_9). The contributions of plant categories viz., grasses, sedges, forbs and legumes to total plant density of herbage in different sub-watersheds was 80.73 % to 98.46 %, 0.85 % to 13.19 %, 0.33 % to 11.07 % and 0.08 % to 3.16 %, respectively.

Among individual species of grasses, higher density contributions was recorded for *Chrysopogon montanus* that varied from 48.60 ± 6.92 (SW_{10}) to 520.67 ± 25.77 (SW_{13}) followed by *Themeda anathera* 22.00 ± 2.51(SW_{11}) to 294.67 ± 10.08 (SW_5) *Heteropogon contortus* 22.67 ± 4.51 (SW_2) to 238.67 ± 26.77(SW_9), *Arundinella nepalensis* 33.33 ± 3.37(SW_8) to 247.33 ± 7.18(SW_{13}) and *Dicanthium annulatum* 7.33 ± 1.64 (SW_7) to 70.67 ± 8.27 (SW_5) tillers/m^2 (Table 12).

The sedges were recorded in some sub-watersheds and they contributed very low density to the total density of herbage which varied from 7.33 (SW_{11}) to 12.67 (SW_2) tiller/m^2. The contributions of forbs to the total density of herbage in sub-watersheds was also very less as compared to grasses and it ranged from 2.67 (SW_{12}) to 74.67 (SW_5) tillers/m^2. Similarly the contributions from legumes to the total density of herbage vegetation in sub-watersheds varied between 1.33 (SW_8) and 21.33 (SW_5) tillers/m^2.

Total density of herbage vegetation in the silvipasture systems of different sub-watersheds at elevation E_3 varied from 612.00 (SW_{10}) to 884.93 (SW_1) tillers/m^2 (Table 3). Among the plant categories per cent contributions of grasses, sedges, forbs and legumes to the total density of herbage in different sub-watersheds ranged 84.53 % to 97.75 %, 0.85 % to 8.66 %, 2.25 % to 12.05 % and 0.46 % to 1.86 %, respectively.

Among constituent species higher plant density was recorded for *Themeda anathera* that varied from 98.67 ± 6.18 (SW_2) to 325.33 ± 8.22(SW_{12}) followed by *Arundinella nepalensis* 20.67 ± 3.39 (SW_{11}) to 240.00 ± 13.19 (SW_6), *Heteropogon contortus*18.67 ± 2.86 (SW_3) to 208.67 ± 6.04 (SW_{13}), *Dicanthium annulatum* 23.33 ± 3.83 (SW_{10}) to 178 ± 6.69 (SW_5) and *Apluda mutica* 36.00 ± 4.63 (SW_3) to 146.67 ± 11.99 (SW_{10}) tillers/m^2.

The contributions of sedges to the total density of herbage vegetation in sub-watersheds was very less and it varied from 6.00 (SW_{11}) to 76.67 (SW_1) tillers/m^2. The forbs contributions to the total density in sub-watersheds was also very low as compared to grasses and it varied from 18.00 (SW_8) to 108 (SW_5) tillers/m^2. Similarly, the legumes contributions to the total density of herbage vegetation in different sub-watersheds fluctuated between 3.78 (SW_2) to 12.67 (SW_4) tillers/m^2 (Table 13).

It was recorded that mean density of herbage in the sub-watersheds selected for study decreased with increase in elevation i.e. maximum mean density of herbage was recorded at elevation E_1 (814.20 tillers/m^2) and least 747.18 tillers/m^2 at elevation E_2. But the difference in density of herbage recorded at three elevations was found to be statistically non-significant. The effect of sub-watersheds, and interaction between elevations and sub-watersheds on mean density of herbage was also found to be non-significant (Table 14).

4.4.1.2 Basal area (cm^2/m^2)

In silvipasture systems at elevation $E_{1,}$ basal area (cm^2/m^2) of herbage vegetation in different sub-watersheds ranged 25.53 (SW_2) to 63.00 (SW_8) (Table 15). The per cent contributions of different plant categories to the basal area of herbage vegetation in different sub-watersheds exhibited that 69.21 % to 98.76 % of total basal area accounted for grasses, 0.04 % to 8.52 % for sedges, 0.09 % to 22.27 % for forbs and 0.02 % to 2.96 % for legumes.

Among different species *Themeda anathera*, *Chrysopogon montanus*, *Heteropogon contortus* and *Arundinella nepalensis* were the major contributors to the total basal area of herbage and their contributions in different sub-watersheds varied from 0.69 ± 0.06 to 15.90 ± 4.60, 3.75 ± 0.95 to 15.49 ± 5.61, 0.57 ± 0.37 to 15.90 ± 4.60 and 0.26 ± 0.06 to 12.53 ± 5.81 cm^2/m^2, respectively.

The contributions of sedges to the total basal of herbage vegetation in the different sub-watersheds, where they were recorded, remained very low and it varied from 0.01 (SW_2) to 2.83 (SW_{12}) cm^2/m^2. The forbs contributions to the total basal area of herbage vegetation in sub-watersheds was also very low as compared to grasses and it ranged from 0.04 (SW_8) to 7.41 (SW_{12}) cm^2/m^2. Similarly, the contributions of legumes was also very low and it fluctuated between 0.01 (SW_3) to 1.61 (SW_{10}) cm^2/m^2 (Table 15).

Further, at elevation E_2, in silvipasture systems of different sub-watersheds, the total basal area of herbage vegetation varied from 31.38 (SW_4) to 46.33 (SW_1) cm^2/m^2. Among the plant categories per cent contributions of grasses, sedges, forbs and legumes to total basal area of herbage in different sub-watersheds varied from 76.82 % to 98.98 %, 0.42 % to 16.29 %, 0.46 % to 8.55 % and 0.09 % to 2.32 %, respectively. It was recorded that among different species *Arunidinella nepalensis*, *Chrysopogon montanus*, *Themeda anathera* and *Heteropogon contortus* were the major contributors to the total basal area of herbage with their contributions ranging from 1.64 ± 0.02 to 26.09 ± 2.47, 0.38 ± 0.20 to 25.09 ± 5.36, 2.86 ± 1.50 to 23.07 ± 3.83 and 1.43 ± 1.15 to 16.76 ± 5.99 cm^2/m^2, respectively (Table 16).

The contribution of sedges to the total basal area of herbage vegetation in different sub-watersheds, where their presence was recorded, remained very low and it varied from 0.19 (SW_{11}) to 3.81 (SW_2) cm^2/m^2. Whereas, the contribution of forbs to the total basal area was also very less as compared to grasses and it varied from 0.18 (SW_{12}) to 5.79 (SW_2) cm^2/m^2. Likewise, the contribution from legumes in different sub-watersehds to the total basal area of herbage varied between 0.05 (SW_{13}) to 0.77 (SW_5) cm^2/m^2 (Table 16).

In silvipasture systems at elevation $E_{3,}$ total basal area of herbage vegetation in the different sub-watersheds varied from 25.05 (SW_{11}) to 51.99 (SW_1) cm^2/m^2. The contributions of different plant categories to the total basal area of herbage vegetation revealed that 36.49 % to 99.23 % basal area was contributed by grasses, 0.64 % to 8.17 % by sedges, 0.77 % to 8.46 % by forbs and 0.83 to 1.08 % by legumes (Table 17).

It was recorded that among different species *Themeda anathera, Chrysopogon montanus, Panicum maximum, Heteropogon contortus* and *Arundinella nepalensis*

Table: 12. Density (tillers/m^2) of herbage species in silvipasture systems at elevation E_2 (1301 - 1700 m) in Giri catchment of HP

Plant species/ Plant categories	SUB-WATERSHEDS												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
DENSITY OF GRASSES													
Apluda mutica	-	-	16.00 ± 2.65	-	-	47.33 ± 11.83	12.00 ± 3.00	84.67 ± 9.60	-	44.67 ± 7.09	-	57.33 ± 3.59	-
Arundinella nepalensis	226.40 ± 7.71	184.80 ± 7.49	132.00 ± 14.01	88.67 ± 6.07	-	34.67 ± 6.30	92.00 ± 10.73	33.33 ± 3.77	-	102± 12.56	133.33 ± 14.23	52.67 ± 10.30	247.33 ± 7.81
Chloris barbata	10.67 ± 2.67	-	-	-	-	-	-	-	35.33 ± 6.00	-	16.00 ± 4.00	8.00 ± 2.00	-
Chrysopogon fulvus	-	2.67 ± 0.67	-	-	3.33 ± 0.83	1.33 ± 0.21	-	-	-	-	2.67 ± 0.67	-	4.00 ± 1.00
Chrysopogon montanus	382.00 ± 16.72	161.33 ± 13.48	156.00 ± 10.78	76.67 ± 10.44	97.33 ± 11.69	48.60 ± 6.92	206.00 ± 12.25	230.00 ± 11.50	193.33 ± 13.65	246.67 ± 13.29	169.33 ± 20.03	230 ± 12.40	520.67 ± 25.77
Cymbopogon martinii	-	-	28.00 ± 3.98	-	-	-	-	-	38.00 ± 7.76	-	-	-	-
Dicanthium annulatum	13.33 ± 3.33	-	-	31.33 ± 7.44	70.67 ± 8.27	-	7.33 ± 1.64	-	48.00 ± 5.54	58.00 ± 5.48	32.00 ±4.82	42.00 ± 3.42	13.33 ± 3.33
Heteropogon contortus	130.00 ± 10.72	22.67 ± 4.57	148.67 ± 17.28	58.00 ± 9.43	82.00 ± 10.48	13.30±2.12	132.67 ± 11.49	110± 12.54	238.67 ± 26.77	202.67 ± 6.74	215 ± 5.19	136.00 ± 12.60	158.67 ± 19.69
Imperata cylindrica	-	7.33 ± 1.83	-	-	16.67 ± 2.99	-	-	1.33 ± 0.33	-	-	-	-	-
Ischaemum aristatum	-	-	38.00 ± 6.95	-	-	-	-	18.67 ± 4.67	5.33 ± 1.33	-	208.00 ±16.26	13.33 ± 2.62	-
Oplismenus burmannii	-	-	-	-	-	-	-	-	36.00 ± 5.72	-	-	0.67 ± 0.17	-
Panicum coloratum	-	-	4.00 ± 1.00	-	-	57.60 ± 6.64	2.67 ± 0.67	2.67 ± 0.67	-	-	-	2.67 ± 0.67	-
Panicum maximum	-	-	20 ± 5.00	-	-	-	210 ± 23.11	28.00 ± 3.12	202.67 ± 19.17	-	97.33 ± 9.27	230.67 ±8.50	-
Paspalum notatum	-	-	-	-	-	-	-	-	-	-	-	-	2.00 ± 0.50
Setaria glauca	-	24.67 ± 4.35	-	-	-	-	-	-	-	-	-	-	-
Themeda anathera	105.33 ± 12.71	129.33 ± 6.23	106.67 ± 10.53	181.33 ± 16.21	294.67 ±10.08	276.67 ± 9.46	175.33 ± 14.19	201.33 ± 20.89	101.33 ± 11.52	72.00 ±1 1.44	22.00±2.51	26.00±4.38	95.33 ± 13.66
Themeda quadrivalvis	-	6.00 ± 1.50	-	-	-	-	-	-	-	31.30 ± 7.83	-	-	1.33 ± 0.33
Urochloa panicoides	-	14.67 ± 2.94	16.00 ± 2.65	-	14.00 ± 2.50	-	80 ± 20	38.67 ± 4.18	-	68.00 ± 4.04	-	-	-
Total density of grasses	**802.40**	**689.81**	**665.33**	**588.67**	**578.67**	**475.33**	**806.67**	**752.67**	**898.67**	**635.20**	**850.67**	**754.00**	**771.47**
DENSITY OF SEDGES													
Cyperus esculantus	-	90.67 ± 14.37	-	-	-	-	-	-	-	-	-	-	-
Cyperus rotundus	-	-	-	-	-	-	15.33 ± 2.43	-	27.33 ± 3.98	-	7.33 ± 0.60	59.33 ± 11.92	-
Eriophorum comosum	-	-	-	-	-	-	-	8.67 ± 1.64	-	-	-	-	-
Fimbristylis rigidula.	-	22.00 ± 3.48	-	-	-	-	-	-	-	-	-	-	-
Total density of sedges	**-**	**112.67**	**-**	**-**		**-**	**15.33**	**-**	**27.33**	**-**	**7.33**	**59.33**	**0.00**
DENSITY OF FORBS													
Achyranthus aspera.	-	-	-	-	-	-	3.33 ± 0.83	-	-	-	2.67 ± 0.67	-	3.33 ± 0.83
Barleria strigosa	-	-	-	-	3.33 +.03	-	-	-	-	-	-	-	-

Continued….

Plant species/ Plant categories	SUB-WATERSHEDS												
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	**SW_7**	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**
DENSITY OF FORBS													
Bidens pilosa	7.33 ± 1.83	-	-	-	1.60 ± 0.37	-	-	-	-	-	-	-	1.33 ± 0.21
Bidens tripartita	-	2.67 ± 0.67	-	5.33 ± 0.61	-	13.33 ± 1.69	-	-	-	24.00 ± 0.58	-	-	-
Cissampetous pariera	-	-	-	-	-	-	-	-	-	-	-	-	6.67 ± 1.67
Commelina benghalensis	-	-	-	-	-	-	-	-	-	12.00 +0 .02	-	2.67 ± 0.67	-
Conyza stricta	-	-	-	-	-	-	-	-	-	-	-	-	0.67 ± 0.17
Dicliptera bupleuroides	-	-	-	8.67 ± 1.64	-	-	-	-	-	-	-	-	-
Erigeron annus	-	-	-	-	36.67 ± 4.18	-	-	-	-	-	-	-	-
Evolvulus alsinoides	-	-	-	1.33 ± 0.33	-	-	-	-	-	-	-	-	-
Geranium nepalensis	-	34.67 ± 4.01	-	-	-	-	-	-	-	-	-	-	-
Gerbera gossypina	-	-	-	-	-	4.67 ± 1.17	-	-	-	-	-	-	-
Justicia simplex	-	3.33 ± 0.83	-	-	-	-	-	-	2.00 ± 0.50	12.00 ± .02	-	-	-
Micromeria biflora	29.33 ± 2.56	-	-	-	-	20 ± 5.00	-	28.67 ± 4.62	11.33 ± 2.83	-	-	-	1.33 ± 0.33
Origanum vulgare	1.33 ± 0.33	-	-	-	-	-	25.33 ± 3.27	-	-	-	-	-	-
Pimpinella diversifolia	-	-	-	3.33 ± 0.83	-	-	-	-	2.00 ± 0.34	-	-	-	-
Platystemma violoides	-	-	9.33 ± 2.33	-	-	-	-	-	-	-	-	-	-
Plectranthus sericea	-	-	6.00 ± 1.50	0.67 ± 0.17	36.67 ± 4.01	-	-	-	-	-	-	2.00 ± 0.50	-
Reinwardtia indica	6.00 ± 1.50	-	2.00 ± 0.50	-	-	-	-	-	-	-	1.33 ± 0.33	-	-
Sonchus arvensis	-	-	-	1.33 ± 0.33	-	-	-	-	-	-	-	-	-
Swertia angustifolia	3.33 ± 0.54	-	-	-	-	-	-	-	-	-	-	-	-
Thalictrum foliosum	19.33 ± 4.26	2.67 ± 0.67	-	-	-	-	-	-	-	-	-	-	-
Tricholepis elongata	-	4.67 ± 1.17	-	-	-	-	-	-	-	-	-	0.67 ± 0.17	-
Total density of forbs	**66.67**	**48.00**	**17.33**	**22.00**	**74.67**	**38.00**	**28.67**	**28.67**	**15.33**	**10.00**	**6.00**	**2.67**	**13.33**
DENSITY OF LEGUMES													
Cassia mimosoides	-	4.80 ± 1.10	-	-	-	-	-	-	4.67 ± 1.17	21.67 ±0.67	-	-	-
Lespedeza gerardiana	0.67 ± 0.17	-	-	-	21.33 ± 3.38	-	-	-	1.33 ± 0.33	6.00 ± 1.5	-	-	-
Rhynchosia himalensis	-	-	-	-	-	-	-	1.33 ± 0.33	-	-	-	-	-
Total	**0.67**	**4.00**	**-**	**-**	**21.33**	**-**	**-**	**1.33**	**6.00**	**8.67**	**-**	**-**	**4.00**
Total density of herbage	**832.00**	**690.00**	**684.00**	**610.67**	**676.00**	**513.33**	**850.67**	**791.33**	**947.33**	**655.33**	**864.33**	**818.00**	**779.00**

'-'= not present in sub-watershed

Table: 13. Density (tillers/m^2) of herbage species in silvipasture systems at elevation E_3 (1701 – 2100 m) in Giri catchment of HP

Plant species/ Plant categories	SUB-WATERSHEDS												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Density of herbage species													
DENSITY OF GRASSES													
Apluda mutica	101.33 ± 11.48	59.33 ± 9.53	36.00 ± 4.63	136.00 ± 13.24	78.67 ± 14.43	-	57.33 ± 10.05	-	53.33 ± 7.56	146.67 ±11.99	-	34.67 ± 5.51	-
Arundinella nepalensis	144.00 ± 16.78	102.67 ± 9.42	123.33 ± 11.78	180.67 ± 17.41	110.53 ±6.15	240 ± 13.19	75.33 ± 8.59	85.33 ± 11.82	141.33 ± 9.28	133.33 ± 8.62	20.67 ± 3.39	180.67 ± 21.85	90.67 ± 8.17
Avena fatua	-	-	-	-	-	7.33 ± 1.83	-	-	-	-	-	-	-
Chrysopogon montanus	116.67 ± 4.50	182.33 ± 13.19	160.67 ± 13.53	144.00 ± 9.55	171.33 ± 13.41	29.33 ± 4.98	90 ± 8.34	14- ± 15.66	266.00 ± 29.82	126.67 ± 5.75	185.60 ± 25.11	157.33 ± 10.91	86.00±10.00
Cymbopogon martinii	-	-	-	-	-	-	-	36.00 ± 4.37	75.33 ± 10.51	-	36.00 ± 4.37	-	-
Dicanthium annulatum	34.67 ± 4.56	-	72.91 ± 8.98	-	178.67 ± 6.69	43.33 ± 6.88	-	-	53.33 ± 4.47	23.33 ± 3.83	-	72.67 ± 4.53	-
Digiteria stricta.	-	12.00 ±7.35	-	-	-	-	-	-	-	-	-	-	-
Heteropogon contortus	98.67 ± 8.36	53.33 ±19.45	18.67 ± 2.86	169.33 ± 10.39	107.33 ± 19.80	131.33 ± 10.92	170.00 ± 14.24	44.00 ± 8.09	-	-	69.33 ± 10.20	25.33 ± 6.33	208.67 ± 6.04
Imperata cylindrica.	-	-	2.36 ± 1.02	-	68.00 ± 9.33	59.33 ± 7.50	-	-	-	-	-	4.00 ± 1.00	-
Ischaemum aristatum	-	-	-	-	-	-	-	16.00 ± 1.91	-	-	20 ± 1.75	58.00 ± 13.15	-
Panicum maximum	110.4 ± 32.13	59.33 ± 8.30	-	-	-	-	-	189.33 ± 18.50	68.00 ± 13.40	-	172.00 ± 19.85	-	60.0 ± 15.00
Themeda anathera	179.33 ±5.65	98.67 ± 6.18	217.33 ± 9.46	108.67 ± 11.70	267.33 ± 23.59	140.67 ± 24.94	161.33 ±11.50	27.00 ± 13.85	177.00 ± 18.10	34.67 ± 5.49	175.33 ± 17.31	325.33 ± 8.22	250.67 ±17.20
Urochloa panicoides	-	-	16.0 ± 2.65	-	-	-	38.60 ± 4.92	-	76.67 ± 15.51	6.00 ± 1.50	-	-	22.67 ± 3.27
Total density of grasses	**748.00**	**567.66**	**710.89**	**738.67**	**750.00**	**646.67**	**592.67**	**780.67**	**822.00**	**573.33**	**678.93**	**831.33**	**662.00**
DENSITY OF SEDGES													
Cyperus rotundus	-	-	-	-	-	10.67 ± 1.45	-	-	-	-	6.00 ± 0.96	10.00 ± 1.23	26.67 ± 1.98
Fimbristylis rigidula	-	32.00 ± 3.80	-	8.67 ± 1.38	-	12.00 ± 2.05	6.00 ± 1.02	-	-	-	-	-	0.67 ± 0.17
Eriophorum comosum	76.67 ± 15.78	-	-	-	36.67 ± 4.53	-	-	-	-	-	-	-	-
Total density of sedges	**76.67**	**32.00**	**-**	**8.67**	**36.67**	**22.67**	**6.00**	**-**	**-**	**-**	**6.00**	**10.00**	**27.33**
DENSITY OF FORBS													
Artemisia roxburghiana	-	0.80 ± 0.18	-	-	8.00 ± 1.13	-	-	-	-	-	-	-	-
Barleria strigosa	1.60 ± 0.37	6.00 ± 1.15	-	-	-	-	-	-	-	-	-	-	-
Bidens pilosa	-	-	-	-	58.67 ± 8.82	-	0.46 ± 0.34	-	-	-	-	-	-
Bidens tripartita	-	-	-	-	-	-	-	2.67 ± 0.67	17.33 ± 2.11	3.33 ± 0.54	4.00 ± 0.68	0.67 ± 0.17	3.33 ± 0.83
Cheilathes farinosa	-	-	-	2.67 ± 0.67	-	-	-	-	-	-	-	-	-
Dicliptera bupleuroides	-	-	-	-	-	-	-	1.33 ± 0.33	-	-	2.00 ± 0.50	-	22.67 ± 2.32

Continued…..

Plant species/ Plant categories	SUB-WATERSHEDS												
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	**SW_7**	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**
DENSITY OF FORBS													
Dicliptera roxburghiana	-	-	-	-	-	-	-	-	13.33 ± 2.17	-	-	-	-
Erigeron annus	2.00 ± 0.50	-	-	1.33 ± 0.33	-	-	-	-	-	-	-	-	-
Evolvulus alsinoides	-	-	-	-	-	-	4.67 ± 0.65	-	-	-	-	-	-
Geranium nepalensis	-	-	-	3.33 ± 0.54	-	-	-	-	6.00 ± 1.50	-	-	-	-
Gerbera gossypina	-	-	-	7.33 ± 1.22	-	16.00 ± 2.02	-	-	-	-	-	-	-
Justicia simplex	-	3.34 ± 3.33	-	-	-	-	-	-	-	0.67 ± 0.17	-	-	-
Leucus lanata	-	-	-	-	-	-	-	-	5.33 ± 1.33	4.67 ± 1.17	-	-	-
Micromeria biflora	39.68 ± 6.22	-	-	-	48.0±7.59	-	-	12.00 ± 2.29	-	27.33 ± 6.83	13.33 ± 2.62	8.67 ± 2.17	40.67 ± 5.08
Origanum vulgare	8.00 ± 2.00	-	-	-	5.33 ± 1.33	12.00 ± 2.45	4.67 ± 2.07	2.00 ± 0.50	-	-	-	37.33 ± 2.96	-
Platystemma violoides	-	-	-	-	-	-	-	-	-	-	-	4.00 ± 0.68	-
Plectranthus sericea	-	-	26.00 ± 4.03	61.33 ± 8.31	-	-	-	-	-	-	-	-	-
Reinwardtia indica.	9.33 ± 1.17	5.30 ± 0.88	-	-	-	-	-	-	-	2.67 ± 0.67	-	-	-
Thalictrum foliosum	-	0.79 ± 0.33	-	-	-	-	-	-	2.67 ± 0.33	-	-	-	-
Total density of forbs	**60.27**	**25.47**	**26.00**	**79.34**	**108.00**	**28.00**	**22.67**	**18.00**	**42.00**	**38.66**	**19.33**	**50.67**	**66.67**
DENSITY OF LEGUMES													
Cassia mimosoides	-	3.78 ± 2.38	-	-	-	-	-	-	4.00 ± 1.00	-	-	-	-
Lespedeza gerardiana	-	-	14.00 ± 2.25	12.67 ± 2.20	-	-	6.00 ± 0.96	-	-	-	-	-	-
Total density of legumes	**0.00**	**3.78**	**14.00**	**12.67**	**-**	**-**	**6.00**	**-**	**4.00**	**-**	**-**	**-**	**0.00**
Total density of herbage	**884.67**	**639.33**	**690.00**	**836.67**	**894.67**	**742.00**	**627.33**	**798.67**	**868.00**	**613.33**	**673.33**	**896.00**	**758.00**

'-'= not present in sub-watershed

Table: 14. Variation in density (tillers/m^2) of herbage in silvipasture system of different sub-watersheds in Giri catchment

Elevation (E)	SUB-WATERSHEDS (SW)													
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}	Mean (E)
Density														
E_1 (900 - 1300 m)	984.67	657.33	671.33	696.67	715.33	768.67	971.33	906.00	819.33	806.00	964.60	746.00	877.33	**814.20**
E_2 (1301 - 1700 m)	832.00	690.67	684.00	610.67	676.00	513.33	850.67	791.33	947.33	655.33	864.00	818.67	779.33	**747.18**
E_3 (1701 - 2100 m)	884.67	639.33	690.00	836.67	894.67	742.00	627.33	798.67	868.00	613.33	673.33	896.00	758.00	**763.23**
Mean (SW)	**900.45**	**662.45**	**681.78**	**714.67**	**762.00**	**674.67**	**816.45**	**832.00**	**878.22**	**691.56**	**833.98**	**820.22**	**804.89**	

Factors	$CD_{0.05}$	SEm±
SW	NS	26.48
E	153.93	55.13
SW×E	NS	95.49

Table: 15. Basal area (cm^2/m^2) of herbage species in silvipasture systems at elevation E_1 (900 - 1300 m) in Giri catchment of HP

Plant species /Plant categories	SUB-WATERSHEDS												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
BASAL AREA OF GRASSES													
Apluda mutica	-	-	1.58 ± 1.09	-	0.52 ± 0.35	-	2.51 ± 1.79	5.20 ± 5.20	3.20 ± 2.70	4.00 ± 2.34	2.93 ± 1.52	-	-
Arundinella nepalensis	1.72 ± 1.72	-	4.50 ± 2.29	-	11.44 ± 8.10	-	9.43 ± 2.31	12.53 ± 5.81	7.76 ± 2.95	0.26 ± 0.26	4.30 ± 2.07	0.31 ± 0.23	2.36 ± 1.87
Chloris barbata	-	-	-	-	-	-	-	-	-	-	-	-	0.74 ± 0.55
Chrysopogon montanus	4.58 ± 2.16	12.85 ± 3.03	10.70 ± 5.87	6.76 ± 2.76	8.05 ± 2.50	6.23 ± 3.21	13.54 ± 2.90	3.75 ± 0.95	10.27 ± 4.00	21.89 ± 6.26	11.76 ± 5.09	8.24 ± 2.15	15.49 ± 5.61
Cymbopogon martinii	-	-	2.99 ± 2.55	0.89 ± 0.89	2.84 ± 2.41	0.65 ± 0.65	-	0.69 ± 0.69	-	1.04 ± 0.83	-	-	1.92 ± 0.58
Dicanthium annulatum	0.65 ± 0.05	-	2.23 ± 1.32	5.85 ± 3.04	0.21 ± 0.21	0.48 ± 0.48	4.15 ± 1.95	2.45 ± 2.45	-	-	0.23± 0.01	-	-
Heteropogon contortus	3.07 ± 1.45	4.41 ± 1.78	0.57 ± 0.37	1.32 ± 0.54	0.88 ± 0.65	15.90 ± 4.60	5.58 ± 2.64	6.55 ± 2.30	6.33 ± 5.02	3.89 ± 2.48	12.34 ± 4.09	7.03±1.72	5.61 ± 2.61
Imperata cylindrica	-	-	-	-	-	-	2.68 ± 0.26	0.05 ± 0.05	1.27 ± 1.27	2.82 ± 1.80	-	-	-
Ischaemum aristatum	-	0.23 ± 0.02	-	1.89 ± 1.37	0.45 ± 0.33	0.61 ± 0.61	-	-	1.40 ± 0.94	-	-	-	1.10 ± 0.43
Oplismenus burmannii	-	-	-	-	-	-	-	-	0.27 ± 0.21	-	-	-	-
Panicum coloratum	-	-	0.15 ± 0.15	2.78 ± 1.79	0.15 ± 0.15	0.73 ± 0.60	-	-	-	-	-	-	-
Panicum maximum	-	3.42 ± 2.21	-	-	-	2.14 ± 1.15	2.68 ± 2.68	14.89 ± 8.84	-	-	0.92 ± 0.58	-	12.23 ± 2.72
Themeda anathera	31.00 ± 2.72	0.69 ± 0.06	6.31 ± 2.41	8.48 ± 1.37	8.11 ± 1.77	4.03 ± 1.75	8.73 ± 2.19	15.49 ± 6.71	22.42 ± 8.17	16.80 ± 4.04	4.55 ± 1.67	7.79 ± 2.32	4.20 ± 1.69
Themeda quadrivalvis	-	-	-	-	-	-	-	-	-	0.5 ± 0.05	-	-	-
Urochloa panicoides	4.73 ± 3.15	-	-	0.19 ± 0.09	-	0.23 ± 0.03	-	-	-	0.19 ± 0.09	0.07 ± 0.06	-	-
Total basal area of grasses	**47.24**	**25.47**	**34.12**	**28.17**	**32.66**	**31.01**	**49.30**	**45.57**	**42.85**	**41.49**	**37.11**	**23.02**	**43.65**
BASAL AREA OF SEDGES													
Cyperus rotundus	0.21 ± 0.11	-	-	0.26 ± 0.17	-	1.48 ± 0.87	-	-	0.41 ± 0.38	-	-	-	0.20 ± 0.13
Eriophorum comosum	-	-	0.48 ± 0.04	-	-	-	-	-	-	0.73 ± 0.73	0.48 ± 0.04	0.81 ± 0.37	-
Fimbristylis rigidula	-	0.10 ± 0.01	-	-	-	-	-	-	-	-	0.42 ± 0.04	2.03±0.31	-
Total basal area of sedges	**0.21**	**0.01**	**0.48**	**0.26**	**-**	**1.48**	**-**	**-**	**0.41**	**0.73**	**0.89**	**2.83**	**0.20**
BASAL AREA OF FORBS													
Ageratum conyzoides	-	-	-	-	-	-	-	-	-	0.12 ± 0.01	-	-	-
Andrachne cordifolia	0.08 ± 0.02	-	-	-	-	-	-	-	-	-	-	-	-
Artemisia roxburghiana	0.15 ± 0.01	-	-	-	-	-	-	-	0.72 ± 0.49	0.03 ± 0..01	0.08 ± 0.02	-	-
Barleria strigosa	-	0.39 ± 0.30	-	-	-	-	-	-	-	-	-	-	-

Continued…..

Plant species /Plant categories	SUB-WATERSHEDS												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Bidens pilosa	-	0.27 ± 0.12	-	-	-	-	-	-	0.15 ± 0.12	-	-	0.26 ± 0.16	-
Bidens tripartita	-	-	-	0.27 ± 0.02	-	0.15 ± 0.10	-	-	-	0.31 ± 0.01	-	-	0.040 ± 0.014
Commelina benghalensis	0.10 ± 0.01	-	-	-	-	-	-	-	-	0.30 ± 0.20	-	0.18± 0.01	-
Cheilathes farinosa	-	0.82 ± 0.67	-	-	-	-	-	-	-	-	-	-	-
Dicliptera bupleuroides	-	0.69 ± 0.09	-	-	-	-	-	-	-	-	-	0.20 ± 0.13	0.30 ± 0.03
Euphorbia heterophylla	0.23±0.09	-	-	-	-	-	-	-	1.23 ± 0.78	-	-	-	-
Evolvulus alsinoides	0.26 ± 0.12	-	-	-	-	-	0.48 ± 0.08	-	-	-	-	-	-
Leucus lanata	-	-	-	-	-	-	-	-	-	-	-	1.22 ± 0.90	-
Micromeria biflora	-	0.75 ± 0.64	-	-	-	0.65 ± 0.05	-	-	-	-	-	1.45 ± 1.25	0.60 ± 0.57
Origanum vulgare	-	0.38 ± 0.26	-	-	-	-	-	-	-	-	-	2.83 ± 1.91	0.20 ± 0.01
Platystemma violoides	-	-	-	-	0.21 ± 0.01	-	-	-	-	-	-	-	-
Reinwardtia indica	-	-	0.72 ± 0.51	-	-	-	-	-	-	-	-	-	-
Rhus cotinus	-	-	0.08 ± 0.06	-	-	-	-	-	-	-	-	-	-
Sonchus arvensis	-	-	-	-	0.04 ± 0.02	-	-	-	-	-	-	0.12 ± 0.02	-
Thalictrum foliosum	-	0.75 ± 0.40	-	-	-	-	-	0.04 ± 0.04	-	-	-	1.16 ± 0.66	-
Tricholepis elongata	-	0.61 ± 0.01	-	-	-	-	-	-	-	-	0.57 ± 0.47	-	-
Viola serpens	-	-	-	-	-	-	-	-	0.64 ± 0.45	0.54 ± 0.04	-	-	-
Total basal area of forbs	**1.68**	**4.66**	**0.80**	**0.27**	**0.26**	**0.80**	**0.48**	**0.04**	**2.73**	**1.81**	**0.64**	**7.41**	**1.06**
BASAL AREA OF LEGUMES													
Cassia mimosoides	-	-	-	-	-	-	-	-	-	0.48 ± 0.48	-	-	-
Lespedeza gerardiana	-	-	0.01 ± 0.01	-	-	-	1.17 ± 0.11	-	-	1.13 ± 0.74	0.15 ± 0.01	-	-
Rhynchosia himalensis	-	-	-	-	-	-	-	1.39 ± 0.72	-	-	-	-	-
Total basal area of legumes	**-**	**-**	**0.01**	**-**	**-**	**-**	**1.17**	**1.39**	**-**	**1.61**	**0.15**	**-**	**-**
Total basal area of herbage	**46.79**	**25.53**	**30.81**	**28.69**	**33.14**	**33.29**	**50.95**	**63.00**	**56.06**	**56.37**	**38.57**	**28.74**	**44.55**

'-'= not present in sub-watershed

Table: 16. Basal area (cm^2/m^2) of herbage species in silvipasture systems at elevation E_2 (1301 - 1700 m) in Giri catchment of HP

Plant species /Plant categories	**SUB-WATERSHEDS**												
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	**SW_7**	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**
BASAL AREA OF GRASSES													
Apluda mutica	-	-	0.84 ± 0.64	-	-	2.45 ± 2.45	2.11 ± 1.35	3.94 ± 1.98	-	3.56 ± 2.44	-	2.67 ± 1.72	-
Arundinella nepalensis	26.09 ± 2.47	6.41± 1.67	4.63 ±1.96	4.18 ± 1.15	-	2.57 ± 1.65	4.16 ± 1.88	1.64 ± 1.02	4.11 ± 1.97	6.08 ± 2.90	5.91 ± 2.61	3.29 ± 2.49	11.25 ± 2.47
Chloris barbata	-	-	-	-	-	-	-	-	1.34 ± 0.91	-	0.51 ± 0.51	0.26 ± 0.26	-
Chrysopogon fulvus	0.4 0± 0.04	0.09 ± 0.01	-	-	0.17 ± 0.17	-0.38 ± 0.25	-	-	-	-	0.01 ± 0.01	-	0.04 ± 0.04
Chrysopogon montanus	25.09 ± 5.36	6.77 ± 0.62	10.37 ± 3.24	6.33 ± 3.66	4.43 ± 1.90	2.62 ± 1.50	7.75 ± 2.37	11.26 ± 2.13	9.86 ± 3.06	13.62 ± 3.98	7.20 ± 3.57	13.71 ± 3.14	25.09 ± 5.36
Cymbopogon martinii	-	-	3.41 ± 2.66	-	-	-	-	-	1.85± 0.79	-	-	-	-
Dicanthium annulatum	0.51 ± 0.51	-	-	1.61 ± 1.54	2.54 ± 1.21	-	0.40 ± 0.33	-	1.27 ± 1.27	1.23 ± 1.16	2.05 ± 1.34	2.85 ± 1.27	0.51 ± 0.51
Heteropogon contortus	4.11 ± 1.37	1.43 ± 1.15	6.12 ± 2.99	2.27 ± 1.49	4.36 ± 2.23	-	6.85 ± 2.67	4.66 ± 1.26	13.71 ± 5.24	6.60 ± 3.26	16.76 ± 5.99	-	4.11 ± 1.37
Imperata cylindrica	-	0.48 ± 0.48	-	-	0.63 ± 0.53	-	-	0.15 ± 0.17	-	-	-	-	-
Ischaemum aristatum	-	-	2.20 ± 1.69	-	-	-	-	0.54 ± 0.54	0.23 ± 0.23	-	8.84 ± 2.05	0.32 ± 0.25	-
Oplismenus burmannii	-	-	-	-	-	-	-	-	1.60 ± 1.05	-	-	0.01 ± 0.01	-
Panicum coloratum	-	-	2.68 ± 2.68	-	-	2.18 ± 1.19	0.12 ± 0.12	0.23 ± 0.23	-	-	-	0.02 ± 0.02	-
Panicum maximum	-	-	0.51 ± 0.51	-	-	-	7.71 ± 3.97	5.98 ± 4.16	-	-	2.82 ± 1.54	5.56 ± 1.28	-
Paspalum notatum	-	-	-	-	-	-	-	-	-	-	-	-	0.08 ± 0.08
Setaria glauca	0.79±0.50	-	-	-	-	-	-	-	-	-	-	-	-
Themeda anathera	2.86 ± 1.50	8.23 ± 2.48	5.78 ± 2.75	16.15 ± 6.94	15.27 ± 2.22	23.07 ± 3.83	10.26 ± 4.38	8.41 ± 2.82	9.40 ± 4.20	4.43 ± 2.96	-	6.11 ± 2.49	2.86 ± 1.50
Themeda quadrivalvis	-	0.21 ± 0.21	-	-	-	-	-	-	-	1.17 ± 1.17	-	-	0.02 ± 0.02
Urochloa panicoides	-	1.89 ± 1.84	1.41 ± 1.02	-	0.67 ± 0.48	-	2.60 ± 2.60	1.56 ± 0.71	-	1.74 ± 1.65	-	-	-
Total basal area of grasses	**44.75**	**25.62**	**37.96**	**30.54**	**28.95**	**33.96**	**41.95**	**38.72**	**53.49**	**38.43**	**44.10**	**36.43**	**34.08**
BASAL AREA OF SEDGES													
Cyperus esculantus	-	0.98 ± 0.62	-	-	-	-	-	-	-	-	-	-	-
Cyperus rotundus	-	-	-	-	-	-	0.54 ± 0.36	-	1.23 ± 0.57	-	0.19 ± 0.08	1.86 ± 1.77	-
Eriophorum comosum	-	-	-	-	-	-	-	0.25 ± 0.23	-	-	-	-	-
Fimbristylis rigidula	-	2.93 ± 1.85	-	-	-	-	-	-	-	-	-	-	-
Total basal area of sedges	**-**	**3.81**	**-**	**-**	**-**	**-**	**0.54**	**-**	**1.23**	**-**	**0.19**	**1.86**	**-**
BASAL AREA OF FORBS													
Achyranthus aspera	-	-	-	-	-	-	0.12 ± 0.12	-	-	-	0.04 ± 0.04	-	0.08 ± 0.08
Barleria strigosa	-	-	-	-	-	-	-	-	-	0.19 ± 0.19	-	-	-

Continued…..

Plant species /Plant categories	**SUB-WATERSHEDS**												
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	**SW_7**	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**
BASAL AREA OF GRASSES													
Bidens pilosa	-	-	-	-	0.05 ± 0.05	-	-	-	-	-	-	-	-
Bidens tripartita	-	0.12 ± 0.12	-	0.27 ± 0.13	-	0.25 ± 0.17	-	-	-	0.26 ± 0.16	-	-	0.31 ± 0.25
Cissampetous pareira	-	-	-	-	-	-	-	-	-	-	-	-	0.51 ± 0.51
Commelina benghalensis													
Conyza stricta	-	-	-	-	-	-	-	-	-	-	-	-	0.05 ± 0.05
Dicliptera bupleuroides	-	-	-	0.30 ± 0.21	-	-	-	-	-	-	0.02 ± 0.01	-	-
Erigeron annus	-	-	-	-	0.05 ± 0.05	-	-	-	-	-	-	-	-
Evolvulus alsinoides	-	-	-	0.01 ± 0.01	-	-	-	-	-	-	-	-	-
Geranium nepalensis	-	2.01 ± 0.94	-	-	-	-	-	-	-	-	-	-	-
Gerbera gossypina	-	-	-	-	-	0.21 ± 0.21	-	-	-	-	-	-	-
Justicea simplex	-	0.31 ± 0.31	-	-	-	-	-	-	0.23 ± 0.01	0.5 0± 0.05	-	-	-
Micromeria biflora	-	-	-	-	-	0.28 ± 0.28	-	0.57 ± 0.37	0.25 ± 0.02	-	-	-	-
Origanum vulgare	0.05 ± 0.05	-	-	-	-	-	1.07 ± 0.69	-	-	-	-	-	-
Pimpinella diversifolia	-	-	-	0.12 ± 0.12	-	-	-	-	0.29 ± 0.25	-	-	-	-
Platystemma violoides	-	-	0.21 ± 0.21	-	-	-	-	-	-	-	-	-	-
Plectranthus sericea	-	-	0.33 ± 0.33	0.12 ± 0.12	2.78 ± 1.33	-	-	-	-	-	-	0.17 ± 0.17	-
Reinwardtia indica	-	-	0.21 ± 0.21	-	-	-	-	-	-	-	0.01 ± 0.01	-	-
Sonchus arvensis	-	-	0.28 ± 0.08	-	-	-	-	-	-	-	-	-	-
Swertia augustifolia	0.53 ± 0.47	-	-	-	-	-	-	-	-	-	-	-	0.53 ± 0.47
Thalictrum foliosum	-	0.21 ± 0.21	-	-	-	-	-	-	-	-	-	-	-
Tricholepis elongata	-	0.58 ± 0.58	-	-	-	-	-	-	-	-	-	-	-
Total basal area of forbs	**1.53**	**5.79**	**1.04**	**0.83**	**2.88**	**1.55**	**1.19**	**0.57**	**0.76**	**2.75**	**0.27**	**0.18**	**1.53**
BASAL AREA OF LEGUMES													
Cassia mimosoides	-	0.23 ± 0.23	-	-	-	-	-	-	0.45 ± 0.45	0.17 ± 0.17	-	-	-
Lespedeza gerardiana	0.05 ± 0.05	-	-	-	0.77 ± 0.49	-	-	-	0.23 ± 0.23	0.05 ± 0.05	-	-	0.05 ± 0.05
Rhynchosia himalensis	-	-	-	-	-	-	-	0.45 ± 0.45	-	-	-	-	-
Total basal area of legumes	**0.05**	**0.23**	**-**	**-**	**0.77**	**-**	**-**	**0.45**	**0.68**	**0.23**	**-**	**-**	**0.05**
Total basal area of herbage	**46.33**	**35.54**	**38.99**	**31.38**	**32.60**	**34.83**	**43.68**	**39.74**	**38.33**	**41.00**	**44.56**	**39.37**	**45.54**

'-'= not present in sub-watershed

were the prominent contributors to the total basal area of herbage with their contributions varying from 2.76 $\pm$ 1.36 cm^2/m^2 to 23.80 $\pm$ 4.40 cm^2/m^2, 0.21 $\pm$ 0.01 cm^2/m^2 to 10.47 $\pm$ 5.09 cm^2/m^2, 2.31 $\pm$ 0.31 cm^2/m^2 to 17.59 $\pm$ 8.14 cm^2/m^2, 0.73 $\pm$ 0.03 cm^2/m^2 to 13.73 $\pm$ 5.68 cm^2/m^2 and 0.61 $\pm$ 0.47 cm^2/m^2 to 8.25 $\pm$ 4.01 cm^2/m^2, respectively.

It was observed that the contribution of sedges in the different sub-watersheds to the total basal area of herbage was very less and it varied from 0.23 cm^2/m^2 (SW_{11}) to 9.46 cm^2/m^2 (SW_6). Forbs contributions to the total basal area of herbage vegetation in sub-watesheds was also very less as compared to grasses and it ranged from 0.50 cm^2/m^2 (SW_8) to 4.02 cm^2/m^2 (SW_5) cm^2/m^2. Likewise, the contributions from legumes, in some sub-watersheds where they were present to the total basal area of herbage vegetation fluctuated between 0.45 cm^2/m^2 (SW_7) to 0.96 cm^2/m^2 (SW_4) (Table 17).

It was recorded that mean basal area of herbage in the sub-watersheds selected for study decreased with increase in elevation i.e. significantly highest mean basal area of herbage was recorded at elevation E_1 (41.23 cm^2/m^2) which was followed by 39.40 cm^2/m^2 at elevation E_2 and 38.24 cm^2/m^2 at elevation E_3. The effect of sub-watersheds, and interaction effects elevations and sub-watersheds on basal area was non-significant (Table 18).

4.4.1.3 IVI of herbvage vegetation

It was recorded that *Heteropogon contortus* displayed IVI values of 8.89 to111.89 in different sub-watershed at elevation E_1 was followed by *Chrysopogon montanus*, *Themada anathera* and *Arundinella nepalensis* with their IVI Values of 29.18 to106.05, 6.02 to 91.97 and 3.57 to 65.21 respectively (Table 19).

The dominant species of herbage vegetation in silvipasture systems at elevation E_2 was *Themeda anathera* with its IVI value of 8.11 to 153.24 followed by *Chrysopogon montanus* with its IVI value of 28.83 to 110.18, *Arundinella nepalensis* with its IVI value 7.05 to 84.18 and *Heteropogon contortus* with its IVI value of 11.42 to 53.82 (Table 20).

Table: 17. Basal aea (cm^2/m^2) of herbage species in silvipasture systems at elevation E_3 (1701 – 2100 m) in Giri catchment of HP

Plant species /Plant categories	SUB-WATERSHEDS												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
BASAL AREA OF GRASSES													
Apluda mutica	5.48 ± 2.94	3.23±1.41	2.17 ± 1.36	4.05 ± 1.95	3.34 ±1.54	-	1.31 ± 0.71	-	1.45 ± 0.76	5.22 ± 2.72	-	0.96 ± 0.66	-
Arundinella nepalensis	8.09 ± 5.16	4.53 ± 2.29	8.25 ± 4.81	4.51 ± 1.97	4.54 ± 0.83	4.57 ± 0.85	7.57 ± 3.88	8.83 ± 5.56	5.70 ± 1.57	4.26±1.14	0.61 ± 0.47	7.72 ± 4.77	3.85 ± 1.82
Avena fatua	-	-	-	-	-	7.33±1.83	-	-	-	-	-	-	-
Chrysopogon montanus	10.47 ± 5.09	6.48±1.68	5.74 ± 1.09	7.69 ± 2.97	4.44 ± 1.59	3.36 ± 2.63	5.77 ± 2.02	8.21 ± 3.84	8.94 ± 3.79	10.56 ± 3.11	4.55 ± 3.01	7.57 ± 2.03	0.21 ± 0.01
Cymbopogon martinii	-	-	-	-	-	-	-	1.63 ± 1.01	3.36 ± 1.90	-	1.49 ± 0.88	-	-
Dicanthium annulatum	2.41 ± 1.37	-	4.94 ± 2.85	-	2.98 ± 0.64	-	-	-	4.12 ± 1.53	0.45 ± 0.45	-	3.47 ± 1.11	-
Digiteria stricta	-	1.91 ± 1.91	-	-	-	-	-	-	-	-	-	-	-
Heteropogon contortus	4.69 ± 1.84	2.74± 1.85	2.19 ± 1.48	6.13 ± 2.20	2.93 ± 1.30	8.90 ± 3.07	13.73 ± 5.68	3.46 ± 2.93	-	-	2.46 ± 1.84	0.73 ± 0.73	9.79 ± 2.34
Imperata cylindrica	-	-	0.66 ± 0.50	-	3.60 ± 2.37	6.13 ± 3.93-	-	-	-	-	-	-	-
Ischaemum aristatum	-	-	-	-	-	-	-	0.44 ± 0.20	-	-	0.99 ± 0.49	2.30 ± 2.23	-
Panicum maximum	17.59 ± 8.14	3.88±1.40	-	-	-	-	-	13.23 ± 5.46	-	-	3.64 ± 1.65	-	2.31 ± 2.31
Setaria glauca	0.79 ±0.50		-	-	-	-	-	-	-	-	-	-	-
Themeda anathera	16.29 ± 3.79	6.68 ± 2.09	5.38 ±1.86	3.76 ±1.36	4.81± 1.54	9.79 ± 2.90	14.37 ± 4.40	23.80 ± 7.31	6.36 ± 1.19	11.91 ± 4.60	9.42 ± 4.27	16.79 ± 2.67	18.11 ± 7.35
Urochloa panicoides	-	-	1.46 ± 1.00	-	-	-	3.03 ± 2.0	-	2.71 ± 1.34	0.28 ± 0.28	-	-	0.66 ± 0.39
Total basal area of grasses	**45.87**	**29.65**	**30.79**	**26.14**	**25.61**	**29.77**	**45.70**	**59.61**	**36.54**	**29.22**	**23.16**	**39.52**	**34.72**
BASAL AREA OF SEDGES													
Cyperus rotundus	-	-	-	-	-	8.37 ± 5.57-	-	-	-	-	1.16 ± 0.73	0.23 ± 0.11	0.84 ± 0.24
Eriophorum comosum	3.98 ± 2.56	-	-	-	1.24 ± 0.60	1.09 ± 0.66	-	-	-	-	-	-	-
Fimbristylis rigidula	-	5.68 ± 3.31	-	0.38 ± 0.28	-	-	0.74 ± 0.52	-	-	-	-	-	0.03 ± 0.03
Total basal area of sedges	**3.98**	**5.68**	**-**	**0.38**	**1.24**	**9.46**	**0.74**	**-**	**-**	**-**	**1.16**	**0.23**	**0.87**
BASAL AREA OF FORBS													
Artemisia roxburghiana	-	0.03 ± 0.03	-	-	0.11 ± 0.06	-	-	-	-	-	-	-	-
Barleria strigosa	-	0.55 ± 0.44	-	-	-	-	-	-	-	-	-	-	-
Bidens pilosa	-	-	-	-	2.93 ± 1.82	-	0.11 ± 0.07	-	-	-	-	-	-

Continued…..

Plant species /Plant categories	SUB-WATERSHEDS												
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	**SW_7**	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**
Bidens tripartita	-	-	-	-	-	-	-	0.04 ± 0.04	0.16 ± 0.10	0.27 ± 0.19	0.12 ± 0.08	0.01 ± 0.01	0.05 ± 0.00
Cheilathes farinosa	-	-	-	0.12 ± 0.10	-	-	-	-	0.28 ± 0.28	0.09 ± 0.09	-	-	-
Dicliptera bupleuroides	-	-	-	-	-	-	-	0.03 ± 0.00	-	-	0.03 ± 0.00	-	0.78 ± 0.45
Dicliptera roxburghiana	-	-	-	-	-	-	-	-	0.59 ± 0.39	-	-	-	-
Erigeron annus	0.38 ± 0.25	-	-	0.48 ± 0.48	-	-	-	-	-	-	-	-	-
Evolvulus alsinoides	-	-	-	-	-	-	0.11 ± 0.06	-	-	-	-	-	-
Geranium nepalensis	-	-	-	-	-	-	-	-	0.19 ± 0.19	-	-	-	-
Gerbera gossypina	-	-	-	0.36 ± 0.30	-	2.13 ± 1.56	-	-	-	-	-	-	-
Justicia simplex	-	1.91 ± 1.91	-	-	-	-	-	-	-	0.02 ± 0.02	-	-	-
Leucus lanata	-	-	-	-	-	-	-	-	0.28 ± 0.28	0.28 ± 0.28	-	-	-
Micromeria biflora	0.42 ± 0.27	-	-	-	1.77 ± 1.31	-	-	0.40 ± 0.35	-	1.49 ± 1.49	0.58 ± 0.58	0.15 ± 0.15	1.11 ± 0.58
Origanum vulgare	0.98 ± 0.98	-	-	-	0.21 ± 0.21	0.57 ± 0.44	1.29 ± 0.79	0.02 ± 0.02	-	-	-	2.10 ± 0.80	-
Platystemma voiloides	-	-	-	-	-	-	-	-	-	-	-	4.00±0.68	-
Plectranthus sericea	-	-	0.98 ± 0.59	1.06 ± 0.47	-	-	-	-	-	-	-	-	-
Reinwardtia indica	0.35 ± 0.20	0.67 ± 0.48	-	0.10 ± 0.10	-	-	-	-	-	0.45 ± 0.45	-	-	-
Thalictrum foliosum	-	0.05 ± 0.05	-	-	-	-	-	-	0.19 ± 0.09	-	-	-	-
Total basal area of forbs	**2.14**	**1.91**	**0.98**	**2.12**	**4.02**	**2.69**	**1.51**	**0.50**	**1.69**	**2.83**	**0.73**	**2.40**	**1.94**
BASAL AREA OF LEGUMES													
Cassia mimosoides	-	0.78 ± 0.51	-	-	-	-	-	-	0.48 ± 0.48	-	-	-	-
Lespedeza gerardiana	-	-	0.84 ± 0.55	0.96 ± 0.79	-	-	0.45 ± 0.29	-	-	-	-	-	-
Total basal area of legumes	**-**	**0.78**	**0.84**	**0.96**	**-**	**-**	**0.45**	**-**	**0.48**	**-**	**-**	**-**	**0.00**
Total basal area of herbage	**51.99**	**33.97**	**32.61**	**29.60**	**30.26**	**34.65**	**48.40**	**60.11**	**38.71**	**32.05**	**25.05**	**42.15**	**37.53**

'-'= not present in sub-watershed

Table: 18. Variation in basal area (cm^2/m^2) of herbage in silvipasture of different sub-watersheds in Giri catchment

Elevation (E)	SUB-WATERSHEDS (SW)													Mean (E)
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}	
Basal area														
E_1 (900 - 1300 m)	46.79	25.53	30.32	28.70	33.14	33.29	50.95	63.00	56.06	56.36	38.57	28.74	44.55	**41.23**
E_2 (1301 - 1700 m)	46.33	35.54	38.99	31.38	32.60	34.84	43.69	39.70	38.27	41.40	44.56	39.37	45.54	**39.40**
E_3 (1701 - 2100 m)	51.99	33.97	32.61	29.60	30.26	34.65	48.40	60.10	38.71	32.05	25.05	42.15	37.53	**38.24**
Mean (SW)	**48.37**	**31.68**	**33.97**	**29.89**	**32.00**	**34.26**	**47.68**	**54.27**	**44.35**	**43.27**	**36.06**	**36.75**	**42.54**	

Factors	$CD_{0.05}$	SEm±
SW	NS	1.70
E	9.93	3.55
SW×E	NS	6.16

Table: 19. IVI of herbage species in Silvipasture systems at elevation E_1 (900- 1300m) in Giri catchment of HP

Plant categories /Plant species	SUB-WATERSHEDS SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
IVI OF GRASSES													
Apluda mutica	-	-	14.57	-	11.10	-	17.02	14.05	15.00	22.72	23.07	-	-
Arundinella nepalensis	9.39	-	59.61	-	65.21	-	56.27	49.39	43.34	3.57	33.50	10.28	13.47
Chloris barbata	-	-	-	-	-	-	-	-	-	-	-	-	10.09
Chrysopogon montanus	29.18	106.05	80.01	42.71	78.23	56.28	72.99	35.53	51.80	96.26	42.29	50.18	74.84
Cymbopogon martinii	-	-	22.71	29.23	20.55	6.02	-	4.76	-	9.90	-	-	21.36
Dicanthium annulatum	4.64	-	21.31	20.04	5.13	5.67	25.58	9.40	-	-	5.68	-	-
Heteropogon contortus	26.71	48.64	12.70	41.57	13.31	111.89	35.41	43.31	30.68	23.17	43.23	8.89	39.47
Imperata cylindrica	6.31	-	-	-	-	-	11.16	3.09	6.03	15.17	-	-	-
Ischaemum aristatum	-	4.94	-	12.02	10.90	8.94	-	-	13.42	-	-	-	17.04
Oplismenus burmannii	--	-	-	-	-	-	-	-	8.06	-	-	-	-
Panicum coloratum	-	-	6.72	26.58	6.55	10.93	-	-	-	-	-	-	-
Panicum maximum	-	36.67	-	-	-	20.00	12.94	51.47	-	-	8.34	-	61.80
Themeda anathera	75.18	16.02	52.61	64.74	70.85	44.86	59.22	63.93	91.97	76.01	35.50	61.36	32.49
Themeda quadrivalvis	-	-	-	-	-	-	-	-	-	3.36	-	-	-
Urochloa panicoides	33.69	-	-	4.91	-	4.85	-	-	-	3.78	6.87	-	-
IVI OF SEDGES													
Cyperus rotundus	4.79	-	-	8.61	-	17.76	-	-	8.16	-	-	-	5.63
Eriophorum comosum	-	-	6.62	-	-	-	-	-	-	5.32	5.82	15.45	-
Fimbristylis rigidula	-	3.39	-	-	-	-	-	-	-	-	6.56	18.97	-
IVI OF FORBS													
Ageratum conyzoides	-	-	-	-	-	-	-	-	-	3.32	-	-	-
Andrachne cordifolia	4.10	-	-	-	-	-	-	-	-	-	-	-	-
Artemisia roxburghiana	3.78	-	-	-	-	-	-	-	10.74	3.00	3.30	-	-
Barleria strigosa	-	6.22	-	-	-	-	-	-	-	-	-	-	-
Bidens pilosa	-	11.65	-	0.94	-	-	-	-	6.62	-	-	5.90	-
Bidens tripartita	-	-	-	7.91	8.45	-	-	-	-	3.90	-	-	2.66
Cheilathes farinosa	-	10.72	-	-	-	-	-	-	-	-	-	-	-
Commelina benghalensis	3.64	-	-	-	-	-	-	-	-	6.99	-	8.20	-
Dicliptera bupleuroides	-	7.56	-	-	-	-	-	-	-	-	-	11.06	2.49
Euphorbia heterophylla	4.04	-	-	-	-	-	-	-	7.34	-	-	-	-
Evolvulus alsinoides	13.29	-	-	-	-	-	5.54	-	-	-	-	-	-
Leucus lanata	-	-	-	-	-	-	-	-	-	-	-	14.11	-
Micromeria biflora	-	9.25	-	-	-	8.60	-	-	-	-	-	13.84	7.15
Origanum vulgare	-	9.42	-	-	-	-	-	-	-	-	-	18.03	2.54
Platystemma violoides	-	-	-	-	5.51	-	-	-	-	-	-	-	-
Reinwardtia indica	-	-	10.98	-	-	-	-	-	-	-	-	-	-
Rhus cotinus	-	-	8.56	-	-	-	-	-	-	-	-	-	-
Sonchus arvensis	-	-	-	-	-	4.21	-	-	-	-	-	5.15	-
Thalictrum foliosum	-	21.48	-	-	-	-	-	3.07	-	-	-	17.67	-
Tricholepis elongata	-	7.98	-	-	-	-	-	-	-	4.48	7.67	-	-
Viola serpens	-	-	-	-	-	-	-	-	4.65	4.25	-	-	-
IVI OF LEGUMES													
Cassia mimosoides	-	-	-	-	-	-	-	-	-	4.05	-	-	-
Lespedeza gerardiana	-	-	3.58	-	-	-	3.88	-	-	10.73	3.88	-	-
Rhynchosia himalensis	-	-	-	-	-	-	-	22.00	-	-	-	-	-

Table: 20. IVI of herbage species in silvipasture systems at elevation E_2 (1301-1700m) in Giri catchment of HP

Plant categories/ Plant species	**SUB-WATERSHEDS**												
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	**SW_7**	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**
IVI OF GRASSES													
Apluda mutica	-	-	10.54	-	-	18.93	8.85	24.40	-	23.31	-	29.36	-
Arundinella nepalensis	84.18	58.85	52.64	59.37	-	21.36	27.41	14.42	7.05	46.00	39.91	19.51	76.30
Chloris barbata	4.33	-	-	-	-	-	-	-	11.29	-	5.75	4.21	-
Chrysopogon fulvus	-	3.32	-	-	3.71	9.65	-	-	-	-	3.05	-	4.05
Chrysopogon montanus	95.94	68.14	65.65	45.24	39.47	28.83	55.82	82.00	50.46	93.07	39.00	76.51	110.18
Cymbopogon martinii	-	-	21.39	-	-	-	-	-	22.38	-	-	-	-
Dicanthium annulatum	5.40	-	-	22.20	25.90	-	7.22	-	15.15	14.07	16.52	22.63	6.24
Heteropogon contortus	33.83	11.42	48.45	25.07	28.03	12.47	43.37	31.23	34.03	28.05	53.82	29.37	47.47
Imperata cylindrica	-	4.70	-	-	17.67	-	-	15.75	25.19	15.37	25.57	-	-
Ischaemum aristatum	-	1.02	16.92	-	2.14	-	-	3.65	3.03	-	36.05	6.24	-
Oplismenus burmannii	-	-	-	-	-	-	-	2.19	8.56	-	24.70	4.13	-
Panicum coloratum	-	-	9.93	-	-	28.16	20.70	2.97	3.80	-	-	2.82	-
Panicum maximum	-	-	7.23	-	-	9.40	56.43	20.83	15.79	-	17.14	30.94	-
Paspalum notatum	-	-	-	-	-	-	-	3.29	21.39	-	11.56	30.08	3.87
Themeda anathera	28.95	50.25	41.51	112.69	127.78	153.24	35.86	32.11	34.03	18.79	8.11	21.29	20.26
Themeda quadrivalvis	-	4.01	-	40.39	-	-	-	23.65	10.70	17.74	-	-	-
Urochloa panicoides	-	9.98	11.87	-	9.01	-	17.05	12.94	-	16.63	-	-	-
IVI OF SEDGES													
Cyperus esculantus	-	21.49	-	-	-	-	-	-	-	-	-	-	-
Cyperus rotundus	-	12.57	-	-	-	-	8.39	-	13.76	-	12.10	10.25	-
Fimbristylis rigidula	-	11.13	-	-	-	-	-	0.42	2.89	-	0.87	6.24	-
Eriophorum comosum	-	3.05	-	-	-	-	-	5.13	-	-	-	-	-
IVI OF FORBS													
Achyranthus aspera	-	-	-	-	0.11	-	3.40	-	-	-	3.02	-	0.67
Barleria strigosa	-	-	-		-	0.71	-	-	-	0.66	-	-	
Bidens pilosa	4.71	-	-	-	3.11	-	-	-	-	-	-	-	
Bidens tripartita	-	3.38	-	10.07	-	14.68	-	-	-	8.62	-	-	1.10
Cissampetous pareira	-	-	-	-	-	-	-	-	-	-	-	-	4.41
Conyza stricta	-	-	-	-	-	-	-	-	-	-	-	-	3.53
Dicliptera bupleuroides	-	-	-	10.01	-	-	-	-	-	-	0.28	-	-
Erigeron annus	-	-	-	-	16.47	-	-	-	-	-	-	-	-
Evolvulus alsinoides	-	-	-	4.39	-	0.61	-	-	-	-	-	-	-
Geranium nepalensis	-	16.97	-	-	-	2.32	-	-	-	-	-	-	-
Gerbera gossypina	-	-	-	-	-	4.93	-	-	0.40	0.14	-	-	-
Justicia simplex	-	3.82	-	-	-	0.81	-	0.97	3.24	4.01	-	-	-
Micromeria biflora	16.07	-	-	-	-	7.43	-	8.50	3.83	-	-	-	2.16
Origanum vulgare	3.27	-	-	-	-	-	16.19	-	0.49	-	-	-	1.14
Pimpinella diversifolia	-	-	0.49	5.09	-	-	-	-	5.47	-	-	-	-
Platystemma violoides	-	-	5.26	-	5.53	-	-	-	-	-	-	0.45	-
Plectranthus sericea	-	-	4.50	4.52	16.47	-	-	-	-	-	0.02	2.91	-
Reinwardtia indica	4.07	-	3.91	-	-	-	-	-	-	-	3.30	-	-
Sonchus arvensis	-	-	-	-	-	-	-	-	-	0.51	-	-	-
Swertia angustifolea	7.32	-	-	-	-	-	-	-	-	-	-	-	-
Thalictrum foliosum	8.75	3.55	-	-	-	-	-	-	-	-	-	-	-
Tricholepis elongata	-	4.52	-	-	-	-	-	-	-	-	-	2.79	-
IVI OF LEGUMES													
Cassia mimosoides	-	3.78	-	-	-	-	-	-	3.89	4.55	-	-	-
Lespedeza gerardiana	3.19	-	-	-	13.09	-	-	-	3.17	4.75	-	-	4.07
Rhynchosia himalensis	-	-	-	-	-	-	-	3.49	-	-	-	-	-

It was recorded that *Themeda anathera* exihibited IVIvalues of 39.84 to 97.60 in different sub watersheds while *Arundinella nepalensis* maintained IVI values 11.41 to 84.92 and *Chrysopogon montanus* exhibited IVI values ranging from 11.35 to 66.82 in different sub-watersheds . Hence, three species is called dominant , co-dominant and associoate species in silvipasture systems at elevation E_3 of Giri catchment (Table 21).

Table: 21. IVI of herbage species in silvipasture systems at elevation E_3 (1701-2100m) in Giri catchment of HP

Plant categories/ Plant species	SUB-WATERSHEDS												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
IVI OF GRASSES													
Apluda mutica	26.50	14.68	19.42	38.63	22.82	-	19.73	-	18.06	58.77	-	11.15	-
Arundinella nepalensis	33.05	44.39	46.23	57.64	34.48	81.12	43.44	35.37	45.24	84.92	11.41	51.07	33.25
Avena fatua	-	5.33	-	-	-	10.28	-	-	-	-	-	-	-
Chrysopogon montanus	42.16	66.82	46.56	50.75	43.64	11.35	39.42	41.19	58.28	53.47	63.11	48.05	-
Cymbopogon martinii	-	-	23.29	-	-	4.21	-	20.56	25.88	-	44.19	-	-
Dicanthium annulatum	14.74	-	29.20	-	37.04	-	-	-	28.09	10.05	5.11	31.39	-
Digiteria stricta	-	7.24	-	-	-	-	-	-	-	6.35	-	-	-
Heteropogon contortus	27.61	27.83	15.92	53.32	31.31	34.96	65.99	17.94	-	-	27.66	7.06	70.09
Imperata cylindrical	-	-	12.98	-	29.08	-	-	-	-	-	-	-	-
Ischaemum aristatum	-	-	-	-	-	-	-	12.74	-	-	19.01	16.95	-
Panicum maximum	47.36	33.14	-	-	-	-	-	59.06	17.95	-	51.30	-	16.81
Themeda anathera	57.71	44.70	73.99	39.84	58.13	75.02	63.31	93.40	53.85	50.52	72.15	91.30	97.60
Urochloa panicoides	-	-	11.14	-	44.80		12.26	-	21.61	5.57	-	-	13.07
SEDGES													
Cyperus rotundus	-	-	-	-	-	17.35	-	-	-	-	11.13	9.17	19.64
Eriophorum comosum	20.84	-	-	-	12.71	-	-	-	-	-	-	-	-
Fimbristylis rigidula	-	21.02	-	7.38	-	10.69	7.76	-	-	-	-	-	2.93
FORBS													
Artemisia roxburghiana	-	2.88	-	-	7.73	-	-	-	-	-	-	-	-
Barleria strigosa	2.94	7.11	-	-	-	-	-	-	-	-	-	-	-
Bidens pilosa	-	-	-	-	16.48	-	5.80	-	-	-	-	-	-
Bidens tripartita	-	-	-	-	-	-	-	3.74	10.34	8.01	7.41	2.61	3.36
Cheilathes farinosa	-	-	-	0.52	-	-	-	-	-	-	-	-	-
Dicliptera bupleuroides	-	-	-	-	-	-	-	3.50	-	-	3.62		16.16
Dicliptera roxburghiana	-	-	-	-	-	-	-	-	8.44	-	-	-	-
Erigeron annus	3.26	-	-	3.81	-	-	8.64	-	-	-	-	-	-
Evolvulus alsinoides	-	-	-	-	-	-	0.23	-	-	-	-	-	-
Geranium nepalensis	-	-	-	6.70	-	-	-	-	3.84	-	-	-	-
Gerbera gossypina	-	-	-	13.10	-	3.58	-	-	-	-	-	-	-
Justicia simplex	-	7.45	-	-	-	-	-	-	-	8.50	-	-	-
Leucus lanata	-	-	-	-	-	-	-	-	4.02	5.35	-	-	-
Micromeria biflora	10.03	-	-	-	12.59	-	-	8.84	-	9.57	10.26	17.05	16.64
Origanum vulgare	4.76	-	-	-	3.15	9.82	13.11	3.62	-	-	-	10.43	-
Platystemmsa violoides	-	-	-	-	-	-	-	-	-	-	-	0.31	-
Plectranthus sericea	-	-	16.55	16.05	-	-	-	-	-	-	-	-	-
Reinwardtia indica	9.04	7.17	-	-	-	-	-	-	-	4.42	-	-	-
Rhus cotinus	-	-	-	3.45	-	-	-	-	-	-	-	-	-
Thalictrum foliosum	-	-	-	-	-	-	-	-	-	-	-	-	-
LEGUMES													
Cassia mimosoides	-	8.79	-	-	-	-	-	-	4.42	-	-	-	-
Lespedeza gerardiana	-	-	9.60	8.81	-	-	7.15	-	-	-	-	-	-

4.4.2 Grasslands (Gr)

4.4.2.1 Density (tiller/m^2)

In grasslands at elevation E_1, total density of herbage in the different sub-watersheds ranged from 543.33 (SW_{10}) to 1157.00 (SW_2) tillers/m^2. The contributions of grasses, sedges, forbs and legumes to the total density of herbage vegetation varied from 89.73 % to 98.68 %, 0.55 % to 4.92 %, 0.17 % to 5.59 % and 0.12 % to 3.22 %, respectively. Among individual species, *Chrysopogon montanus* contributed highest density to the total density of herbage vegetation and was followed by *Arundinella nepalensis, Heterpogon contortus* and *Themeda anathera* in decreasing order. Their contributions ranged from 60.67 $\pm$ 12.07 to 302.00 $\pm$ 9.12, 5.33 $\pm$ 1.33 to 279.33 $\pm$ 19.22, 6.00, 1.02 to 253.33 $\pm$ 25.36 and 29.33 $\pm$ 4.98 to 240.00 $\pm$ 9.48 tillers/m^2, respectively. It was also recorded that *Apluda mutica*, *Dicanthium annulatum* and *Urochloa panicoides* also contributed noticeably to the total density of herbage in grasslands of different watersheds.

The sedges were recorded only in SW_1, SW_{11} and SW_{12} sub-watersheds and their density was appreciably low as compared to grasses and it was 6.00 tillers/m^2, 17.33 tillers/m^2 and 30.40 tillers/m^2, respectively. The forbs contributions to the total density of herbage vegetation in sub-watersheds was also very low as compared to grasses and it ranged from 1.33 (SW_8) to 70.00 (SW_2) tillers/m^2. Similarly, the contribution from legumes in few sub-watersheds to the total density of herbage fluctuated between 0.67 (SW_3) to 20.00 (SW_{11}) tillers/m^2 (Table 22).

The herbage vegetation of grasslands, at elevation E_2, showed that in the sub-watersheds density of herbage varied from 481.33 (SW_2) to 1002.00 (SW_4) tiller/m^2. The contributions of different plant categories to the density of herbage vegetation showed that grasses contributed 86.81 % to 96.69 % of total density sedges contributed 0.23 % to 11.15 % of total density and forbs contributed 0.17 to 5.53 % of the total density of herbage. It was recorded that among different species. *Themda anathera*, *Chrysopogon montanus*, *Heteropogon contortus* and *Arundinella nepalensis* were the major contributors to total density of herbage with their contributios varing from 38.00 $\pm$ 6.95 to 32.64 $\pm$ 8.38 tillers/m^2, 94.00 $\pm$ 13.95 to 325.33 $\pm$ 14.44 tillers/m^2, 9.33 $\pm$ 2.33 to 319.33 $\pm$ 30.45 tillers/m^2 and 13.33 $\pm$ 1.58 to 181.33 $\pm$ 16.30 tillers/m^2, respectively (Table 23).

The contribution of sedges to the total density of herbage in the sub-watersheds, where they were recorded remained very low and it varied 5.33 (SW_{12}) to 27.33 (SW_9) tillers/m^2. The contributions of forbs to the total density of herbage was also very less as compared to grasses and it ranged from 2.00 (SW_7) to 96.67 (SW_1) tillers/m^2. Likewise, the contribution of legumes where they were present in sub-watersheds, to the total density of herbage fluctuated between 1.33 (SW_8) to 52.67 (SW_6) tillers/m^2 (Table 23).

The total density of herbage in the grasslands at elevation E_3, in different sub-watersheds ranged from 513.33 (SW_{10}) to 996.67 (SW_1) tiller/m^2. The contributions of different plant categories to the density of herbage vegetation exhibited that 75.18 % to 91.05 % of total density of herbage accounted for grasses, 0.17 % to 10.80 % for sedges 4.29 % to 17.74 % for forbs and 0.20 % to 11.92 % for legumes. Among the individual species highest density was recorded for *Themeda anathera* ranging from 98.65 $\pm$ 12.11 to 385.33 $\pm$ 13.68 tillers/m^2 followed by *Chrysopogon montanus* and *Heteropogon contortus* with their range of density as 10.00 $\pm$ 4.19 to 341.33 $\pm$ 22.45 tillers/m^2 and 58.00 $\pm$ 14.50 to 306.00 $\pm$ 15.20 tillers/m^2, respectively (Table 24).

The sedges contribution to the total density of herbage in sub-watersheds was very low and it varied from 1.60 (SW_7) to 82.00 (SW_5) tillers/m^2. The contributions of forbs to the total density of herbage in different sub-watersheds was also very less as compared to grasses and it ranged from 42.13 (SW_2) to 74.44 (SW_{11}) tillers/m^2. Likewise, the contribution from legumes in the sub-watersheds where they were present to the total density of herbage fluctuated between 2.00 (SW_{10}) to 91.33 (SW_3) tillers/m^2 (Table 24).

Table: 22. Density (tillers/m^2) of herbage species in Grasslands at elevation E_1 (900-1300 m) in Giri catchment of HP

Plant categories/ Plant species	SUB-WATERSHEDS												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
DENSITY OF GRASSES													
Apluda mutica	10.67 ± 2.12	86.00 ± 13.77	3.33 ± 0.83	-	23.33 ± 2.02	72.00 ± 4.02	21.33 ± 3.83	27.33 ± 4.37	15.33 ± 3.83	-	71.33 ± 9.33	28.00 ± 5.13	-
Arundinella nepalensis	279.33 ± 19.22	136.00 ± 9.15	184.00 ± 17.54	-	268.67 ± 13.45	214.00 ± 12.00	64.67 ± 5.79	104.67 ± 7.71	5.33 ± 1.33	72.00 ± 11.53	102.00 ± 10.20	46.67 ± 10.51	188.67 ± 22.18
Cenchrus ciliaris	-	-	-	-	-	-	-	-	-	-	-	-	14.67 ± 3.67
Chloris barbata	-	-	-	-	-	-	-	-	-	-	118.00 ± 7.47	-	-
Chrysopogan fulvus	-	120 ± 5.00	-	42.67 ± 3.76	8.00 ± 2.00	-	-	-	-	-		-	-
Chrysopogon montanus	219.33 ± 13.88	302.00 ± 18.14	200.67 ± 17.54	247.33 ± 20.76	244.00 ± 21.71	165.33 ± 21.36	214.00 ± 12.37	97.33 ± 8.88	265.33 ± 19.82	84.67 ± 7.88	60.67 ± 12.07	185.33 ± 10.02	104.00 ± 14.71
Cymbopogon martinii	-	-	-	-	-	-	-	11.33 ± 2.83	8.00 ± 1.29	38.00 ± 7.22	-	-	-
Dicanthium annulatum	-	-	12.00 ± 1.97	74.67 ± 10.13	32.67 ± 4.74	62.00 ± 5.61	4.67 ± 1.17	17.33 ± 4.33	-	-	2.00 ± 0.50	27.33 ± 4.37	-
Heteropogon contortus	215.33 ± 21.79	166.67 ± 18.65	6.00 ± 1.02	228.67 ± 26.25	23.33 ± 4.58	154.67 ± 15.50	128.00 ± 15.33	131.33 ± 20.65	172.00 ± 14.61	253.33 ± 25.36	-	32.67 ± 7.40	245.33 ± 7.56
Imperata cylindrica	26.67 ± 5.39	8.00 ± 2.00	-	-	6.00 ± 1.02	-	2- ± 5.00	22.00 ± 3.68	13.33 ± 2.11	25.33 ± 4.14	-	-	-
Ischaemum aristatum	17.33 ± 4.33	32.80 ± 6.21	-	16.00 ± 2.73	2.00 ± 0.50	-	-	6.67 ± 1.67	16.80 ± 2.83	4.67 ± 0.83	-	58.00 ± 10.46	2.00 ± 0.50
Oplismenus burmannii	-	10.67 ± 2.67	-	-	-	-	-	8.00 ± 2.00	-	-	-	-	-
Panicum coloratum	-	-	12.67 ± 3.17	-	-	-	-	-	-	-	-	-	-
Panicum maximum	-	-	-	18.00 ± 4.50	-	-	81.33 ± 18.04	171.33 ± 20.73	-	-	36.00 ± 6.61	124.67 ± 19.73	-
Paspalum notatum	-	-	-	-	-	-	-	-	2.00 ± 0.50	-	-	-	-
Setaria glauca	-	8.00 ± 2.00	-	-	-	-	-	-	10.67 ± 1.91	5.33 ± 0.84	-	10.67 ± 2.67	-
Themeda anathera	189.33 ± 12.63	24- ± 9.48	103.33 ± 9.84	36.67 ± 5.80	168.00 ± 18.29	140.67 ± 17.90	178.67 ± 9.30	198.00 ± 18.36	132.00 ± 11.91	29.33 ± 4.98	145.33 ± 13.11	178.00 ± 13.13	-
Urochloa panicoides	74.67 ± 9.77	69.33 ± 9.49	-	67.33 ± 14.05	-	14.00 ± 1.82	-	-	-	-	28.67 ± 4.93	32.00 ± 3.86	-
Total density of grasses	**1032.67**	**1074.00**	**522.00**	**731.33**	**776.00**	**822.67**	**712.67**	**795.33**	**640.80**	**512.67**	**564.00**	**723.33**	**554.67**
DENSITY OF SEDGES													
Fimbristylis rigidula	6.00 ± 1.23	-	-	-	-	-	-	-	-	-	17.33 ± 2.26	-	-
Eriophorum comosum	-	-	-	-	-	-	-	-	-	-	-	-	30.40 ± 4.70
Total density of sedges	**6.00**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**17.33**	**-**	**30.40**
DENSITY OF FORBS													
Achyranthus aspera	-	-	-	0.67 ± 0.18	-	-	-	-	-	-	-	-	-
Ageratum conyzoides	-	-	-	3.33 ± 0.40	-	-	-	-	-	1.33 ± 0.33	-	-	-
Artemisea roxburghiana	-	7.33 ± 0.79	-	-	-	0.67 ± 0.17	-	-	-	-	3.33 ± 0.83	2.67 ± 0.67	-

Continued…..

Plant categories/ Plant species	SUB-WATERSHEDS												
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	**SW_7**	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**
Barleria strigosa	25.33 ± 3.73	-	-	3.33 ± 0.83	3.33 ± 0.83	6.67 ± 1.09	-	-	-	2.00 ± 0.50	2.67 ± 0.67	-	-
Bidens pilosa	-	2.00 ± 0.34	-	-	5.33 ± 0.80	-	-	-	-	-	-	-	-
Cheilathes farinosa	9.33 ± 1.56	-	-	-	-	16.67 ± 2.99	2.67 ± 0.67	-	16.00 ± 4.00	5.33 ± 1.33	-	2.67 ± 0.67	-
Cristella dentata	-	-	-	-	-	1.33 ± 0.33	-	-	-	-	-	-	-
Commelina benghalensis	-	-	-	-	-	-	-	-	-	1.33 ± 0.33	-	-	-
Conyza stricta	-	-	-	-	3.33 ± 0.54	-	-	-	-	-	-	-	-
Dicliptera roxburghiana	-	-	-	-	10.67 ± 1.86	-	-	-	-	-	-	-	17.33 ± 2.85
Dryopteris panda	-	7.33 ± 1.83	-	-	-	-	-	-	-	-	-	-	-
Euphorbia heterophylla	-	8.00 ± 1.29	-	-	-	12.67 ± 1.56	-	-	-	1.33 ± 0.33	-	2.00 ± 0.50	-
Evolvulus alsinoides	-	-	-	-	-	-	6.67 ± 1.67	-	-	-	-	-	-
Justicia simplex	-	16.00 ± 4.00	-	-	-	-	-	-	2.00 ± 0.50	-	-	-	-
Leucus lanata	-	-	-	-	-	-	-	-	-	0.67 ± 0.17	-	-	-
Micromeria biflora	4.00 ± 0.00	-	-	-	18.00 ± 4.50	-	-	-	-	2.67 ± 0.67	-	4.00 ± 0.82	-
Origanum vulgare	-	-	-	16.00 ± 4.00	-	-	18.67 ± 4.67	-	-	-	2.67 ± 0.67	-	-
Parthenium hyrtophorus	-	2.00 ± 0.50	-	-	-	-	-	-	-	-	-	-	-
Plectranthus sericea	-	-	3.33 ± 0.65	-	-	-	-	-	-	-	-	-	-
Reinwardtia indica	-	-	19.33 ± 3.62	-	-	1.33 ± 0.03	-	-	-	-	2.67 ± 0.67	-	-
Rhus cotinus	4.67 ± 0.00	-	4.67 ± 0.83	-	-	2.00 ± 0.34	-	-	-	-	-	-	-
Swertia angustifolea	-	-	-	-	2.67 ± 0.67	-	-	-	-	-	-	-	-
Thalictrum foliosum	-	-	-	1.30 ± 0.03	-	3.33 ± 0.65	-	1.33 ± 0.24	-	-	2.00 ± 0.50	1.33 ± 0.33	-
Tricholepis elongata	-	6.67 ± 1.17	-	1.34 ± 0.02	2.00 ± 0.50	-	-	-	-	-	1.33 ± 0.33	-	1.33 ± 0.33
Xanthium *indicum*	-	20.67 ± 2.65	-	-	-	12.67 ± 2.04	-	-	12.00 ± 1.91	1.33 ± 0.33	-	-	30.40 ± 2.66
Total density of forbs	**43.33**	**70.00**	**27.33**	**26.00**	**34.67**	**57.33**	**28.00**	**1.33**	**30.00**	**16.00**	**19.33**	**12.67**	**31.73**
DENSITY OF LEGUMES													
Cassia abscus	-	-	-	-	-	-	-	-	1.33 ± 0.21	0.67 ± 0.17	-	-	-
Cassia mimosoides	-	3.33 ± 0.65	-	-	-	-	-	-	-	6.00 ± 0.56	-	-	-
Lespedeza gerardiana	8.00 ± 0.00	-	0.67 ± 0.17	3.33 ± 0.83	12.67 ± 3.17	6.00 ± 1.31	17.33 ± 2.43	-	-	8.00 ± 1.26	20.00± 4.08	-	1.33 ± 0.33
Rhynchosia himalensis	-	-	-	-	-	-	-	9.33 ± 1.50	-	-	-	-	-
Total density of legumes	**8.00**	**3.33**	**0.67**	**3.33**	**12.67**	**6.00**	**17.33**	**9.33**	**-**	**-**	**20.00**	**-**	**1.33**
Total density of herbage	**1090.00**	**1157.00**	**550.00**	**760.67**	**823.33**	**886.00**	**758.00**	**806.00**	**669.33**	**543.33**	**620.67**	**736.00**	**618.13**

Table: 23. Density (tillers/m^2) of herbage species in Grasslands at elevation E_2 (1301-1700 m) in Giri catchment of HP

Plant categories/ Plant species	SUB-WATERSHEDS												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
DENSITY OF GRASSES													
Apluda mutica	116.00 ± 11.09	-	9.33 ± 1.48	25.33 ± 6.33	40.00 ± 3.67	103.33 ± 16.61	25.33 ± 6.33	78.00 ± 9.14	-	39.33 ± 8.51	4.00 ± 0.63	67.33 ± 5.90	66.00 ± 10.48
Arundinella nepalensis	99.33 ± 10.33	181.33 ± 16.30	72.67 ± 8.76	88.67 ± 4.59	-	74.67 ± 13.46	161.33 ± 10.92	13.33 ± 1.58	-	-	26.67 ± 2.97	30.67 ± 2.56	21.33 ± 3.90
Bothriochloa pertusa	-	-	-	-	-	-	-	-	-	-	-	2.67 ± 0.67	2.67 ± 0.67
Chloris barbata	1- ± 2.50	-	-	-	-	-	-	-	9.33 ± 2.33	-	-	-	-
Chrysopogan fulvus	12.00 ± 3.00	12.00 ± 3.00	-	-	1.33 ± 0.33	-	-	-	-	-	-	-	-
Chrysopogon montanus	199.33 ± 17.50	94.00 ± 13.95	148.67 ± 11.84	325.33 ± 14.44	-	295.33 ± 12.75	115.33 ± 5.20	195.33 ± 18.13	185.33 ± 14.69	186.67 ± 12.97	142.67 ± 7.99	11- ± 6.10	130.67 ± 17.97
Cymbopogon martinii	-	-	10.67 ± 1.86	50.67 ± 8.09	-	43.33 ± 5.89	16.00 ± 2.58	-	36.67 ± 7.43	-	28.67 ± 4.58	-	9.33 ± 1.67
Dicanthium annulatum	72.67 ± 10.41	-	18.00 ± 2.87	34.00 ± 2.85	58.67 ± 10.90	66.67 ± 7.65	22.67 ± 5.67	-	37.33 ± 4.25	8.00 ± 2.00	14.00 ± 1.71	12.00 ± 1.91	-
Heteropogon contortus	48.67 ± 6.72	16.67 ± 4.17	118.67 ± 9.57	9.33 ± 2.33	58.00 ± 11.44	152.00 ± 18.13	166.00 ± 18.32	95.33 ± 10.32	319.33 ± 30.45	132.00 ± 11.82	225.73 ± 20.53	92.67 ± 11.02	75.33 ± 13.04
Imperata cylindrica	-	7.33 ± 0.98	-	15.33 ± 2.43	9.33 ± 2.33	-	3.33 ± 0.54	0.67 ± 0.17	-	-	-	-	-
Ischaemum aristatum	-	-	35.33 ± 6.45	-	-	-	-	6.00 ± 1.50	3.33 ± 0.83	-	2- ± 5.00	-	29.33 ± 4.75
Oplismenus burmannii	-	-	-	-	-	16.00 ± 2.58	-	-	18.00 ± 4.50	-	-	-	-
Panicum maximum	-	-	20.00 ± 5.00	173.33 ± 22.68	-	-	165.33 ± 22.10	16.00 ± 2.11	135.33 ± 16.49	-	-	127.33 ± 13.57	48.67 ± 13.33
Setaria glauca	-	-	-	-	-	41.33 ± 5.57	-	-	-	1.33 ± 0.33	-	-	-
Themeda anathera	210.00 ± 20.33	96.00 ± 6.34	94.00 ± 11.89	213.33 ± 24.17	326.67 ± 8.38	38.00 ± 6.95	182.00 ± 10.59	308.00 ± 24.86	86.67 ± 10.41	65.33 ± 12.13	140.67 ± 28.26	116.00 ± 15.72	72.00 ± 6.12
Urochloa panicoides	-	8.67 ± 1.80	-	-	6.00 ± 1.10	6.67 ± 1.67	-	26.00 ± 5.56	-	34.67 ± 6.16	4.67 ± 1.17	32.00 ± 5.20	48.67 ± 7.70
Total density of grasses	**768.00**	**416.00**	**527.33**	**935.33**	**500.00**	**837.33**	**857.33**	**738.67**	**831.33**	**467.33**	**607.07**	**590.67**	**504.00**
DENSITY OF SEDGES													
Cyperus rotundus	-	-	-	-	-	-	-	-	27.33 ± 4.17	-	12.00 ± 1.97	5.33 ± 1.33	-
Eriophorum comosum	-	-	-	-	-	-	-	8.00 ± 1.63	-	-	-	-	-
Fimbristylis rigidula	-	11.33 ± 2.83	14.67 ± 3.67	-	-	-	-	-	-	-	-	-	-
Total density of sedges	**0.00**	**11.33**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**8.00**	**27.33**	**0.00**	**12.00**	**5.33**	**0.00**
DENSITY OF FORBS													
Achyranthus aspera	-	-	-	-	-	-	-	-	-	-	-	2.67 ± 0.67	-
Ageratum conozoides	10.67 ± 2.67	-	-	-	-	-	-	-	-	1.33 ± 0.33	-	1.33 ± 0.33	-
Artemisia roxburghiana	1.33 ± 0.37	-	-	-	-	16.00 ± 2.58	-	-	1.33 ± 0.33	-	-	4.67 ± 1.17	3.33 ± 0.65
Barleria strigosa	-	-	16.00 ± 2.72	5.33 ± 0.84	-	-	-	-	-	6.00 ± 0.96	2.00 ± 0.50	-	-

Continued…..

Plant categories/ Plant species	SUB-WATERSHEDS												
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	**SW_7**	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**
Bidens pilosa	10.00 ± 1.82	-	-	2.00 ± 0.34	1.33 ± 0.21	-	-	-	-	-	-	0.67 ± 0.17	-
Cheilathes farinosa	-	-	2.00 ± 0.50	-	-	-	-	-	-	11.33 ± 1.90	-	-	18.67 ± 4.67
Commelina benghalensis	-	2.00 ± 0.50	-	-	-	5.33 ± 1.33	-	-	-	-	-	-	6.67 ± 1.09
Conyza stricta	4.00 ± 0.63	-	-	-	-	-	-	-	-	-	3.33 ± 0.54	-	-
Dicliptera roxburghiana	-	-	-	26.67 ± 6.67	-	2.67 ± 0.67	-	-	-	-	21.33 ± 2.19	-	-
Erigeron annus	-	-	-	1.33 ± 0.21	1.33 ± 0.33	8.67 ± 2.17	-	-	-	-	-	1.33 ± 0.33	-
Euphorbia heterophylla	-	-	-	-	-	8.67 ± 2.17	-	-	-	1.33 ± 0.33	-	3.33 ± 0.65	-
Evolvulus alsinoides	-	1.33 ± 0.33	4.67 ± 0.75	-	-	-	-	-	-	4.00 ± 1.00	-	-	-
Geranium nepalensis	-	21.33 ± 2.40	-	-	-	-	-	-	-	-	-	4.00 ± 1.00	-
Justicia simplex	-	7.33 ± 0.98	-	-	-	3.33 ± 0.83	-	-	6.67 ± 1.31	0.67 ± 0.17	-	-	-
Leucus lanata	-	-	-	14.00 ± 3.50	-	3.33 ± 0.83	-	-	-	6.00 ± 1.50	6.67 ± 1.31	6.67 ± 1.67	-
Micromeria biflora	56.00 ± 10.25	-	-	-	-	-	-	26.67 ± 4.59	11.33 ± 2.83	-	-	-	-
Origanum vulgare	2.00 ± 0.34	-	-	-	1- ± 1.15	-	-	-	-	-	-	-	10.67 ± 2.67
Oxalis corniculata	-	-	-	-	-	-	-	-	2.00 ± 0.50	-	-	-	-
Pimpinella diversifolia	-	-	-	-	-	-	-	-	2.00 ± 0.34	1.33 ± 0.33	-	-	-
Platystemmsa violoides	-	-	9.33 ± 2.56	-	-	-	-	-	-	-	-	-	-
Plectranthus sericea	-	-	6.00 ± 1.50	-	41.33 ± 4.88	-	-	-	-	-	-	-	-
Reinwardtia indica	6.00 ± 1.50	-	1.33 ± 0.33	-	-	2.67 ± 0.67	-	-	-	-	-	4.67 ± 1.17	-
Rhus cotinus	-	-	-	-	-	2.00 ± 0.50	-	-	-	-	-	-	-
Swertia angustifolia	4.00 ± 1.00	-	-	-	-	-	-	-	-	-	-	-	-
Thalictrum foliosum	2.67 ± 0.42	-	-	3.33 ± 0.54	-	-	2.00 ± 0.50	-	-	-	-	-	-
Tricholepis elongata	-	7.33 ± 1.22	-	-	0.67 ± 0.17	-	-	-	-	-	-	2.00 ± 0.34	1.33 ± 0.33
Xanthium indicum	-	7.33 ± 1.17	-	-	-	2.00 ± 0.50	-	-	-	3.33 ± 0.54	-	-	-
Total density of forbs	**96.67**	**46.67**	**52.67**	**52.67**	**54.67**	**54.67**	**2.00**	**26.67**	**23.33**	**35.33**	**33.33**	**31.33**	**46.00**
DENSITY OF LEGUMES													
Cassia abscus	-	-	-	-	-	8.67 ± 0.95	-	-	-	3.33 ± 0.54	-	-	-
Cassia mimosoides	-	3.33 ± 0.91	-	1.33 ± 0.37	-	11.33 ± 1.76	-	-	10.00 ± 1.23	1.33 ± 0.33	-	4.00 ± 1.00	4.67 ± 1.17
Lespedeza gerardiana	2.00 ± 0.50	4.00 ± 0.68	-	12.67 ± 1.72	21.33 ± 3.79	32.67 ± 7.58	-	-	2.00 ± 0.34	-	19.33 ± 4.83	7.33 ± 1.83	-
Rhynchosia himalensis							27.33±3.79	1.33±0.82					
Total density of legumes	**2.00**	**7.33**	**-**	**14.00**	**21.33**	**52.67**	**27.33**	**1.33**	**12.00**	**4.67**	**19.33**	**11.33**	**4.67**
Totoal density of herbage	**866.67**	**481.33**	**581.33**	**1002.00**	**576.00**	**944.67**	**886.67**	**774.67**	**894.00**	**507.33**	**671.73**	**638.67**	**549.33**

Table: 24. Density (tillers/m^2) of herbage species in Grasslands at elevation E_3 (1701-2100 m) in Giri catchment of HP

Plants species/Plant categoris	SUB-WATERSHEDS												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
DENSITY OF GRASSES													
Apluda mutica	64.00 ± 8.27	94.00 ± 7.25	67.33 ± 8.35	112.67 ± 12.23	69.33 ± 9.06	90.67 ± 8.97	116.67 ± 14.43	54.67 ± 11.10	23.33 ± 5.08	34.00 ± 4.46	42.00 ± 9.91	122.00 ± 14.73	50.67 ± 9.67
Arundinella nepalensis	74.00 ± 13.96	64.67 ± 8.77	-	94.67 ± 14.44	114.67 ± 8.06	26.00 ± 2.70	18.67 ± 3.00	-	-	-	1.33 ± 0.33	-	-
Avena fatua	-	24.67 ± 3.95	-	-	-	5.33 ± 1.33	-	-	-	18.67 ± 2.95	-	-	-
Bothriochloa pertusa	-	-	-	-	-	10.00 ± 1.31	-	-	-	-	-	-	9.33 ± 2.33
Cenchrus ciliaris	-	-	-	-	-	-	-	-	-	-	-	-	4.00 ± 0.91
Chloris barbata	-	-	-	-	10.00± 2.50	-	-	-	-	-	-	-	-
Chrysopogon fulvus	26.67 ± 6.67	-	-	69.33 ± 12.72	14.67 ± 2.94	-	-	-	-	-	1.33 ± 0.33	-	-
Chrysopogon montanus	16.67 ± 2.88	62.00 ± 7.28	10.00- ± 4.19	76.00 ± 12.24	116.00 ± 14.82	78.67 ± 6.91	179.33 ± 17.71	86.00 ± 10.11	44.67 ± 17.06	96.67 ± 6.56	166.00 ± 14.75	341.33 ± 22.45	-
Cymbopogon martinii	-	-	42.67 ± 10.67	-	-	-	-	-	40.67 ± 9.67	-	1- ± 2.13	43.20 ± 5.68	-
Dicanthium annulatum	52.00 ± 5.63	-	28.00 ± 4.89	-	123.33 ± 4.45	-	-	-	20.67 ± 3.29	-	-	-	28.00 ± 4.32
Digiteria stricta	-	10.67 ± 1.76	-	-	-	-	-	8.00 ± 2.00	-	6.00 ± 0.96	-	-	38.00 ± 4.54
Heteropogon contortus	80.67 ± 10.60	-	85.33 ± 17.27	93.33 ± 12.10	110.67 ± 14.09	58.00 ± 14.50	76.00 ± 6.41	107.33 ± 9.84	306.00 ± 15.20	114.67 ± 12.57	6- ± 4.87	112.00 ± 11.78	88.00 ± 6.81
Imperata cylindrica	-	10.67 ± 2.67	-	-	24.00 ± 6.00	-	-	26.00 ± 2.17	-	-	-	-	-
Ischaemum aristatum	-	-	-	-	-	-	-	-	-	-	34.67 ± 6.71	-	-
Panicum maximum	196.00 ± 40.17	14.67 ± 3.67	-	-	-	-	104.67 ± 21.23	232.00 ± 17.35	73.33 ± 10.90	128.67 ± 14.88	144.00 ± 20.96	-	16.67 ± 4.17
Themeda anathera	385.33 ± 15.68	166.67 ± 8.20	238.67 ± 16.27	179.33 ± 10.89	153.33 ± 15.53	221.33 ± 14.45	305.33 ± 17.61	263.33 ± 13.29	104.67 ± 7.27	-	195.33 ± 13.48	98.67 ± 12.11	132.67 ± 9.66
Urochloa panicoides	-	-	14.00 ± 2.25	-	-	50.00 ± 7.93	76.00 ± 10.48	12.67 ± 2.04	142.00 ± 12.66	-	57.33 ± 6.20	4- ± 5.94	6.00 ± 1.50
Total density of grasses	**983.33**	**549.47**	**766.13**	**772.00**	**867.33**	**595.33**	**926.27**	**925.60**	**842.67**	**513.33**	**941.33**	**841.07**	530.00
DENSITY OF SEDGES													
Cyperus esculantus	-	-	-	-	-	-	-	-	-	-	-	-	15- ± 20.79
Cyperus rotundus	-	-	2.67 ± 0.67	-	-	-	-	-	-	-	11.33 ± 2.83	-	-
Fimbristylis rigidula	-	59.33 ± 6.72	-	16.00 ± 2.11	-	12.00 ± 1.34	1.60 ± 0.37	18.00 ± 2.13	-	-	-	-	-
Eriophorum comosum	36.00 ± 9.00	-	-	-	10.67 ± 2.67	-	-	-	-	24.67 ± 4.25	41.60 ± 9.49	11.20 ± 2.56	-
Total density of sedges	**36.00**	**59.33**	**2.67**	**16.00**	**82.00**	**12.00**	**1.60**	**18.00**	**-**	**24.67**	**52.93**	**11.20**	**-**
DENSITY OF FORBS													
Achyranthus aspera	-	1.33 ± 0.33	-	-	-	-	-	1.33 ± 0.33	-	9.33 ± 2.33	-	-	-
Artemisia roxburghiana	-	0.67 ± 0.17	-	-	10.0 ± 1.31	22.67 ± 2.59	2.00 ± 0.50	4.00 ± 0.82	-	-	-	4.00 ± 0.52	6.00 ± 1.50
Barleria strigosa	-	4.67 ± 1.17	32.00 ± 4.48	3.33 ± 0.65	-	-	-	-	-	-	-	-	-

Table continued ……

Bidens pilosa	1.33 ± 0.21	1.33 ± 0.33	1.33 ± 0.33	-	26.67 ± 5.52	-	6.67 ± 1.31	6.67 ± 0.76	-	4.00 ± 0.45	6.00 ± 0.81	6.67 ± 1.28	-
Bidens tripartita	-	-	-	-	-	-	-	29.60 ± 5.89	17.33 ± 2.56	16.00 ± 1.48	-	2.67 ± 0.67	13.33 ± 2.06
Cheilathes farinosa	-	2.00 ± 0.50	-	2.67 ± 0.67	-	-	-	-	7.33 ± 1.83	15.33 ± 2.10	-	-	-
Cristella dentata	-	-	-	-	30.67 ± 6.54	-	-	-	-	-	-	-	-
Commelina benghalensis	-	6.40 ± 1.06	-	-	-	-	-	-	-	4.67 ± 0.75	-	-	-
Dicliptera bupleuroides	-	-	3.33 ± 0.83	-	-	-	-	-	-	-	-	-	-
Erigeron annus	2.00 ± 0.34	-	8.80 ± 1.24	7.33 ± 1.47	-	-	-	0.67 ± 0.17	-	-	-	-	-
Euphorbia heterophylla	-	-	-	-	-	-	-	-	12.67 ± 1.47	-	-	-	-
Evolvulus alsinoides	-	-	-	-	0.67 ± 0.17	-	4.67 ± 0.75	-	-	-	-	-	-
Geranium nepalensis	-	-	-	3.33 ± 0.54	-	-	-	-	5.33 ± 1.33	-	-	-	0.67 ± 0.17
Gerbera gossypina	-	-	-	2.00 ± 0.50	-	2.00 ± 0.50	-	-	-	0.67 ± 0.17	-	-	-
Justicia simplex	-	18.40 ± 3.02	-	-	-	-	-	-	-	5.33 ± 0.88	-	10.67 ± 2.67	-
Leucus lanata	-	-	1.33 ± 0.33	-	-	-	-	-	5.33 ± 1.33	1- ± 2.50	14.40 ± 2.03	-	-
Micromeria biflora	23.33 ± 5.83	-	-	-	8- ± 6.94	-	10.00 ± 2.50	70.00 ± 5.97	28.67 ± 5.42	-	142.67 ± 13.26	-	75.33 ± 12.83
Origanum vulgare	9.33 ± 1.96	-	2.00 ± 0.50	-	13.33 ± 2.75	16.67 ± 1.83	20.67 ± 1.94	5.33 ± 1.33	-	-	10.67 ± 1.45	-	5.33 ± 1.33
Oxychium contigium	-	-	-	-	-	-	-	-	-	17.33 ± 2.79	-	-	3.33 ± 0.83
Plectranthus sericea	-	-	-	90.00 ± 8.88	-	-	-	-	-	-	-	-	-
Polygala crotalariodes	-	-	-	-	-	-	-	-	-	-	-	10.00 ± 2.50	-
Reinwardtia indica	15.33 ± 1.96	6.67 ± 0.76	-	2.67 ± 0.67	2.00 ± 0.50	-	-	-	3.33 ± 0.83	4.67 ± 0.83	-	2.67 ± 0.67	-
Rhus cotinus	-	-	41.33 ± 10.13	-	-	-	-	-	-	-	0.67 ± 0.17	-	-
Sonchus arvensis	0.67 ± 0.17	-	4.67 ± 0.65	-	-	2.00 ± 0.50	-	-	-	2.67 ± 0.67	-	-	-
Thalictrum foliosum	-	0.67 ± 0.17	1.33 ± 0.33	-	-	-	-	-	4.00 ± 0.45	-	-	-	-
Viola indica	-	-	-	-	-	-	-	-	-	-	-	-	52.67 ± 8.61
Viola serpens	-	-	-	-	-	-	-	-	-	-	-	25.33 ± 5.94	-
Total density of forbs	**52.00**	**42.13**	**96.13**	**111.33**	**163.33**	**43.33**	**44.00**	**117.60**	**84.00**	**90.00**	**174.40**	**62.00**	156.67
DENSITY OF LEGUMES													
Cassia mimosoides	-	-	-	-	-	-	-	-	3.33 ± 0.83	-	-	6.00 ± 1.50	-
Lespedeza gerardiana	-	-	91.33 ± 15.13	19.33 ± 2.10	-	-	4.00 ± 0.68	-	-	-	2.00 ± 0.50	4.67 ± 1.17	-
Total density of legumes	**-**	**-**	**91.33**	**19.33**	**-**	**-**	**4.00**	**-**	**3.33**	**-**	**2.00**	**10.67**	-
Total density of herbage	**996.67**	**548.00**	**759.33**	**772.00**	**866.67**	**595.33**	**926.00**	**882.00**	**914.00**	**513.33**	**932.00**	**825.33**	**529.33**

It was recorded that mean density of herbage in the sub-watersheds affected significantly. Highest (773.85 tillers/m^2) mean density was found at elevation E_3, which was followed by elevation E_1 (768.56 tillers/m^2) and 721.11 tillers/m^2 at elevation E_2. The effect of elevations and interaction between elevations and sub-watersheds on mean density of herbage was found to be non-significant (Table 25).

4.4.2.2 Basal area of herbage vegetation (cm^2/m^2)

The basal area of herbage vegetation in different sub-watersheds at elevation E_1, ranged from 21.38 (SW_{11}) to 72.89 (SW_2) cm^2/m^2. The contribution of different plant categories to the basal area of herbage vegetation showed that 86.95 % to 99.08 % of total basal area of herbage was contributed by grasses, 0.31 % to 4.63 % by sedges, 0.29 % to 11.44 % by forbs and 0.15 % to 4.05 % by legumes (Table 26).

It was observed that among different species *Heteropogon contortus*, *Chrysopogon montanus*, *Arundinela nepalensis* and *Themeda anathera* were the major contributors in the community basal area with their basal area values ranging from 0.57 $\pm$ 1.04 to 23.62 $\pm$ 5.31 cm^2/m^2, 0.51 $\pm$ 0.01 to 21.41 $\pm$ 7.04 cm^2/m^2, 3.95 $\pm$ 2.37 to 19.26 $\pm$ 9.78 cm^2/m^2 and 2.02 $\pm$ 0.23 to 18.25 $\pm$ 7.40 cm^2/m^2, respectively (Table 26).

The contribution of sedges to the total basal area of herbage in the sub-watersheds, where they were recorded, remained very less and it varied from 0.21 (SW_1) to 3.87 (SW_{13}) cm^2/m^2. The forbs contribution to the total basal area of herbage in different sub-watersheds was also very less as compared to grasses and it ranged from 0.12 (SW_8) to 4.97 (SW_9) cm^2/m^2. Likewise, the contributions from legumes to the total basal area of herbage in the sub-watwrsheds where they were present fluctuated between 0.01 (SW_3) to 1.86 (SW_7) cm^2/m^2 (Table 26).

Further in grasslands, at elevation E_2, the basal area of herbage vegetation in sub-watersheds varied from 28.09 (SW_{10}) to 64.61 (SW_7) cm^2/m^2. The contributions of different plant categories to the basal area of herbage vegetation in sub-watersheds revealed that 82.98 % to 99.82 % of basal area was pooled by grasses, 0.56 % to 9.78 % by sedges, 0.18 % to 10.48 % by forbs and 0.11 % to 5.33 % by legumes.

It was recorded that among individual species *Chrysopogon contortus* and *Themeda anathera* were the major contributions to the basal area of community with their contributions as: 4.30 ±1.03 to 24.27 ± 6.95 cm^2/m^2 and 2.28 ± 1.43 to 17.93 ± 4.62 cm^2/m^2, respectively (Table 27).

The contributions of sedges to the total basal area of herbage in the sub-watersheds, where they were present, was very low and it varied from 0.23 (SW_8) to 4.20 (SW_3) cm^2/m^2. The contributions of forbs to the total basal area of herbage in different sub-watersheds was also very less as compared to grasses and it ranged from 0.12 (SW_7) to 5.31 (SW_{12}) cm^2/m^2. Similarly, the contributions to the total basal area of herbage of legumes in sub-watersheds fluctuated between 0.06 (SW_1), to 2.77 (SW_6) cm^2/m^2 (Table 27).

Similarly in grasslands at elevation E_3, it was observed that the basal area of herbage vegetation in the different sub-watersheds varied from 23.20 (SW_{11}) to 57.44 (SW_7). The contributions from different plant categories to the basal area showed that 69.03 % to 96.21 % of basal area was contributed by grasses, 0.58 % to 16.43 % by sedge, 2.98 % to 16.75 % by forbs and 0.04 % to 9.14 % by legumes. It was recorded that among different species *Themeda anathera*, *Chrysopogon montanus*, *Heteropogon contortus* and *Apluda mutica* were the major contributors to the community with their basal area contributions ranging from 2.81 ± 0.78 to 19.12 ± 5.68 cm^2/m^2, 0.85 ± 0.40 to 22.74 ± 6.35 cm^2/m^2, 1.11 ± 0.48 to 18.92 ± 4.5 cm^2/m^2 and 0.70 ± 0.09 to 13.56 ± 5.26 cm^2/m^2, respectively (Table 28).

The contributions of sedges to the total basal area of herbage in sub-watersheds was low and it varied from 0.31 (SW_3) to 7.00 (SW_2) cm^2/m^2. The contributions of forbs to the total basal area of herbage in sub-watersheds was also very less as compared to grasses and it ranged 1.71 (SW_7) to 15.38 (SW_4) cm^2/m^2. Likewise, the contributions from legumes, in the sub-watersheds to the total basal area of herbage of community ranged from 0.01 (SW_{11}) to 4.91 (SW_3) cm^2/m^2 (Table 28).

Table 25. Variation in density (tillers/m^2) of herbage in grasslands of different sub-watersheds in Giri catchment

Sub-watersheds (SW) Elevation (E)	Sub-watersheds													
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}	Mean (E)
Density														
E_1(900-1300m)	1090.00	1147.33	550.00	760.67	823.33	886.00	758.00	805.33	669.33	543.33	620.67	729.33	608.00	768.56
E_2(1301-1700m)	866.67	481.33	581.33	1002.00	576.00	944.67	886.67	774.67	894.00	507.33	671.73	638.67	549.33	721.11
E_3(1701-2100m)	996.67	548.00	759.33	772.00	866.67	595.33	926.00	882.00	914.00	513.33	932.00	825.33	529.33	773.85
Mean (SW)	984.45	725.56	630.22	844.89	755.33	808.67	856.89	820.67	825.78	521.33	741.47	731.11	562.22	

Factors	$CD_{0.05}$	SEm±
SW	NS	25.87
E	150.40	53.87
SW×E	260.50	93.30

Table: 26. Basal area (cm^2/m^2) of herbage species in grasslands at elevation E_1 (900 – 1300 m) in Giri catchment of HP

Plants species/ Plant categories	SUB-WATERSHEDS												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
BASAL AREA OF GRASSES													
Apluda mutica	0.05 ± 0.01	1.97 ± 1.18	0.21 ± 0.20	-	0.92 ± 0.16	5.34 ± 2.27	0.12 ± 0.11	1.87 ± 1.25	-	-	- ± 0.75	2.76 ± 2.11	-
Arundinella nepalensis	16.10 ± 8.58	10.48 ± 5.25	7.35 ± 2.93	-	16.93 ± 5.63	13.56 ± 3.92	4.96 ± 2.88	7.03 ± 2.47	0.04 ± 0.04	3.95 ± 2.37	5.44 ± 2.69	4.66 ± 3.94	19.26 ± 9.78
Cenchrus ciliaris	-	-	-	-	-	-	-	-	-	-	-	-	1.33 ± 0.23
Chloris barbata	-	-	-	-	-	-	-	-	0.19 ± 0.18	-	4.93 ± 0.55	-	-
Chrysopogon fulvus	-	0.93 ± 0.56	-	1.02 ± 0.34	0.54 ± 0.50	-	-	-	-	-		-	-
Chrysopogon montanus	17.45 ± 8.98	21.41 ± 7.04	12.85 ± 5.66	16.25 ± 5.60	12.79 ± 6.35	11.65 ± 5.86	14.01 ± 3.94	1.63 ± 0.61	14.97 ± 4.99	2.58 ± 0.93	0.51 ± 0.11	10.58 ± 3.67	7.19 ± 3.63
Cymbopogon martinii	-	-	-	-	-	-	-	0.94 ± 0.87	0.31 ± 0.22	1.37 ± 0.87	-	-	-
Dicanthium annulatum	-	-	0.64 ± 0.31	2.48 ± 1.25	2.09 ± 1.16	1.65 ± 0.65	2.05 ± 1.52	1.79 ± 1.65	-	-	0.03 ± 0.01	1.65 ± 1.05	-
Heteropogon contortus	10.23 ± 4.89	11.49 ± 5.12	0.24 ± 0.18	8.51 ± 6.61	3.57 ± 3.04	6.23 ± 2.97	7.42 ± 3.29	5.11 ± 3.17	14.51 ± 5.07	16.99 ± 6.33	-	1.94 ± 1.76	23.62 ±5.31
Imperata cylindrica	-	0.98 ± 0.91	-	-	0.60 ± 0.41	-	-	0.98 ± 0.60	0.66 ± 0.43	1.38 ± 0.90	-	-	-
Ischaemum aristatum	0.94 ± 0.27	2.45 ± 1.81	-	0.57 ± 0.11	0.12 ± 0.11	-	-	0.21 ± 0.03	0.30 ± 0.11	0.21 ± 0.11	-	4.95 ± 1.93	0.23 ± 0.12
Oplismenus burmannii	-	0.48 ± 0.21	-	-	-	-	-	0.21 ± 0.00	-	-	-	-	-
Panicum coloratum	-	-	0.49 ± 0.32	-	-	-	-	-	-	-	-	-	-
Panicum maximum	-	-	-	0.31 ± 0.18	-	-	3.36 ± 2.45	10.98 ± 6.03	-	-	0.72 ± 0.48	11.74 ± 7.58	-
Paspalum notatum	-	-	-	-	-	-	-	-	0.15 ± 0.04	-	-	-	-
Setaria glauca	-	0.06 ± 0.06	-	-	-	-	-	-	0.27 ± 0.21	0.33 ± 0.19	-	0.21 ± 0.20	-
Themeda anathera	18.25 ± 7.40	14.42 ± 3.75	7.31 ± 3.08	2.02 ± 0.23	7.69 ± 3.25	10.25 ± 4.95	8.47 ± 2.44	10.74 ± 5.26	7.03 ± 2.80	2.30 ± 1.60	5.81 ± 2.02	17.25 ± 5.59	-
Urochloa panicoides	1.60 ± 0.75	4.29 ± 2.26	-	2.05 ± 0.48	-	1.49 ± 0.73	-	-	-	-	1.03 ± 0.63	1.63 ± 0.77	-
Total basal area of grasses	**64.62**	**68.96**	**29.09**	**33.21**	**45.25**	**50.17**	**40.39**	**41.49**	**38.45**	**29.12**	**18.47**	**57.37**	**55.50**
BASAL AREA OF SEDGES													
Fimbristylis rigidula	0.21 ± 0.20	-	-	-	-	-	-	0.51 ± 0.47	-	-	0.99 ± 0.56	-	-
Eriophorum comosum	-	-	-	-	-	-	-	-	-	-	-	-	3.87 ± 2.40
Total basal area of sedges	0.21	-	-	-	-	-	-	0.51	-	-	0.99	-	3.87
BASAL AREA OF FORBS													
Achyranthus aspera	-	-	-	0.05 ± 0.02	-	-	-	-	-	-	-	-	-
Ageratum conyzoides	-	-	-	0.08 ± 0.06	-	-	-	-	-	0.05 ± 0.01	-	-	-
Artemisia roxburghiana	-	0.78 ± 0.42	-	-	-	0.04 ± 0.04	0.98 ± 0.60	-	-	-	0.48 ± 0.44	0.09 ± 0.08	-

Continued…

Barleria strigosa	2.64 ± 1.92	-	-	0.21 ± 0.20	0.05 ± 0.05	0.45 ± 0.17	-	-	-	0.03 ± 0.00	0.10 ± 0.00	-	-
Bidens pilosa	-	0.14 ± 0.11	-	-	0.83 ± 0.06	-	-	-	-	-	-	-	-
Cheilathes farinosa	0.36 ± 0.24	-	-	-	-	0.77 ± 0.19	0.02 ± 0.02	0.09 ± 0.01	1.03 ± 0.05	0.09 ± 0.03	-	0.05 ± 0.01	-
Cristella dentata	0.05 ± 0.05	-	-	-	-	0.04 ± 0.04	-	-	-	-	-	-	-
Commelina benghalensis	-	-	-	-	-	-	-	-	0.06 ± 0.06	0.21 ± 0.20	-	-	-
Conyza stricta	-	-	-	-	0.12 ± 0.09	-	-	-	-	-	-	-	-
Dicliptera roxburghiana	-	-	-	-	0.62 ± 0.33	-	-	-	-	-	-	-	1.76 ± 1.09
Dryopteris panda	-	0.51 ± 0.47	-	-	-	-	-	-	-	-	-	-	-
Euphorbia heterophylla	-	0.65 ± 0.50	-	-	-	1.72 ± 0.84	-	-	3.82 ± 1.80	0.17 ± 0.16	-	0.15 ± 0.14	-
Evolvulus alsinoides	-	-	-	-	-	-	0.21 ± 0.20	-	-	-	-	-	-
Justicia simplex	-	0.12 ± 0.01	-	-	-	-	-	-	0.02 ± 0.00	-	-	-	-
Leucus lanata	-	-	-	-	-	-	-	-	-	0.03 ± 0.00	-	-	-
Micromeria biflora	0.02 ± 0.00	-	-	-	0.26 ± 0.24	-	-	-	-	0.51 ± 0.47	-	0.06 ± 0.01	-
Origanum vulgare	-	-	-	1.12 ± 1.04	-	-	2.99 ± 2.76	-	-	-	0.10 ± 0.00	-	-
Parthenium hystophorus	-	0.21 ± 0.00	-	-	-	-	-	-	-	-	-	-	-
Plectranthus sericea	-	-	0.28 ± 0.20	-	-	-	-	-	-	-	-	-	-
Reinwardtia indica	-	-	1.70 ± 1.36	-	-	0.21 ± 0.00	-	-	-	-	0.10 ± 0.00	-	-
Rhus cotinus	0.11 ± 0.06	-	0.33 ± 0.21	-	-	0.07 ± 0.04	-	-	-	-	-	-	0.23 ± 0.18
Swertia angustifolea	-	-	-	-	0.10 ± 0.00	-	-	-	-	-	-	-	-
Thalictrum foliosum	-	-	-	0.02 ± 0.00	-	0.06 ± 0.02	-	0.03 ± 0.00	-	-	0.14 ± 0.13	0.17 ± 0.16	-
Tricholepis elongata	-	0.55 ± 0.44	-	0.34 ± 0.17	0.08 ± 0.07	-	-	-	-	-	0.31 ± 0.28	-	0.33 ± 0.31
Xanthium indicum	-	0.73 ± 0.32	-	-	-	-	-	-	0.03 ± 0.01	0.06 ± 0.06	-	-	3.56 ± 1.70
Total basal area of forbs	3.44	3.69	2.31	1.84	1.45	3.36	4.20	0.12	4.97	1.17	1.35	0.53	4.12
BASAL AREA OF LEGUMES													
Cassia abscus	-	-	-	-	-	0.65 ± 0.60	-	-	-	0.02 ± 0.02	-	-	-
Cassia mimosoides	-	0.25 ± 0.16	-	-	-	-	-	-	-	0.72 ± 0.40	-	-	-
Lespedeza gerardiana	0.14 ± 0.13	-	0.01 ± 0.00	0.08 ± 0.07	0.70 ± 0.00	0.08 ± 0.05	1.62 ± 1.11	0.54 ± 0.32	-	0.54 ± 0.32	0.57 ± 0.36	-	0.09 ± 0.08
Rhynchosia himalensis	-	-	-	-	-	-	0.24 ± 0.15	0.24 ± 0.10	-	-	-	-	-
Total basal area of legumes	0.14	0.25	0.01	0.08	0.70	0.73	1.86	0.78	-	1.28	0.57	-	0.09
Total Basal area of herbage	68.41	72.89	31.41	35.13	47.39	54.26	46.45	42.90	43.42	31.57	21.38	57.90	59.71

Table: 27. Basal area (cm^2/m^2) of herbage species in grasslands at elevation E_2 (1301 – 1700 m) in Giri catchment of HP

Plants species/ Plant categories	**Sub-watersheds**												
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	**SW_7**	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**
BASAL AREA OF GRASSES													
Apluda mutica	7.76 ± 3.90	-	0.54 ± 0.34	0.85 ± 0.79	1.76 ± 1.00	3.89 ± 2.32	6.08 ± 5.63	3.14 ± 1.39	-	1.32 ± 0.01	0.15 ± 0.09	4.13 ± 2.07	6.56 ± 1.34
Arundinella nepalensis	8.14 ± 4.53	14.24 ± 5.67	4.59 ± 2.21	2.65 ± 0.76	-	4.77 ± 2.50	15.83 ± 7.38	0.61 ± 0.29	-	-	1.52 ± 1.00	3.32 ± 1.42	5.32 ± 1.12
Bothriochloa pertusa	-	-	-	-	-	-	-	-	-	-	-	-	0.23 ± 0.02
Chloris barbata	0.26 ± 0.24	-	-	-	-	-	-	-	0.54 ± 0.10	-	-	-	-
Chrysopogon fulvus	0.33 ± 0.31	0.09 ± 0.08	-	-	0.03 ± 0.00	-	-	-	-	-	-	-	-
Chrysopogon montanus	10.36 ± 3.95	5.42 ± 3.51	11.54 ± 5.03	24.27 ± 6.95	-	14.95 ± 4.45	4.30 ± 1.03	10.67 ± 4.60	10.46 ± 3.15	9.86 ± 3.75	10.14 ± 2.84	5.97 ± 1.72	9.95 ± 1.10
Cymbopogon martinii	-	-	2.02 ± 1.52	3.66 ± 2.27	-	3.57 ± 1.71	1.23 ± 0.74	-	4.97 ± 4.10	-	0.99 ± 0.60	-	0.81 ± 0.49
Dicanthium annulatum	4.48 ± 3.56	-	2.02 ± 1.52	1.20 ± 0.43	3.55 ± 2.87	3.18 ± 1.51	2.17 ± 2.01	-	4.32 ± 2.31	0.26 ± 0.00	0.62 ± 0.30	0.72 ± 0.43	-
Heteropogon contortus	1.90 ± 1.13	0.61 ± 0.57	6.87 ± 2.73	0.33 ± 0.31	1.11 ± 0.78	10.65 ± 4.84	7.30 ± 3.30	4.62 ± 1.89	15.81 ± 6.44	6.33 ± 0.00	21.83 ± 5.44	8.34 ± 4.01	6.90 ± 5.06
Imperata cylindrica	-	0.36 ± 0.19	-	1.04 ± 0.67	0.09 ± 0.08	-	0.26 ± 0.19	-	-	-	-	-	-
Ischaemum aristatum	-	-	3.15 ± 2.44	-	-	-	-	0.33 ± 0.01	0.14 ± 0.00	-	0.42 ± 0.39	-	1.16 ± 0.70
Oplismenus burmannii	-	-	-	-	-	0.64 ± 0.42	-	-	0.54 ± 0.50	-	-	-	-
Panicum maximum	-	-	1.02 ± 0.48	5.32 ± 3.22	-	-	15.83 ± 9.01	0.37 ± 0.20	8.63 ± 4.05	-	-	8.13 ± 3.64	3.57 ± 3.30
Setaria glauca	-	-	-	-	-	0.99 ± 0.46	-	-	-	0.15 ± -0.00	-	-	-
Themeda anathera	14.25 ± 5.62	5.24 ± 1.74	5.81 ± 2.95	14.41 ± 6.80	17.93 ± 4.62	2.28 ± 1.43	11.50 ± 2.66	14.82 ± 5.81	3.85 ± 1.80	5.78 ± 0.00	7.75 ± 6.42	6.48 ± 3.28	11.24 ± 4.16
Urochloa panicoides	-	0.40 ± 0.30	-	-	0.25 ± 0.19	0.31 ± 0.28	-	0.74 ± 0.63	-	1.32 ± 0.00	0.06 ± 0.06	1.77 ± 1.25	4.45 ± 2.71
Total basal area of grasses	**47.47**	**26.36**	**37.57**	**53.73**	**24.71**	**45.28**	**64.49**	**35.55**	**49.26**	**25.01**	**43.47**	**38.85**	**50.19**
BASAL AREA OF SEDGES													
Cyperus rotundus	-	-	-	-	-	-	-	-	3.22 ± 2.13	-	0.66 ± 0.43	0.26 ± 0.24	-
Fimbristylis rigidula	-	1.12 ± 1.04	4.20 ± 3.89	-	-	-	-	-	-	-	-	-	-
Eriophorum comosum	-	-	-	-	-	-	-	0.23 ± 0.19	-	-	-	-	-
Total basal area of sedges	**0.00**	**1.12**	**4.20**	**0.00**	**0.00**	**0.00**	**0.00**	**0.23**	**3.22**	**0.00**	**0.66**	**0.26**	**0.00**
BASAL AREA OF FORBS													
Achyranthus aspera	-	-	-	-	-	-	-	-	-	-	-	0.28 ± 0.26	-
Ageratum conyzoides	0.15 ± 0.14	-	-	-	-	-	-	-	-	0.04 ± 0.00	-	0.19 ± 0.18	-
Artemisia roxburghiana	0.08 ± 0.07	-	-	-	-	0.86 ± 0.50	-	-	0.12 ± 0.11	-	-	0.85 ± 0.79	0.30 ± 0.00

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Barleria strigosa	-	-	0.53 ± 0.25	0.45 ± 0.11	-	-	-	-	-	0.26 ± 0.00	0.21 ± 0.00	-	-
Bidens pilosa	0.65 ± 0.44	-	-	0.54 ± 0.14	0.03 ± 0.02	-	-	-	-	-	-	0.04 ± 0.00	-
Cheilathes farinosa	-	-	0.02 ± 0.00	-	-	-	-	-	-	0.02 ± 0.00	-	-	2.17 ± 0.04
Commelina benghalensis	-	0.77 ± 0.71	-	-	-	0.81 ± 0.05	-	-	-	-	-	-	0.54 ± 0.07
Conyza stricta	0.03 ± 0.02	-	-	-	-	-	-	-	-	-	0.17 ± 0.11	-	-
Dicliptera roxburghiana	-	-	-	2.45 ± 2.27	-	0.08 ± 0.07	-	-	-	-	1.38 ± 0.63	-	-
Erigeron annus	-	-	-	0.96 ± 0.57	0.05 ± 0.00	0.51 ± 0.47	-	-	-	-	-	0.15 ± 0.14	-
Euphorbia heterophylla	-	-	-	-	-	0.98 ± 0.01	-	-	-	0.17 ± 0.00	-	0.31 ± 0.26	-
Evolvulus alsinoides	-	0.36 ± 0.33	0.05 ± 0.03	-	-	-	0.07 ± 0.01	-	-	0.28 ± 0.00	-	-	-
Geranium nepalensis	-	0.67 ± 0.26	-	-	-	-	-	-	-	-	-	1.27 ± 1.18	-
Justicea simplex	-	0.29 ± 0.16	-	-	-	0.03 ± 0.00	-	-	0.28 ± 0.06	0.11 ± 0.00	-	-	-
Leucus lanata	-	-	-	1.07 ± 1.00	-	0.48 ± 0.13	-	-	-	1.57 ± 0.00	0.14 ± 0.08	0.33 ± 0.31	-
Micromeria biflora	1.69 ± 1.18	-	-	-	-	-	-	0.50 ± 0.32	0.14 ± 0.13	-	-	-	-
Origanum vulgare	0.07 ± 0.05	-	-	-	0.54 ± 0.00	-	-	-	-	-	-	-	0.48 ± 0.14
Oxalis corniculata	-	-	-	-	-	-	-	-	0.12 ± 0.11	-	-	-	-
Pimpinella diversifolia	-	-	-	-	-	-	-	-	0.51 ± 0.31	0.08 ± 0.01	-	-	-
Platystemmsa violoides	-	-	0.21 ± 0.01	-	-	-	-	-	-	-	-	-	-
Plectranthus sericea	-	-	0.31 ± 0.11	-	2.72 ± 0.63	-	-	-	-	-	-	-	-
Reinwardtia indica	0.31 ± 0.11	-	0.08 ± 0.07	-	-	0.09 ± 0.01	-	-	-	-	-	1.27 ± 0.18	-
Rhus cotinus	-	-	-	-	-	0.12 ± 0.03	-	-	-	-	-	-	-
Swertia angustifolia	0.08 ± 0.07	-	-	-	-	-	-	-	-	-	-	-	-
Thalictrum foliosum	0.25 ± 0.16	0.31 ± 0.02	-	0.14 ± 0.08	-	-	0.04 ± 0.00	-	-	-	-	-	-
Tricholepis elongata	-	0.26 ± 0.07	-	-	0.05 ± 0.00	-	-	-	-	-	-	0.60 ± 0.38	0.52 ± 0.14
Strumanium indicum	-	0.60 ± 0.14	-	-	-	0.33 ± 0.01	-	-	-	0.16 ± 0.00	-	-	-
Total basal area of forbs	**3.30**	**3.25**	**1.19**	**3.17**	**3.39**	**4.21**	**0.12**	**0.50**	**1.16**	**2.73**	**0.53**	**5.31**	**4.02**
BASAL AREA OF LEGUMES													
Cassia abscus	-	-	-	-	-	0.21 ± 0.20	-	-	-	0.18 ± 00	-	-	-
Cassia mimosoides	-	0.06 ± 0.00	-	0.05 ± 0.00	-	0.49 ± 0.26	-	-	1.17 ± 0.51	0.17 ± 00	-	0.65 ± 0.60	0.19 ± 0.18
Lespedeza gerardiana	0.05 ± 0.00	0.24 ± 0.16	-	0.90 ± 0.57	0.46 ± 0.23	1.96 ± 1.76	-	-	0.08 ± 0.06	-	0.23 ± 0.22	0.98 ± 0.91	-
Total basal area of legumes	**0.06**	**0.30**	**-**	**0.96**	**0.46**	**2.77**	**-**	**-**	**1.24**	**0.35**	**0.23**	**1.84**	**0.19**
Total Basal area of herbage	**50.83**	**31.04**	**42.97**	**57.85**	**28.57**	**52.26**	**64.61**	**36.05**	**54.89**	**28.09**	**44.89**	**46.27**	**54.40**

Table: 28. Basal area (cm^2/m^2) of herbage species in grasslands, at elevation E_3 in Giri catchment of HP

Plants species/ Plant categories	Sub-watersheds												
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	SW_7	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**
BASAL AREA OF GRASSES													
Apluda mutica	2.55 ± 1.43	13.56 ± 5.26	2.42 ± 1.68	6.11 ± 3.88	2.96 ± 1.61	-	7.67 ± 3.60	3.17 ± 2.70	0.75 ± 0.55	2.02 ± 0.00	0.70 ± 0.69	12.07 ± 6.62	1.85 ± 1.17
Arundinella nepalensis	4.71 ± 3.94	4.12 ± 2.21	-	5.96 ± 3.46	6.74 ± 1.67	2.22 ± 1.00	0.70 ± 0.47	-	-	-	0.02 ± 0.02	-	-
Avena fatua	-	0.63 ± 0.13	-	-	-	0.04 ± 0.04	-	-	-	0.24 ± 0.00	-	-	-
Bothriochloa pertusa	-	-	-	-	-	0.64 ± 0.35	-	-	-	-	-	-	0.73 ± 0.00
Cenchrus ciliaris	-	-	-	-	-	-	-	-	-	-	-	-	0.09 ± 0.00
Chloris gayana	-	-	-	-	0.26 ± 0.26	-	-	-	-	-	-	-	-
Chrysopogon fulvus	0.54 ± 0.04	-	-	2.21 ± 1.94	0.60 ± 0.54	-	-	-	-	-	0.54 ± 0.54	-	-
Chrysopogon montanus	3.38 ± 2.23	0.85 ± 0.44	6.26 ± 1.49	4.79 ± 3.20	9.08 ± 2.68	6.84 ± 2.64	21.09 ± 7.60	5.50 ± 3.06	10.53 ± 7.33	7.31 ± 2.68	2.12 ± 1.88	22.74 ± 6.35	-
Cymbopogon martinii	-	-	3.95 ± 3.81	-	-	-	-	-	3.64 ± 1.87	-	2.25 ± 2.24	3.52 ± 2.38	-
Dicanthium annulatum	1.86 ± 0.87	-	7.52 ± 4.32	-	6.86 ± 1.76	-	-	-	0.62 ± 0.53	-	-	-	1.44 ± 0.60
Digiteria stricta	-	0.82 ± 0.64	-	-	-	-	-	0.69 ± 0.19	-	0.28 ± 0.00	-	-	3.70 ± 0.00
Heteropogon contortus	2.98 ± 1.54	-	7.46 ± 4.33	4.89 ± 2.72	7.12 ± 4.69	6.54 ± 6.54	2.95 ± 1.15	6.14 ± 2.75	18.92 ± 4.54	11.69 ± 0.00	1.11 ± 0.48	3.72 ± 1.73	3.67 ± 0.93
Imperata cylindrica	-	0.73 ± 0.73	-	-	0.69 ± 0.69	-	-	1.96 ± 0.93	-	-	-	-	-
Ischaemum aristatum	-	-	-	-	-	-	-	-	-	-	0.89 ± 0.25	-	-
Panicum maximum	12.68 ± 12.19	0.28 ± 0.01	-	-	-	-	5.40 ± 5.05	13.16 ± 5.86	2.12 ± 1.58	15.92 ± 0.00	2.91 ± 2.22	-	0.68 ± 0.57
Themeda anathera	17.68 ± 4.78	11.77 ± 3.25	12.96 ± 4.96	13.40 ± 5.24	11.01 ± 3.29	17.02 ± 5.07	14.04 ± 3.25	19.12 ± 5.68	3.84 ± 1.87	-	2.81 ± 0.78	6.08 ± 3.35	5.64 ± 0.95
Urochloa panicoides	-	-	1.58 ± 1.09	-	-	2.93 ± 1.87	3.42 ± 2.19	0.24 ± 0.17	6.19 ± 3.43	-	4.81 ± 4.10	0.49 ± 0.32	0.06 ± 0.06
Total basal area of grasses	**46.39**	**32.76**	**42.15**	**37.36**	**45.32**	**36.24**	**55.27**	**49.99**	**46.61**	**37.45**	**18.16**	**48.62**	**17.85**
BASAL AREA OF SEDGES													
Cyperus rotundus	-	-	0.31 ± 0.20	-	-	-	-	-	-	-	0.12 ± 0.12	-	-
Fimbristylis rigidula	-	7.00 ± 2.67	-	0.73 ± 0.45	-	1.15 ± 0.54	0.32 ± 0.08	2.02 ± 1.28	-	-	-	-	-
Eriophorum comosum	0.48 ± 0..01	-	-	-	0.48 ± 0.48	-	-	-	-	3.11 ± 0.01	1.03 ± 1.03	0.38 ± 0.28	-
Total basal area of sedges	**0.48**	**7.00**	**0.31**	**0.73**	**0.48**	**1.15**	**0.32**	**2.02**	**-**	**3.11**	**1.15**	**0.38**	**-**
BASAL AREA OF FORBS													
Achyranthus aspera	-	0.23 ± 0.23	-	-	-	-	-	0.21 ± 0.02	-	0.60 ± 0.01	-	-	-
Artemisia roxburghiana	-	0.03 ± 0.00	-	-	0.36 ± 0.17	1.28 ± 0.70	0.21 ± 0.01	0.48 ± 0.04	-	-	-	0.36 ± 0.22	0.23 ± 0.01
Barleria strigosa	-	0.17 ± 0.07	2.35 ± 1.48	0.12 ± 0.10	-	-	-	-	-	-	-	-	-

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Bidens pilosa	0.06 ± 0.05	0.21 ± 0.01	0.04 ± 0.00	-	1.11 ± 0.76	-	0.10 ± 0.00	0.58 ± 0.40	-	0.69 ± 0.00	0.11 ± 0.05	0.42 ± 0.32	-
Bidens tripartita	-	-	-	-	-	-	-	0.96 ± 0.08	0.98 ± 0.75	0.96 ± 0.10	-	0.12 ± 0.02	0.73 ± 0.00
Cheilathes farinosa	-	0.03 ± 0.00	-	7.21 ± 6.91	-	-	-	-	0.26 ± 0.26	0.51 ± 0.01	-	-	-
Cristella dentata	-	-	-	-	1.43 ± 1.15	-	-	-	-	-	-	-	-
Commelina benghalensis	-	0.27 ± 0.21	-	-	-	-	-	-	-	0.75 ± 02	-	-	-
Dicliptera bupleuroides	-	-	0.33 ± 0.03	-	-	-	-	-	-	-	-	-	-
Erigeron annus	0.31 ± 0.01	-	1.43 ± 1.06	0.29 ± 0.21	-	-	-	0.23 ± 0.03	-	-	-	-	-
Euphorbia heterophylla	-	-	-	-	-	-	-	-	0.21 ± 0.01	-	-	-	-
Evolvulus alsinoides	-	-	-	-	0.03 ± 0.00	-	0.07 ± 0.01	-	-	-	-	-	-
Geranium nepalensis	-	-	-	0.15 ± 0.12	-	-	-	-	-	-	-	-	0.03 ± 0.00
Gerbera gossypina	-	-	-	-	-	0.65 ± 0.0.2	-	-	-	0.03 ± 0.02	-	-	-
Justicea simplex	-	1.10 ± 0.87	-	-	-	-	-	-	-	0.29 ± 0.00	-	0.21 ± 0.01	-
Leucus lanata	-	-	0.12 ± 0.01	-	-	6.84 ± 2.64	-	-	1.72 ± 1.46	1.85 ± 0.0	0.28 ± 0.18	-	-
Micromeria biflora	0.21 ± 0.01	-	0.03 ± 0.01	-	4.97 ± 3.18	-	0.10 ± 0.00	1.73 ± 0.75	1.74 ± 1.10	-	3.17 ± 1.22	-	2.26 ± 0.51
Origanum vulgare	0.93 ± 0.01	-	-	-	0.26 ± 0.18	0.98 ± 0.51	1.22 ± 0.48	0.08 ± 0.02	-	-	0.31 ± 0.21	-	0.21 ± 0.0
Oxychium continum	-	-	-	-	-	-	-	-	-	0.12 ± 0.01	-	-	0.09 ± 0.00
Plectranthus sericea	-	-	-	7.50 ± 3.97	-	-	-	-	-	-	-	-	-
Polygala crotalariodes	-	-	-	-	-	-	-	-	-	-	-	0.33 ± 0.00	-
Reinwardtia indica	0.61 ± 0.46	0.77 ± 0.47	-	0.10 ± 0.00	0.02 ± 0.02	-	-	-	0.28 ± 0.00	0.49 ± 0.01	-	0.21 ± 0.01	-
Rhus cotinus	-	-	1.75 ± 1.72	-	-	-	-	-	-	-	0.02 ± 0.02	-	-
Sonchus arvensis	0.03 ± 0.00	-	0.21 ± 0.10	-	-	0.21 ± 0.00	-	-	-	0.39 ± 0.01	-	-	-
Thalictrum foliosum	-	0.05 ± 0.00	0.06 ± 0.01	-	-	-	-	-	0.66 ± 0.44	-	-	-	-
Viola indica	-	-	-	-	-	-	-	-	-	-	-	-	2.47 ± 0.01
Viola serpens	-	-	-	-	-	-	-	-	-	-	-	0.65 ± 0. 02	-
Total basal area of forbs	**2.16**	**2.86**	**6.32**	**15.38**	**8.18**	**9.96**	**1.71**	**4.28**	**5.85**	**6.67**	**3.89**	**2.56**	**6.04**
BASAL AREA OF LEGUMES													
Cassia mimosoides	-	-	-	-	-	-	-	-	0.05 ± 0.02	-	-	0.05 ± 0.01	-
Lespedeza gerardiana	-	-	4.91 ±0.32	0.65 ± 0.49	-	-	0.14 ± 0.09	-	-	-	0.01 ± 0.00	0.21 ± 0.01	-
Total basal area of legumes	**-**	**-**	**4.91**	**0.65**	**-**	**-**	**0.14**	**-**	**0.05**	**-**	**0.01**	**0.27**	**-**
Total basal area of herbage	**49.02**	**42.62**	**53.69**	**54.12**	**53.98**	**47.35**	**57.44**	**56.28**	**52.51**	**47.23**	**23.20**	**51.83**	**23.89**

It was recorded that mean basal area of herbage significantly affected by elevation and interactions between sub-watershed and elevation. It was recorded that mean basal area was found to be significantly highest at elevation E_1 (47.29cm^2/m^2), which was followed by elevation E_3 (47.24cm^2/m^2) and 45.57cm^2/m^2 at elevation E_3. In the effect of interaction maximum basal area of herbage 72.89 cm^2/m^2 which was significantly higher than all other interactions.The, effect of sub-watershed was found to be non-significant on basal area of herbage (Table 29).

4.4.2.3 IVI of herbage vegetation

Importance Value Index of constituent species in grasslands in different sub-watersheds revealed that *Heteropogon contortus* exhibited IVI value 8.30(SW_3) to 106.65 (SW_{10}) in different sub-watersheds at elevation E_1 was followed by *Chrysopogon montanus* with IVI value ranging from 27.62 (SW_8) to 95.86 (SW_3) and *Arundinella nepalensis* with IVI value range of 3.66 (SW_9) to 81.75 (SW_5). Thus, *H. contortus* can be considered as dominant species in this system, and *C. montanus* and *A. nepalensis* were the co-dominant and associate species, respectively (Table 30). There presence in almost all subwatersheds also revealed their dominant character in the giri catchment.

The dominant species of herbage vegetation of grasslands at elevation E_2, was *Themeda anathera* with its IVI value of 138.41 (SW_5). Co-dominant species was *Heteropogon contortus* with its IVI value of 96.99 (SW_{11}). *Arundinella nepalensis* with IVI value as 91.62 (SW_2) and *Chrysopogon montanus* with IVI value as 86.36 (SW_4) were the associate species (Table 31).

The dominant species of herbage vegetation in grasslands at elevation E_3 was *Chrysopogon montanus* with IVI value of 98.36 (SW_{12}). *Themeda anathera* with IVI of 92.71 (SW_1) was the co-dominant species and *Heteropogon contortus* with IVI value as 83.12 (SW_9) was the main associate species (Table 32).

Table 29. Variation in basal area (cm^2/m^2) of herbage in grasslands of different sub-watersheds in Giri catchment

Elevation (E)	Sub-watersheds (SW)													
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}	Mean (E)
	Basal area ($cm^2 m^{-2}$)													
E_1	68.41	72.89	31.41	35.13	47.39	54.26	46.45	42.89	43.42	31.57	23.34	57.90	59.72	47.29
E_2	50.82	31.04	42.97	57.85	28.57	52.16	64.61	36.05	54.89	28.05	44.89	46.05	54.40	45.57
E_3	49.02	42.62	53.69	47.19	53.98	47.35	57.44	56.28	52.51	47.23	23.21	51.83	31.82	47.24
Mean (SW)	56.09	48.85	42.69	46.72	43.31	51.25	56.17	45.08	50.27	35.61	30.48	51.93	48.64	

Factors	$CD_{0.05}$	SEm±
SW	NS	2.21
E	12.85	4.60
SW×E	22.26	7.97

Table: 30. IVI of herbage species in grasslands at elevation E_1 (900 – 1300 m) in Giri catchment of HP

Plant Categories /Plant Species	Sub-watersheds												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
IVI OF GRASSES													
Apluda mutica	6.18	14.91	4.49	-	14.24	30.35	9.13	13.63	5.03	-	19.19	14.61	-
Arundinella nepalensis	64.54	37.41	75.66	-	81.75	60.89	34.30	44.05	3.66	29.72	52.56	20.41	69.03
Cenchrus ciliaris	-	-	-	-	-	-	-	-	-	-	-	-	7.42
Chloris gayana	-	-	-	-	-	-	-	-	0.42	-	55.50	-	-
Chrysopogon fulvus	-	14.66	-	21.51	4.47	-	0.46-	-	-	-	14.53	-	-
Chrysopogon montanus	58.45	68.07	95.86	84.85	70.18	45.66	76.40	27.62	88.59	32.61	-	61.49	36.63
Cymbopogon martinii	-	-	-	-	-	-	-	6.53	7.41	15.78	-	-	-
Dicanthium annulatum	-	-	10.62	23.98	13.02	18.36	8.17	9.25	-	-	8.16	12.61	-
Heteropogon contortus	44.97	37.61	8.30	61.83	14.99	36.87	47.91	39.96	68.32	106.65	-	13.83	93.83
Imperata cylindrica	7.96	4.14	-	-	1.97	-	5.67	13.84	8.96	13.59	-	-	-
Ischaemum aristatum.	5.52	10.54	-	8.90	2.87	-	-	4.26	8.69	6.33	-	22.45	3.71
Oplismenus burmannii	-	3.70	-	-	-	-	-	4.43	-	-	-	-	-
Panicum coloratum	-	-	7.04	-	-	-	-	-	-	-	-	-	-
Panicum maximum	-	-	-	5.74	-	-	23.99	58.57	-	-	14.02	43.18	-
Paspalum notatum	-	-	-	-	-	-	-	-	3.41	-	-	-	-
Setaria glauca	-	2.89	-	-	-	-	-	-	10.50	6.82	-	4.84	-
Themeda anathera	59.43	54.67	54.49	15.34	45.68	40.41	56.84	67.20	45.96	17.13	63.70	72.02	-
Urochloa panicoides	16.88	16.50	-	19.21	-	10.61	-	-	-	-	14.16	16.23	-
IVI OF SEDGES													
Fimbristylis rigidula	3.42	-	-	-	-	-	-	1.19	-	-	14.73	-	-
Eriophorum comosum	-	-	-	-	-	-	-	-	-	-	-	-	16.95
IVI OF FORBS													
Achyranthus aspera	-	-	-	2.93	-	-	-	-	-	-	-	-	-
Ageratum conyzoides	-	-	-	8.74	-	-	-	-	-	2.84	-	-	-
Artemisia roxburghiana	-	9.92	-	-	-	2.28	2.11	-	-	-	5.15	3.55	-
Barleria strigosa	16.44	-	-	3.68	12.41	5.80	-	-	-	2.90	3.44	-	-
Bidens pilosa	-	4.46	-	-	9.52	-	-	-	-	-	-	-	-
Cheilathes farinosa	6.51	-	-	-	-	7.48	3.42	0.21	7.39	3.65	-	3.48	-
Cristella dentata	-	-	-	-	-	2.35	-	-	-	-	-	-	-
Commelina benghalensis	-	-	-	-	-	-	-	-	0.14	3.33	-	-	-
Conyza stricta	-	-	-	-	5.42	-	-	-	-	-	-	-	-
Dicliptera roxburghiana	-	-	-	-	7.33	-	-	-	-	-	-	-	11.56
Dryopteris panda	-	3.43	-	-	-	-	-	-	-	-	-	-	-
Euphorbia heterophylla	-	5.72	-	-	-	4.50	-	-	8.42	3.20	-	3.57	-
Evolvulus alsinoides	-	-	-	-	-	-	4.36	-	-	-	-	-	-
Justicia simplex	-	3.72	-	-	-	-	-	-	8.67	-	-	-	-
Leucus lanata	-	-	-	-	-	-	-	-	-	2.66	-	-	-
Micromeria biflora	2.96	-	-	-	5.07	-	-	-	-	4.48	-	3.68	-
Origanum vulgare	-	-	-	7.68	-	-	11.89	-	-	-	3.44	-	-
Parthenium hystophorus	-	0.48	-	-	-	-	-	-	-	-	-	-	-
Plectranthus sericea	-	-	7.92	-	-	-	-	-	-	-	-	-	-
Reinwardtia indica	-	-	15.28	-	-	2.66	-	-	-	-	3.44	-	-
Rhus cotinus	3.15	-	8.33	-	-	4.60	-	-	-	-	-	-	0.38
Swertia angustifolia	-	-	-	-	2.92	-	-	-	-	-	-	-	-
Thalictrum foliosum	-	-	-	2.92	-	4.73	-	3.19	-	-	3.47	3.51	-
Tricholepis elongata	-	5.47	-	3.79	2.78	-	-	-	-	-	4.09	-	3.77
Xanthium indicum	-	9.07	-	-	-	5.66	-	-	7.39	2.87	-	-	25.54
IVI OF LEGUMES													
Cassia abscus	-	-	-	-	-	1.17	-	-	5.75	2.62	-	-	-
Cassia mimosoides	-	4.74	-	-	-	-	-	-	-	13.04	-	-	-
Lespedeza gerardiana	3.50	-	3.37	3.32	5.36	5.06	14.84	1.25	-	7.94	10.80	-	3.38
Rhynchosia himalensis	-	-	-	-	-	-	0.51	4.66	-	-	-	-	-

Table: 31. IVI of herbage species in grasslands at elevation E_2 (1301 – 1700 m) in Giri catchment of HP

Plant categories / Plants Species	**Sub-watersheds**												
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	**SW_7**	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**
IVI OF GRASSES													
Apluda mutica	31.34	-	8.40	6.21	25.63	21.58	15.14	26.60	-	16.55	6.33	25.94	28.35
Arundinella nepalensis	38.28	91.62	31.30	26.88	-	20.31	57.24	11.47	-	-	20.77	18.56	16.67
Bothriochloa pertusa	-	-	-	-	-	-	-	-	-	-	-	-	12.62
Chloris barbata.	1.66	-	-	-	-	-	-	-	4.38	-	-	-	-
Chrysopogon fulvus	4.74	5.00	-	-	3.48	-	-	-	-	-	-	-	-
Chrysopogon montanus.	54.17	42.42	65.82	86.36	-	69.38	37.27	67.49	51.09	81.54	59.37	39.84	45.17
Cymbopogon martinii	-	-	12.03	17.94	-	16.82	9.58	-	15.36	-	11.81	-	6.90
Dicanthium annulatum	28.00	-	13.28	14.48	32.02	18.46	8.84	-	19.01	4.85	8.82	6.77	-
Eriophorum comosum	-	-	-	-	-	-	-	7.05	-	-	-	-	-
Heteropogon contortus	17.46	7.55	49.97	3.75	13.95	41.04	41.71	35.55	75.43	60.04	96.99	37.10	30.52
Imperata cylindrica	-	9.55	-	3.26	4.75	-	6.65	2.80	-	-	-	-	-
Ischaemum aristatum	-	-	18.84	-	-	-	-	4.37	2.99	-	6.58	-	10.90
Oplismenus burmannii	-	-	-	-	-	6.66	-	-	5.34	-	-	-	-
Panicum maximum	-	-	8.54	35.20	-	-	51.80	11.13	44.69	-	-	43.70	16.36
Setaria glauca	-	-	-	-	-	11.81	-	-	-	3.31	-	-	-
Themeda anathera	65.75	49.25	37.76	56.54	138.41	11.96	55.85	95.82	23.59	36.00	43.09	40.14	39.35
Urochloa panicoides.	-	7.60	-	-	8.16	3.17	-	10.72	-	15.71	3.54	13.77	19.83
IVI OF SEDGES													
Cyperus rotundus	-	-	-	-	-	-	-	-	15.95	-	8.62	3.06	-
Fimbristylis rigidula	-	8.04	14.95	-	-	-	-	-	-	-	-	-	-
IVI OF FORBS													
Achyranthus aspera	-	-	-	-	-	-	-	-	-	-	-	2.70	-
Ageratum congoides	4.23	-	-	-	-	-	-	-	-	2.95	-	2.31	-
Artemisia roxburghiana													
Barleria strigosa	3.01	-	-	-	-	9.00	-	-	2.74	-	-	4.22	5.00
Bidens pilosa	-	-	12.28	5.83	-	-	-	-	-	7.06	3.46	-	-
Cheilathes farinosa	-	3.71	-	-	-	4.50	-	-	-	4.48	-	6.76	6.65
Commelinabenghalensis.	-	-	3.16	-	-	-	-	-	-	7.23	-	-	8.86
Conyza stricta	-	5.08	-	-	-	3.97	-	-	-	-	-	-	25.60
Dicliptera roxburghiana	5.93	-	-	-	-	-	-	3.54-	-	-	6.27	-	-
Erigeron annus	-	4.14	-	-	-	-	-	-	-	-	-	-	-
Euphorbia heterophylla	-	-	-	6.26	3.54	3.75	-	-	-	-	-	2.23	-
Evolvulus alsinoides.	-	11.99	-	-	-	-	-	-	-	3.18	-	-	-
Geranium nepalensis	-	13.31	-	-	-	-	-	-	-	-	-	5.02	-
Justicia simplex	-	9.34	-	-	-	2.33	-	-	5.99	3.04	-	-	-
Leucus lanata	-	-	-	5.45	-	3.15	-	-	-	8.83	6.70	3.43	-
Micromeria biflora	15.19	-	-	-	-	-	-	10.16	3.87	-	-	-	-
Origanum vulgare	5.78	-	-	-	9.88	-	-	-	-	-	-	-	4.60
Oxalis corniculata	-	-	-	-	-	-	-	-	2.82	-	-	-	-
Pimpinella diversifolia	-	-	-	-	-	-	-	-	5.91	3.06	-	-	-
Platystemmsa violoides	-	-	4.86	-	-	-	-	-	-	-	-	-	-
Plectranthus sericea	-	-	4.51	-	32.36	-	-	-	-	-	-	-	-
Reinwardtia indica	1.29	-	3.18	-	-	2.36	-	-	-	-	-	5.12	-
Rhus cotinus	-	-	-	-	-	2.35	-	-	-	-	-	-	-
Swertia angustifolia	3.31	-	-	-	-	-	-	-	-	-	-	-	-
Thalictrum foliosum	6.20	-	-	5.11	-	-	3.23	-	-	-	-	-	-
Tricholepis elongata	-	6.90	-	-	3.43	-	-	-	-	-	-	4.97	3.08
Xanthium indicum	-	7.96	-	-	-	2.13	-	-	-	6.26	-	-	-
IVI OF LEGUMES													
Cassia abscus	-	-	-	-	-	8.97	-	-	-	6.30	-	-	-
Cassia mimosoides	-	3.19	-	2.49	-	7.84	-	-	10.34	3.37	-	3.69	3.08
Lespedeza gerardiana	3.04	6.18	-	9.58	17.82	10.82	-	-	5.12	-	6.09	4.91	-

Table: 32. IVI of herbage species in grasslands at elevation E_3 (1701 – 2100 m) in Giri catchment of HP

Plant categories / Plants Species	Sub-watersheds												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
IVI OF GRASSES													
Apluda mutica	20.54	61.16	22.10	35.82	17.13	22.50	38.14	15.27	8.27	14.69	13.75	44.81	18.35
Arundinella nepalensis	19.98	28.81	-	30.73	36.99	19.31	8.12	-	-	-	2.43	-	-
Avena fatua	-	10.93	-	-	-	3.14	-	-	-	8.16	-	-	-
Bothriochloa pertusa	-	-	-	-	-	9.48	-	-	-	-	-	-	6.26
Cenchrus ciliaris	-	-	-	-	-	-	-	-	-	-	-	-	4.06
Chloris gayana	-	-	-	-	3.21	-	-	-	-	-	-	-	-
Chrysopogon fulvus	7.92	-	-	18.03	6.10	-	-	5.99	-	-	2.43	-	-
Chrysopogon montanus	8.47	20.70	37.80	23.65	42.57	35.63	65.83	24.60	31.05	43.56	35.94	98.36	-
Cymbopogon martinii	-	-	14.93	-	-	-	-	-	15.66	-	5.51	19.14	-
Dicanthium annulatum	25.82	-	21.82	-	36.39	-	-	-	7.71	-	-	-	16.56
Digiteria stricta	-	6.35	-	-	-	-	-	4.12	-	5.86	-	-	21.65
Eriophorum comosum	9.79	-	-	-	3.67	-	-	-	-	15.18	10.93	4.49	-
Heteropogon contortus	23.88	-	31.30	28.57	30.29	22.93	23.09	32.14	83.12	53.84	22.17	30.05	39.43
Imperata cylindrica	-	6.13	-	-	5.23	-	-	12.40	-	-	-	-	-
Ischaemum aristatum	-	-	-	-	-	-	-	-	-	-	8.95	-	-
Panicum maximum	44.46	5.81	-	-	-	-	25.58	54.80	16.58	65.16	42.31	-	7.19
Themeda anathera	92.71	72.63	65.45	62.89	52.98	77.82	72.04	72.40	27.58	-	50.49	30.58	49.89
Urochloa panicoides	-	-	9.22	-	-	17.36	21.47	5.96	40.44	-	16.42	10.52	2.24
IVI OF SEDGES													
Cyperus rotundus	-	-	3.18	-	-	-	-	-	-	-	4.75	-	-
Fimbristylis rigidula	-	37.07	-	10.92	-	8.44	3.18	11.66	-	-	-	-	-
IVI OF FORBS													
Achyranthus aspera	-	3.29	-	-	-	-	-	2.63	-	5.06	-	-	-
Artemisia roxburghiana	-	2.68	-	-	7.10	17.08	7.90	5.48	-	-	-	8.47	4.82
Barleria strigosa	-	3.75	15.18	5.66	-	-	-	-	-	-	-	-	-
Bidens pilosa	5.40	3.24	2.52	-	9.94	-	5.78	8.06	-	8.43	7.19	8.90	-
Bidens tripartita	-	-	-	-	-	-	-	8.93	10.08	13.31	-	2.98	13.56
Commelina benghalensis	-	6.78	-	-	-	-	-	-	-	6.58	-	-	-
Dicliptera bupleuroides	-	-	3.30	-	-	-	-	-	-	-	-	-	-
Erigeron annus	5.53	-	8.28	6.48	-	-	-	2.59	-	-	-	-	-
Euphorbia heterophylla	-	-	-	-	-	-	-	-	8.11	-	-	-	-
Evolvulus alsinoides	-	-	-	-	1.96	-	5.51	-	-	-	-	-	-
Geranium nepalensis	-	-	-	5.71	-	-	-	-	2.70	-	-	-	3.28
Gerbera gossypina	-	-	-	2.76	-	3.77	-	-	-	2.26	-	-	-
Justica simplex	-	8.41	-	-	-	-	-	-	-	5.76	-	4.10	-
Leucus lanata	-	-	2.66	-	-	12.63	-	-	5.90	7.75	6.64	-	-
Micromeria biflora	7.25	-	0.05	-	25.48	-	3.70	18.68	10.73	-	32.65	-	21.70
Origanum vulgare	7.00	-	2.53	-	7.22	13.37	14.10	2.81	-	-	7.78	-	4.67
Oxychium continum	-	-	-	-	-	-	-	-	-	7.66	-	-	3.96
Plectranthus sericea	-	-	-	35.47	-	-	-	-	-	-	-	-	-
Polygala crotalariodes	-	-	-	-	-	-	-	-	-	-	-	4.25	-
Reinwardtia indica	13.33	10.50	-	3.04	2.06	-	-	-	2.99	6.06	-	3.16	-
Rhus cotinus	-	-	13.01	-	-	-	-	-	-	-	2.20	-	-
Sonchus arvensis	2.70	-	7.80	-	-	2.96	-	-	-	3.38	-	-	-
Thalictrum foliosum	-	2.74	2.56	-	-	-	-	-	10.03	-	-	-	-
Viola indica	-	-	-	-	-	-	-	-	-	-	-	-	19.84
Viola serpens	-	-	-	-	-	-	-	-	-	-	-	9.10	-
IVI OF LEGUMES													
Cassia mimosoides	-	-	-	-	-	-	-	-	2.57	-	-	3.25	-
Lespedeza gerardiana	-	-	25.14	11.19	-	-	5.55	-	-	-	2.59	3.39	-

4.5 Density of shrubs (number plants ha^{-1})

4.5.1 Silvipasture (SP)

In silvipasture system, at elevation, E_1 total density (Plant ha^{-1}) of shrubs in different sub-watershed varied from 1666.67 (SW_{12}) to 2466.67 (SW_3). It was recorded that among different species *Berberis lyceum*, *Carissa carandus* and *Rubus ellipticus* were the major contribution to the total density of shrubs varied from 66.67 + 0.00 (SW_5) to 1433.33 $\pm$ 233.33 (SW_{13}), 100.00 $\pm$ 40.82 (SW_7 to SW_{12}) to 1400 $\pm$ 57.44 (SW_{11}) and 66.67 $\pm$ 00 (SW_1) to 400 $\pm$ 57.74 (SW_3) respectively. It was also recorded also recorded that *Myrise ofricana*, *Randia tetrasperma* also contributed noticeably to the total density of shrubs (Table 33).

The shrub density of silvipasture system at elevation E_2, in the sub-watersheds varied from 1466.67 (SW_{11}) to 2166.67 (SW_7). It was noted that among different species, *Berberis lyceum*, *Carrisa carandus*, *Meriandra strobifalia* and *Rubus ellipticus* were the major contributors to the total density of shrubs with their contributions ranging from 66.67 $\pm$ 0.00 (SW_8) to 1333.33 $\pm$ 88.19 (SW_{13}), 166.67 $\pm$ 0.00 (SW_4) to 866.67 $\pm$ 384.42 (SW_1), 133.33 $\pm$ 0.00 (SW_8) to 366.67 $\pm$ 33.33 (SW_1) and 133.33 $\pm$ 0.00 (SW_1) to 433.33 $\pm$ 0.00 (SW_8) respectively (Table 34).

At elevation E_3, total density of shrubs in silivipasture system of different sub-watersheds varied between 1533.33 (SW_5) to 2600.00 (SW_4). Among all the species found at E_3, *Berberis lycium*, attain the higher density ranging from 100.00 $\pm$ 0.00 (SW_3) to 1400 $\pm$ 100.00 (SW_4) followed by *Rabdosia regusa* 166.67 $\pm$ 133.33 (SW_7) to 666.67 $\pm$ 153.33 (SW_6). It was also recorded that *Rubus ellipticus*, *Myrsine africana* and *Meriandra strobifolia* also contributed noticeably to the total density of shrubs (Table 35).

The interaction effect between sub-watershed and elevation on density of shrubs was found to be non-significant (Table 36).

Table 33. Density (plants ha^{-1}) of shrub species in silvipasture at elevation E_1 (900-1300m) of Giri catchment of HP

Plant Species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
DENSITY OF SHRUBS													
Adhatoda vasica	-	-	-	-	233.33 ± 40.82	-	-	-	-	-	-	266.67 ± 81.65	-
Asparagus adscendens	-	-	-	133.33 ± 0.00	-	66.67 ± 0.00	-	166.67 ± 33.33	-	-	-	-	-
Berberis lycium	466.67 ± 408.25	1233.33 ± 66.67	-	333.33 ± 88.19	66.67 ± 0.00	0.00 ± 0.00	100.00 ± 0.00	866.67 ± 81.65	133.33 ± 0.00	266.67 ± 0.00	200.00 ± 81.65	-	1433.33 ± 233.33
Carissa carandas	933.33 ± 317.98	233.33 ± 40.82	400.00 ± 163.30	133.33 ± 0.00	533.33 ± 408.25	333.33 ± 0.00	100.00 ± 40.82	-	1233.33 ± 66.67	-	1400.00 ± 57.74	100.00 ± 0.00	-
Hypericum oblongifolium	-	-	-	400.00 ± 81.65	-	-	-	-	-	-	-	-	-
Indigofera pulchella	-	-	-	-	-	-	-	-	200.00 ± 0.00	-	-	-	-
Inula cuspidata	-	-	-	-	-	-	-	-	-	-	-	-	-
Lantana camara	133.33 ± 0.00	200.00 ± 81.65	233.33 ± 40.82	133.33 ± 0.00	-	-	-	-	100.00 ± 0.00	-	-	-	200.00 ± 163.30
Leptodermis lanceolata	-	-	-	-	-	-	-	-	-	-	-	-	-
Meriandra strobilifera	200.00 ± 0.00	-	-	300.00 ± 57.74	833.33 ± 40.82	-	200.00 ± 81.65	-	-	133.33 ± 81.65	-	66.67 ± 0.00	-
Mimosa rubicaulis	-	-	-	-	-	600.00 ± 0.00	-	-	-	-	-	-	-
Myrsine africana	-	300.00 ± 122.47	1766.67 ± 202.76	-	66.67 ± 0.00	933.33 ± 296.27	433.33 ± 88.19	466.67 ± 0.00	-	766.67 ± 133.33	233.33 ± 40.82	1000.00 ± 200.00	133.33 ± 0.00
Osyris arborea	-	-	-	-	-	-	-	33.33 ± 0.00	-	-	-	-	-
Prinsepia utilis	-	-	-	-	-	-	100.00 ± 40.82	-	-	-	-	-	-
Prunus ceracoides	-	-	66.67 ± 0.00	-	-	66.67 ± 0.00	133.33 ± 0.00	-	-	-	100.00 ± 40.82	33.33 ± 0.00	33.33 ± 0.00
Rabdosia rugosa	-	-	-	433.33 ± 122.47	-	-	100.00 ± 40.82	-	-	-	-	-	-
Randia tetrasperma	-	-	-	-	66.67 ± 0.00	200.00 ± 0.00	500.00 ± 285.77	200.00 ± 57.74	-	233.33 ± 122.47	-	-	-
Rosa moschata	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubus ellipticus	66.67 ± 0.00	200.00 ± 81.65	400.00 ± 57.74	-	-	-	200.00 ± 81.65	-	100.00 ± 0.00	200.00 ± 81.65	200.00 ± 81.65	200.00 ± 0.00	200.00 ± 81.65
Smilex aspera	-	-	-	-	-	-	-	-	-	-	-	-	-
Woodfordia fruticosa	-	-	-	333.33 ± 120.19	100.00 ± 0.00	-	-	-	-	-	-	-	-
Zanthoxylem alatum	-	-	-	-	-	-	66.67 ± 0.00	-	-	133.33 ± 0.00	100.00 ± 40.82	-	-
Total	**1800.00**	**2166.67**	**2466.67**	**2200.00**	**1900.00**	**2200.00**	**1933.33**	**1733.33**	**1766.67**	**1733.33**	**2233.33**	**1666.67**	**2166.67**

Table 34. Density (plants ha^{-1}) of shrub species in silvipasture at elevation E_2 (900-1300m) of Giri catchment of HP

Plant Species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
							DENSITY OF SHRUBS						
Adhatoda vasica	-	-	-	-	-	-	-	-	100.00 ± 0.00	-	433.33 ± 133.33	-	-
Asparagus adscendens	-	-	-	100.00 ± 0.00	-	-	33.33 ± 0.00	-	-	-	-	-	-
Berberis lycium	200.00 ± 0.00	233.33 ± 88.19	233.33 ± 33.33	-	333.33 ± 120.19	-	266.67 ± 81.65	66.67 ± 0.00	566.67 ± 449.07	266.67 ± 0.00	-	200.00 ± 81.65	1333.33 ± 88.19
Carissa carandas	866.67 ± 384.42	266.67 ± 0.00	366.67 ± 122.47	166.67 ± 0.00	-	-	-	-	833.33 ± 40.82	-	433.33 ± 185.59	233.33 ± 33.33	233.33 ± 122.47
Hamiltonia suaveolens	-	-	-	-	-	-	333.33 ± 163.30	-	-	-	--		-
Hypericum oblongifolium	-	-	-	-	-	-	266.67 ± 81.65	-	-	-	-	-	-
Indigofera pulchella	-	-	-	600.00 ± 173.21	66.67 ± 0.00	766.67 ± 260.34	-	-	-	-	-	-	-
Lantana camara	133.33 ± 0.00	-	100.00 ± 40.82	-	-	-	-	-	200.00 ± 57.74	-	-	-	-
Leptodermis lanceolata	-	-	-	-	-	100.00 ± 0.00	-	-	-	-	-	-	-
Meriandra strobilifera	366.67 ± 33.33	-	166.67 ± 0.00	200.00 ± 81.65	-	-	-	133.33 ± 0.00	166.67 ± 40.82	133.33 ± 81.65	133.33 ± 0.00	-	-
Mimosa rubicaulis	-	-	-	-	-	-	366.67 ± 66.67	-	-	-	-	-	-
Myrsine africana	-	466.67 ± 166.67	733.33 ± 202.76	-	1366.67 ± 88.19	-	-	433.33 ± 0.00	-	766.67 ± 133.33	-	1400.00 ± 57.74	-
Osyris arborea	-	-	-	-	-	-	200.00 ± 81.65	-	-	-	-	-	-
Prinsepia utilis	-	-	-	33.33 ± 0.00	-	-	-	-	-	-	66.67 ± 0.00	-	-
Prunus ceracoides	-	-	-	-	-	-	-	-	-	-	-	-	-
Rabdosia rugosa	-	-	-	-	-	366.67 ± 204.12	233.33 ± 66.67	-	-	-	266.67 ± 81.65	-	400.00 ± 57.74
Randia tetrasperma	-	-	133.33 ± 0.00	-	-	-	466.67 ± 145.30	500.00 ± 449.07	-	233.33 ± 122.47	-	-	-
Rosa moschata	-	-	33.33 ± 0.00	-	-	-	-	-	-	-	-	-	-
Rubus ellipticus	133.33 ± 0.00	333.33 ± 33.33	-	133.33 ± 0.00	166.67 ± 40.82	-	-	433.33 ± 0.00	-	200.00 ± 81.65	133.33 ± 81.65	166.67 ± 40.82	433.33 ± 33.33
Woodfordia fruticosa	233.33 ± 122.47	-	66.67 ± 0.00	566.67 ± 120.19	-	366.67 ± 204.12	-	-	-	-	-	-	-
Zanthoxylem alatum	-	-	-	-	33.33 ± 0.00	-	-	-	-	133.33 ± 0.00	-	-	-
Total	**1933.33**	**1533.33**	**1833.33**	**1800.00**	**1966.67**	**1600.00**	**2166.67**	**1566.67**	**1866.67**	**1733.33**	**1466.67**	**2000.00**	**1900.00**

Table 35. Density (plants ha^{-1}) of shrub species in silvipasture at elevation E_3 (900-1300m) of Giri catchment of HP

Plant Species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
DENSITY OF SHRUBS													
Berberis lycium	300.00 ± 204.12	1200.00 ± 57.74	100.00 ± 0.00	1400.00 ± 100.00	233.33 ± 40.82	366.67 ± 120.19	1300.00 ± 57.74	1033.33 ± 122.47	1266.67 ± 33.33	233.33 ± 40.82	366.67 ± 66.67	500.00 ± 367.42	400.00 ± 163.30
Carissa carandas	-	-	1433.33 ± 133.33	200.00 ± 0.00	-	-	-	-	-	-	-	-	-
Indigofera pulchella	-	-	-	-	-	-	200.00 ± 81.65	-	-	-	-	-	733.33 ± 484.19
Inula cuspidata	-	-	-	-	-	200.00 ± 81.65	-	-	-	-	-	-	-
Leptodermis lanceolata	-	-	-	-	-	-	100.00 ± 0.00	-	-	-	-	-	-
Meriandra strobilifera	533.33 ± 326.60	-	233.33 ± 40.82	300.00 ± 40.82	566.67 ± 120.19	-	-	-	-	133.33 ± 0.00	833.33 ± 317.98	-	-
Myrsine africana	-	200.00 ± 81.65	-	266.67 ± 81.65	-	400.00 ± 81.65	233.33 ± 0.00	700.00 ± 204.12	-	-	-	-	-
Prinsepia utilis	100.00 ± 0.00	-	-	-	-	-	-	-	133.33 ± 0.00	-	200.00 ± 81.65	33.33 ± 0.00	-
Prunus ceracoides	-	-	-	-	-	--	-	-	-	-	-	-	33.33 ± 0.00
Rabdosia rugosa	600.00 ± 200.00	-	466.67 ± 33.33	233.33 ± 40.82	400.00 ± 152.75	666.67 ± 133.33	166.67 ± 40.82	233.33 ± 0.00	233.33 ± 40.82	400.00 ± 57.74	-	266.67 ± 0.00	-
Randia tetrasperma	-	366.67 ± 88.19	-	-	-	-	-	-	266.67 ± 0.00	266.67 ± 81.65	200.00 ± 81.65	1533.33 ± 120.19	-
Rosa moschata	-	-	-	-	-	-	-	33.33 ± 0.00	-	-	-	-	-
Rubus ellipticus	166.67 ± 0.00	333.33 ± 88.19	33.33 ± 0.00	-	266.67 ± 0.00	100.00 ± 40.82	-	166.67 ± 40.82	66.67 ± 0.00	433.33 ± 33.33	-	200.00 ± 0.00	1533.33 ± 133.33
Woodfordia fruticosa	-	-	-	200.00 ± 81.65	-	66.67 ± 0.00	133.33 ± 0.00	-	-	-	-	-	-
Zanthoxylem alatum	133.33 ± 0.00	-	-	-	-	-	-	-	-	-	-	-	-
Total	**1833.33**	**2100.00**	**2266.67**	**2600.00**	**1533.33**	**1800.00**	**2133.33**	**2166.67**	**1966.67**	**1666.67**	**1600.00**	**2533.33**	**2366.67**

Table 36. Variation in density (Plants ha^{-1}) of shrubs in silvipastures of different elevations in sub-watersheds of Giri catchment of HP

Elevation (E)	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Density													
E_1 (900-1300 m)	1633.33	2166.67	2466.67	2200.00	1900.00	2200.00	1933.33	1733.33	1766.67	1733.33	2233.33	1666.67	2166.67
E_2 (1301-1700 m)	1933.33	1533.33	1833.33	1800.00	1966.67	1600.00	2166.67	1566.67	1866.67	1733.33	1466.67	2000.00	1900.00
E_3 (1701-2100 m)	1833.33	2100.00	2266.67	2600.00	1533.33	1800.00	2133.33	2166.67	1966.67	1666.67	1600.00	2433.33	2366.67
Mean (SW)	1800.00	1933.33	2188.89	2200.00	1800.00	1866.67	2077.78	1822.22	1866.67	1711.11	1766.67	2033.33	2144.44

Factors	$CD_{0.05}$	SEm±
SW	NS	153.598
SW×E	NS	266.040

4.5.2 Grassland (Gr)

In grasslands at elevation E_1, total density of shrubs in different sub-watershed varied from 2133.33 m^2/ha (SW_3) to 4100.00 m^2/ha (SW_{12}). It was noted that among different species of shrubs, *Carrisa carandus* was the major contributor to the total density of shrubs with its contribution varied from 66.27 + 0.001 (SW_{10}) to 2566.67 + 120.19 (SW_{13}) followed by *Myrsine africana*, *Rubus elliplicus* and *Berberis lycium* with their contributions ranging from 266.67 $\pm$ 0.001 (SW_4) to 3133.33 $\pm$ 66.67 (SW_{12}), 33.33 $\pm$ 0.001 (SW_{12}) to 2033.33 $\pm$ 120.19 (SW_{10}) and 66.67 $\pm$ 0.00 $\pm$ 1933.33 $\pm$ 317.98 (SW_9) respectively (Table 37). It was also recorded that *Mimosa rubicaulis*, *Lantana camara* and *Asparagus adscendens* also contributed noticeably to the total density of shrubs.

Further, in grasslands, at elevation E_2 in different watersheds the total density of shrubs varied from 1733.33 m^2/ha (SW_1) and 3700.00 m^2/ha (SW_4). It was also reported that among shrubs species *Rubus ellipticus* and *Berberis lycium* were the prominent contributors to the total density with their contributions ranging from 66.67 + 00 m^2/ha (SW_3) to 1566.67 + 120.19 m^2/ha (SW_{12}) and 133.33 + 81.65 m^2/ha (SW_7) to 1333.33 + 88.19 m^2/ha (SW_{12}). It was noted that *Randia tetrasperma*, *Myrisine africana* and *Carrisa caramelus* also contributed noticeably to the total density of shrubs (Table 38).

At elevation E_3, (Table 39) total density of shrubs in grasslands in different sub-watersheds varied between 1633.33 m^2/ha (SW_3 and SW_7) to 3133.33 m^2/ha (SW_{12}). It was recorded that among shrubs *Berberis lycium* were the significant contributors to the total density with its contribution varying from 66.67 $\pm$ 0.001 m^2/ha (SW_1) to 1400.00 $\pm$ 00 (SW_{13}) followed by *Meriandra strobilifera* and *Rabdosia rugosa* with their contributions varied from 266.67 $\pm$ 81.65 m^2/ha (SW_4) to 1000.00 $\pm$ 152.75 (SW_{11}) and 200.00 $\pm$ 81.65 m^2/ha to 700.00 $\pm$ 264.58 m^2/ha (SW_{10}).

The data presented in Table 40 revealed that highest mean density (3388.89 plants ha^{-1}) of shrubs was recorde in SW_{12} which was significantly higher than all othe sub-watersheds. Minimum mean density was recorded in SW_1 and SW_2 (2122.22 plant ha^{-1}). The interaction effect of between sub-watershed and elevations on density of shrubs was found to be non-significant.

Table 37. Density (plants ha^{-1}) of shrub species in grasslands at elevation E_1 (900-1300m) of Giri catchment of HP

Plant Species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
	DENSITY OF SHRUBS												
Adhatoda vasica	-	-	-	-	133.33± 0.00	-	-	-	-	-	-	-	-
Aechmanthera gossypina	-	-	-	266.67± 0.00	-	-	-	-	-	-	-	-	-
Asparagus adscendens	-	-	-	1200.00±351.19	-	33.33 ± 0.00	1100.00± 450.92	566.67± 145.30	233.33± 33.33	-	-	-	-
Berberis lycium	866.67 ± 333.33	233.33 ± 33.33	-	700.00± 40.82	100.00± 40.82	300.00± 0.00	333.33± 66.67	400.00± 163.30	1933.33±317.98	66.67± 0.00	466.67± 88.19	-	-
Carissa carandas	1400.00± 571.55	1566.67±120.19	600.00±152.75	-	1133.33± 244.95	800.00± 115.47	400.00± 326.60	-	133.33± 81.65	-	-	133.33± 0.00	2566.67± 120.19
Caryopteris wallichiana	-	-	-	-	-	-	-	-	-	-	-	33.33 ± 0.00	-
Colebrookea oppositifolia	-	-	-	-	-	-	-	-	-	-	-	500.00± 57.74	566.67± 33.33
Elaeagnus umbellata	-	-	66.67 ± 0.00	-	-	-	-	-	-	-	-	-	-
Hamiltonia suaveolens	-	-	-	-	-	-	-	433.33± 367.42	-	-	-	-	-
Indigofera pulchella	-	-	-	666.67± 240.37	-	166.67± 0.00	-	-	366.67± 33.33	-	-	-	-
Inula cuspidata	-	-	-	-	-	-	-	-	-	-	-	-	-
Lantana camara	233.33 ± 66.67	166.67 ± 40.82	466.67 ± 33.33	-	66.67± 0.00	-	-	-	-	-	-	100.00± 0.00	66.67± 0.00
Meriandra strobilifera	66.67 ± 0.00	-	-	100.00± 0.00	166.67± 40.82	-	266.67± 163.30		-	433.33± 66.67	-	-	-
Mimosa rubicaulis	-	-	-	-	-	533.33± 88.19	266.67± 0.00	-	-	-	-	-	-
Myrsine africana	-	533.33 ± 33.33	866.67± 66.67	266.67± 0.00	433.33± 0.00	1366.67± 338.30	533.33 ± 163.30	1033.33± 88.19	-	-	2733.33± 120.19	3133.33± 66.67	266.67± 0.00
Osyris arborea	-	-	-	-	-	-	33.33 ± 0.00	166.67± 40.82	-	-	-	-	-
Prunus ceracoides	-	-	100.00 ± 0.00	100.00± 0.00	-	133.33± 81.65	333.33± 88.19	-	233.33± 40.82	-	233.33± 33.33	166.67 ± 40.82	66.67± 0.00
Rabdosia rugosa	-	-	66.67 ± 0.00	-	233.33± 133.33	-	33.33 ± 0.00	-	-	66.67 ± 0.00	-	-	-
Randia tetrasperma	-	-	-	-	-	300.00± 0.00	266.67± 33.33	1366.67± 88.19	-	-	-	-	-
Rosa moschata	-	-	-	-	-	-	-	100.00± 0.00	-	-	-	-	-
Rubus ellipticus	133.33 ± 81.65	166.67 ± 40.82	133.33 ± 0.00	133.33± 0.00	-	-	233.33± 40.82	533.33± 326.60	333.33± 66.67	2033.33± 120.19	166.67± 40.82	33.33 ± 0.00	200.00± 81.65
Smilex aspera	-	-	-	-	-	-	-	366.67± 0.00	-	-	-	-	-
Woodfordia fruticosa	-	-	-	-	66.67 ± 0.00	-	-	-	-	333.33± 33.33	-	-	-
Total	**2433.33**	**2666.67**	**2133.33**	**3433.33**	**2333.33**	**3633.33**	**3800.00**	**3255.56**	**3233.33**	**2933.33**	**3600.00**	**4100.00**	**3466.67**

Table 38 Density (plants ha^{-1}) of shrub species in grasslands at elevation E_2 (1301 -1700 m) of Giri catchment of HP

Plant Species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
DENSITY OF SHRUBS													
Adhatoda vasica	-	-	-	-	-	-	-	-	266.67 ± 81.65	-	-	-	-
Aechmanthera gossypina	-	-	-	-	133.33 ± 0.00	-	-	-	-	-	-	-	-
Asparagus adscendens	-	-	-	100.00 ± 40.82	-	-	33.33 ± 0.00	100.00 ± 0.00	-	-	-	-	-
Berberis lycium	166.67 ± 33.33	300.00 ± 57.74	500.00 ± 173.21	-	166.67 ± 40.82	-	566.67 ± 120.19	133.33 ± 81.65	166.67 ± 122.47	333.33 ± 66.67	233.33 ± 0.00	-	1333.33 ± 88.19
Carissa carandas	1033.33 ± 202.76	400.00 ± 163.30	700.00 ± 152.75	66.67 ± 0.00	-	-	-	-	1433.33 ± 33.33	-	666.67 ± 163.30	600.00 ± 100.00	233.33 ± 0.00
Caryopteris wallichiana	-	-	-	100.00 ± 0.00	133.33 ± 0.00	-	-	-	-	-	-	-	-
Colebrookea oppositifolia	-	-	-	-	-	-	-	-	-	-	133.33 ± 0.00	-	-
Elaeagnus umbellata	-	-	33.33 ± 0.00	-	133.33 ± 0.00	-	-	-	-	-	-	-	-
Hamiltonia suaveolens	-	-	-	-	-	-	266.67 ± 0.00	333.33 ± 88.19	-	-	-	-	-
Hypericum oblongifolium	-	-	-	-	-	-	200.00 ± 0.00	-	-	-	-	-	-
Indigofera pulchella	-	-	-	1333.33 ± 417.67	66.67 ± 0.00	833.33 ± 120.19	-	-	-	-	-	-	-
Lantana camara	100.00 ± 40.82	-	133.33 ± 0.00	-	-		-	-	233.33 ± 33.33	-	-	-	-
Leptodermis lanceolata	-	-	233.33 ± 88.19	-	-	500.00 ± 152.75	-	-	-	-	-	-	-
Meriandra strobilifera	-	-	-	266.67 ± 163.30	-	166.67 ± 40.82	-	266.67 ± 0.00	333.33 ± 66.67	133.33 ± 0.00	400.00 ± 57.74	-	-
Mimosa rubicaulis	-	-	-	-	-	100.00 ± 40.82	-	-	-	-	-	-	-
Myrsine africana	-	1500.00 ± 208.17	1133.33 ± 66.67	1233.33 ± 33.33	666.67 ± 66.67	-	1233.33 ± 284.80	233.33 ± 0.00	-	-	-	700.00 ± 208.17	-
Osyris arborea	-	-	-	-	-	-	33.33 ± 0.00	-	-	-	-	-	-
Prinsepia utilis	-	-	-	100.00 ± 40.82	-	-	-	-	-	-	66.67 ± 0.00	-	-
Prunus ceracoides	-	-	133.33 ± 0.00	-	-	-	-	-	-	-	-	-	-
Rabdosia rugosa	33.33 ± 0.00	-	-	-	-	300.00 ± 40.82	66.67 ± 0.00	-	-	900.00 ± 152.75	733.33 ± 145.30	-	633.33 ± 166.67
Randia tetrasperma	-	-	366.67 ± 204.12	-	-	66.67 ± 0.00	400.00 ± 81.65	533.33 ± 326.60	-	600.00 ± 152.75	-	-	-
Rosa moschata	-	-	33.33 ± 0.00	-	-	-	33.33 ± 0.00	-	-	-	-	-	-
Rubus ellipticus	400.00 ± 200.00	666.67 ± 176.38	66.67 ± 0.00	733.33 ± 145.30	100.00 ± 0.00	-	333.33 ± 0.00	1000.00 ± 244.95	-	1166.67 ± 166.67	100.00 ± 0.00	1566.67 ± 120.19	233.33 ± 40.82
Smilex aspera	-	-	-	-	-	-	-	133.33 ± 0.00	-	-	-	-	-
Woodfordia fruticosa	-	-	-	233.33 ± 0.00	-	800.00 ± 208.17	-	-	-	-	-	-	-
Zanthoxylem alatum	-	-	-	33.33 ± 0.00	66.67 ± 0.00	-	100.00 ± 40.82	-	-	1.00 ± 0.00	-	66.67 ± 0.00	-
Total	**1733.33**	**2866.67**	**3333.33**	**3700.00**	**1833.33**	**2766.67**	**3266.67**	**2733.33**	**2433.33**	**3134.33**	**2333.33**	**2933.33**	**2433.33**

Table 39. Density (plants ha^{-1}) of shrub species in grasslands at elevation E_3 (1701-2100 m) of Giri catchment of HP

Plant Species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
	DENSITY OF SHRUBS												
Berberis lycium	66.67 ± 0.00	500.00 ± 57.74	100.00 ± 40.82	133.33 ± 81.65	833.33 ± 272.85	400.00 ± 230.94	300.00 ± 152.75	700.00 ± 100.00	200.00 ± 115.47	400.00 ± 115.47	1300.00 ± 100.00	1200.00 ± 57.74	1400.00 ± 0.00
Carissa carandas	-	-	466.67 ± 120.19	266.67 ± 81.65	-	-	0.00 ± 212.13	-	-	-	-	-	-
Hamiltonia suaveolens	-	-	66.67 ± 0.00	-	-	-	-	-	200.00 ± 0.00	-	-	-	-
Hypericum oblongifolium	-	-	-	-	-	200.00 ± 212.13	-	-	-	-	-	-	-
Indigofera pulchella	-	-	-	-	-	-	500.00 ± 251.66	-	-	-	-	-	200.00 ± 212.13
Leptodermis lanceolata	-	-	-	-	-	-	300.00 ± 0.00	-	-	200.00 ± 0.00	-	-	-
Meriandra strobilifera	600.00 ± 251.66	-	433.33 ± 88.19	266.67 ± 81.65	633.33 ± 284.80	-	-	-	-	-	1000.00 ± 152.75	-	-
Myrsine africana	-	100.00 ± 0.00	66.67 ± 0.00	633.33 ± 88.19		400.00 ± 565.69	-	-	-	-	-	-	-
Prinsepia utilis	233.33 ± 133.33	-	-	-	-	100.00 ± 212.13	-	-	-	-	200.00 ± 212.13	-	-
Rabdosia rugosa	600.00 ± 163.30	-	200.00 ± 81.65	466.67 ± 244.95	300.00 ± 40.82	500.00 ± 636.40	-	0.00 ± 424.26	500.00 ± 360.56	700.00 ± 264.58	-	500.00 ± 57.74	300.00 ± 100.00
Randia tetrasperma	-	933.33 ± 66.67	-	133.33 ± 0.00	-	-	-	-	600.00 ± 200.00	300.00 ± 264.58	300.00 ± 0.00	900.00 ± 152.75	-
Rosa moschata	-	-	-	66.67 ± 0.00	-	100.00 ± 0.00	-	100.00 ± 0.00	-	-	-	-	-
Rubus ellipticus	633.33 ± 120.19	366.67 ± 33.33	-	66.67 ± 0.00	500.00 ± 204.12	200.00 ± 282.84	-	1200.00 ± 665.83	200.00 ± 57.74	1000.00 ± 288.68	-	0.00 ± 141.42	400.00 ± 57.74
Woodfordia fruticosa	-	-	-	-	-	0.00 ± 70.71	200.00 ± 0.00	-	-	-	-	-	-
Zanthoxylem alatum	266.67 ± 244.95	-	66.67 ± 0.00	66.67 ± 0.00	-	-	-	-	-	-	-	-	-
Total	**2333.33**	**1900.00**	**1633.33**	**2100.00**	**2266.67**	**2733.33**	**1633.33**	**3066.67**	**1833.33**	**2833.33**	**2666.67**	**3133.33**	**2466.67**

Table 40. Variation in density (Plants ha^{-1}) of shrubs in grasslands of different sub-watersheds of Giri catchment

Elevation (E)	SUB-WATERSHED													
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	**SW_7**	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**	**Mean**
	Density													
E_1 (900-1300 m)	2433.33	2666.67	2133.33	3433.33	2333.33	3633.33	3800.00	3533.33	3233.33	2933.33	3600.00	4100.00	3466.67	3176.92
E_2 (1301-1700 m)	1600.00	2866.67	3233.33	3700.00	1833.33	2766.67	3266.67	2733.33	2433.33	3134.33	2333.33	2933.33	2433.33	2712.90
E_3 (1701-2100 m)	2333.33	1900.00	1633.33	2166.67	2200.00	2733.33	1633.33	3066.67	1833.33	2833.33	2666.67	3133.33	2400.00	2348.72
Mean (SW)	2122.22	2477.78	2333.33	3100.00	2122.22	3044.44	2900.00	3111.11	2500.00	2967.00	2866.67	3388.89	2766.67	

Factors	**$CD_{0.05}$**	**SEm±**
SW	774.41	274.396
SW×E	NS	475.268

4.5.3 Silvipasture

4.5.3.1 Basal area (m^2/ha) in shrub

In silvipasture system, at elevation E_1. It was noted that the total basal area (m^2/ha) of shrubs in the different watersheds varied from 0.08 (SW_8) to 0.49 (SW_1). Among all the species recorded in the different sub-watersheds higher contribution was recorded from *Carissa carandus* 0.01 $\pm$ 000 it 0.14 + 0.01 m^2/ha followed by *Rubus ellipticus* 0.01 $\pm$ 0.00 to 0.04 $\pm$ 0.01 m^2/ha and *Lantana camara* 0.01 $\pm$ 0.01 to 0.12 $\pm$ 0.02 m^2/ha (Table 41).

Further, basal area of shrubs in the silvipasture at elevation E_2 revealed that the total basal area of shrubs varied from 0.11 m^2/ha (SW_5) to 0.68 m^2/ha (SW_6). *Berberis lycium*, *Meriandra strobilifera* and *Rubus ellipticus* were the major contributors among the different species with their contribution to the shrubs basal area ranging from 0.01 $\pm$ 0.00 m^2/ha, to 0.06 $\pm$ 0.02 m^2/ha, 0.02 $\pm$ 0.01 m^2/ha to 0.16 $\pm$ 0.02 m^2/ha and 0.01 $\pm$ 0.001 m^2/ha to 0.02 $\pm$ 0.01 m^2/ha (Table 42).

Similarly in the grasslands of different sub-watersheds at elevation E_3, basal area of shrubs varied from 0.20 m^2/ha (SW_2) to 0.79 m^2/ha (SW_9). Among different species *Berberis lycium* was the highest contributors to the total basal area of shrubs with its contribution ranging from 0.01 $\pm$ 0.004 to 0.67 $\pm$ 0.02 m^2/ha followed by *Rabdosia regusa* and *Meriandra strobilifera* were other contributors with their contribution varied from 0.01 $\pm$ 0.004 m^2/ha to 0.04 $\pm$ 0.01 m^2/ha and 0.03 + 0.00 m^2/ha to 0.27 $\pm$ 0.14 m^2/ha (Table 43).

A perusal of data in Table 44 revealed that the mean maximum basal area (0.65 m^2 ha^{-1}) was recorded in SW_4 which was statistically at par with SW_9 and SW_6 (0.46 m^2 ha^{-1}), (0.49m^2 ha^{-1}) respectively. The interaction between sub-watersheds and elevations on basal area of shrubs was found to be non-significant.

4.5.4 Grasslands

4.5.4.1 Basal area of shrubs (m^2/ha)

In grasslands, at elevation E_1, it was observed that the basal area (m^2/ha) of shrubs in the sub-watersheds ranged from 0.11 m^2/ha (SW_{10}) to 1.36 m^2/ha (SW_5). It was noted that among different shrubs species, *Myrsine africana*, *Rubus ellipticus*, *Berberis lycium* and *Carissa carandus* were the major contributors to total basal area of shrubs in different sub-watersheds varied from 0.01 $\pm$ 0.00 m^2/ha to 0.39 $\pm$ 0.01 m^2/ha, 0.01 $\pm$ 0.00 m^2/ha to 0.02 $\pm$ 0.02 m^2/ha, 0.01 $\pm$ 0.00 m^2/ha to 0.23 $\pm$ 0.02 m^2/ha and 0.01 $\pm$ 0.00 m^2 to 0.33 m^2/ha (Table 45).

Table 41 Basal area (m^2/ha) of shrub species in silvipasture at elevation E_1 (900-1300m) of Giri catchment of HP

Plant Species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
BASAL AREA OF SHRUBS													
Adhatoda vasica	-	-	-	-	0.01 ± 0.00	-	-	-	-	-	-	0.19 ± 0.06	-
Asparagus adscendens	-	-	-	0.01 ± 0.00	-	0.01 ± 0.00	-	0.01 ± 0.00	-	-	-	-	-
Berberis lycium	0.01 ± 0.00	0.05 ± 0.00	-	0.23 ± 0.08	-	-	-	0.01 ± 0.00	-	0.02 ± 0.00	0.03 ± 0.02	-	0.18 ± 0.04
Carissa carandas	0.13 ± 0.05	0.03 ± 0.00	0.02 ± 0.01	0.01 ± 0.00	0.05 ± 0.03	0.03 ± 0.00	0.01 ± 0.00	-	0.05 ± 0.00	-	0.14 ± 0.01	0.01 ± 0.00	-
Colebrookea oppositifolia	-	-	-	-	-	-	-	-	-	-	-	-	0.03 ± 0.00
Hypericum oblongifolium	-	-	-	0.06 ± 0.01	-	-	-	-	-	-	-	-	-
Indigofera pulchella	-	-	-	-	-	-	-	-	0.08 ± 0.00	-	-	-	-
Inula cuspidata	-	-	-	-	-	-	-	-	-	-	-	-	-
Lantana camara	0.01 ± 0.00	0.07 ± 0.03	0.12 ± 0.02	0.03 ± 0.00	-	-	-	-	0.04 ± 0.00	-	-	-	0.04 ± 0.03
Leptodermis lanceolata	-	-	-	-	-	-	-	-	-	-	-	-	-
Meriandra strobilifera	0.09 ± 0.00	-	-	0.03 ± 0.01	0.12 ± 0.03	-	0.04 ± 0.02	-	-	0.03 ± 0.02	-	0.01 ± 0.00	-
Mimosa rubicaulis	-	-	-	-	-	0.02 ± 0.00	-	-	-	-	-	-	-
Myrsine africana	-	0.02 ± 0.01	0.04 ± 0.00	-	0.01 ± 0.00	0.10 ± 0.02	-	0.02 ± 0.00	-	0.06 ± 0.01	0.04 ± 0.01	0.09 ± 0.01	-
Prinsepia utilis	-	-	-	-	-	-	0.01 ± 0.00	-	-	-	-	-	-
Prunus ceracoides	-	-	-	-	-	-	0.02 ± 0.00	-	-	-	0.01 ± 0.00	-	-
Rabdosia rugosa	-	-	-	0.06 ± 0.02	-	-	0.01 ± 0.01	-	-	-	-	-	-
Randia tetrasperma	-	-	-	-	0.01 ± 0.00	0.04 ± 0.00	0.06 ± 0.03	0.04 ± 0.01	-	0.03 ± 0.01	-	-	-
Rubus ellipticus	0.01 ± 0.00	0.02 ± 0.01	0.04 ± 0.01	-	-	-	-	-	-	0.02 ± 0.01	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00
Smilex aspera	-	-	-	-	-	-	-	-	-	-	-	-	-
Woodfordia fruticosa	-	-	-	0.04 ± 0.02	0.10 ± 0.00	-	-	-	-	-	-	-	-
Zanthoxylem alatum	-	-	-	-	-	-	-	-	-	0.01 ± 0.00	0.01 ± 0.00	-	-
Total	**0.49**	**0.18**	**0.19**	**0.47**	**0.29**	**0.21**	**0.15**	**0.08**	**0.18**	**0.17**	**0.23**	**0.32**	**0.27**

Table 42. Basal area (m^2/ha) of shrub species in silvipasture at elevation E_2 (1303-1700 m) of Giri catchment of HP

Plant Species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
BASAL AREA OF SHRUBS													
Adhatoda vasica	-	-	-	-	-	-	-	-	0.01 ± 0.00	-	0.52 ± 0.44	-	-
Asparagus adscendens	-	-	-	0.01 ± 0.00	-	-	-	-	-	-	-	-	-
Berberis lycium	0.01 ± 0.00	0.03 ± 0.01	0.02 ± 0.00	-	0.011±0.00	-	0.05 ± 0.01	0.02 ± 0.00	0.03 ± 0.02	0.02 ± 0.00	-	0.01 ± 0.00	0.06 ± 0.02
Carissa carandas	0.07 ± 0.03	0.05 ± 0.00	0.10 ± 0.05	0.01 ± 0.00	-	-	-	-	0.28 ± 0.01	-	0.06 ± 0.03	0.02 ± 0.00	0.04 ± 0.02
Hamiltonia suaveolens	-	-	-	-	-	-	0.08 ± 0.05	-	-	-	-	-	-
Indigofera pulchella	-	-	-	0.26 ± 0.06	0.002±0.00	0.43 ± 0.12	-	-	-	-	-	-	-
Lantana camara	0.04 ± 0.01	-	0.02 ± 0.02	-	-	-	-	-	0.05 ± 0.01	-	-	-	
Leptodermis lanceolata	-	-		-	-	0.01 ± 0.00	-		-	-	-	-	-
Meriandra strobilifera	0.16 ± 0.02	-	0.07 ± 0.00	0.02 ± 0.01	-	-		0.06 ± 0.00	0.07 ± 0.02	0.03 ± 0.02	0.02 ± 0.00	-	-
Mimosa rubicaulis	-	-	-	-	-	-	0.06 ± 0.01	-	-	-	-	-	-
Myrsine africana	-	0.14 ± 0.08	0.13 ± 0.04	-	0.092±0.00	-	-	-	-	0.06 ± 0.01	-	0.12 ± 0.00	-
Osyris arborea	-	-	-	-	-	-	0.03 ± 0.01	-	-	-	-	-	-
Prinsepia utilis	-	-	-	-	-	-	-	-	-	-	0.04 ± 0.00	-	-
Rabdosia rugosa	-	-	-	-	-	0.06 ± 0.03	0.02 ± 0.01	-	-	-	0.02 ± 0.01	-	0.05 ± 0.01
Randia tetrasperma	-	-	0.03 ± 0.00	-	-	-	0.13 ± 0.05	0.03 ± 0.00	-	0.03 ± 0.01	-	-	-
Rubus ellipticus	0.01 ± 0.00	0.02 ± 0.00	-	0.01 ± 0.00	0.003±0.00	-	-	0.01 ± 0.00	-	0.02 ± 0.01	0.01 ± 0.00	0.02 ± 0.01	0.02 ± 0.00
Woodfordia fruticosa	0.03 ± 0.01	-	0.03 ± 0.00	0.43 ± 0.16	-	0.18 ± 0.00	-	-	-	-	-	-	-
Zanthoxylem alatum	-	-	-	-	0.002±0.00	-	-	-	-	0.01 ± 0.00	-	-	-
Total	**0.31**	**0.21**	**0.40**	**0.74**	**0.11**	**0.68**	**0.37**	**0.12**	**0.43**	**0.17**	**0.67**	**0.17**	**0.18**

Table 43. Basal area (m^2 ha^{-1}) of shrub species in silvipasture at elevation E_3 (1701-2100 m) of Giri catchment of HP

Plant Species	**SUB-WATERSHED**												
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	**SW_7**	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**
BASAL AREA OF SHRUBS													
Berberis lycium	0.01 ± 0.004	0.07 ± 0.01	0.02 ± 0.00	0.39 ± 0.06	0.02 ± 0.00	0.15 ± 0.07	0.37 ± 0.11	0.64 ± 0.76	0.67 ± 0.02	0.02 ± 0.03	0.01 ± 0.00	0.03 ± 0.02	0.35 ± 0.21
Carissa carandas	-	-	0.13 ± 0.01	0.02 ± 0.00	-	-	-	-	-	-	-	-	-
Indigofera pulchella	-	-	-	-	-	-	0.25 ± 0.10	-	-	-	-	-	0.06 ± 0.04
Inula cuspidata	-	-	-	-	-	0.05 ± 0.03	-	-	-	-	-	-	-
Leptodermis lanceolata	-	-	-	-	-	-	0.06 ± 0.00	-	-	-	-	-	-
Meriandra strobilifera	0.27 ± 0.14	-	0.16 ± 0.00	0.08 ± 0.02	0.31 ± 0.05	-	-	-	-	0.03 ± 0.00	0.31 ± 0.11	-	-
Myrsine africana	-	0.02 ± 0.01	-	0.03 ± 0.01	-	0.06 ± 0.00	0.01 ± 0.00	0.06 ± 0.04	-	-	-	-	-
Prinsepia utilis	0.03 ± 0.00	-	-	-	-	-	-	-	0.04 ± 0.00	-	0.05 ± 0.01	0.01 ± 0.00	-
Rabdosia rugosa	0.06 ± 0.02	-	0.04 ± 0.01	0.03 ± 0.01	0.11 ± 0.08	0.09 ± 0.03	0.01 ± 0.00	0.03 ± 0.00	0.02 ± 0.00	0.13 ± 0.02	-	0.02 ± 0.00	-
Randia tetrasperma	-	0.05 ± 0.01	-	-	-	-	-	-	0.05 ± 0.00	0.01 ± 0.01	0.02 ± 0.01	0.35 ± 0.03	-
Rubus ellipticus	0.02 ± 0.00	0.06 ± 0.04	-	-	0.03 ± 0.01	0.09 ± 0.00	-	0.08 ± 0.07	-	0.03 ± 0.03	-	0.02 ± 0.00	0.05 ± 0.01
Woodfordia fruticosa	-	-	-	0.20 ± 0.00	-	0.01 ± 0.00	0.03 ± 0.00	-	-	-	-	-	-
Zanthoxylem alatum	0.01 ± 0.00	-	-	-	-	-	-	-	-	-	-	-	-
Total	**0.39**	**0.20**	**0.36**	**0.75**	**0.61**	**0.45**	**0.72**	**0.82**	**0.79**	**0.28**	**0.39**	**0.42**	**0.41**

Table 44. Variation in basal area (m^2 ha^{-1}) of shrubs in different sub-watersheds of Giri catchment

Elevation (E)	**SUB-WATERSHED**													
	SW_1	**SW_2**	**SW_3**	**SW_4**	**SW_5**	**SW_6**	**SW_7**	**SW_8**	**SW_9**	**SW_{10}**	**SW_{11}**	**SW_{12}**	**SW_{13}**	**Mean**
Basal area														
E_1 (900-1300 m)	0.24	0.18	0.21	0.47	0.29	0.21	0.15	0.08	0.18	0.17	0.23	0.32	0.27	0.23
E_2 (1301-1700 m)	0.31	0.21	0.40	0.74	0.11	0.68	0.37	0.12	0.43	0.17	0.67	0.17	0.18	0.35
E_3 (1701-2100 m)	0.39	0.20	0.36	0.75	0.61	0.45	0.72	0.82	0.79	0.28	0.39	0.61	0.41	0.52
Mean (SW)	0.32	0.20	0.32	0.65	0.34	0.45	0.42	0.34	0.46	0.21	0.43	0.36	0.28	

Factors	**$CD_{0.05}$**	**SEm±**
SW	0.244	0.086
SW×E	NS	0.150

Table 45 . Basal area ($m^2\ ha^{-1}$) of shrub species in grasslands at elevation E1 (900-1300m) of Giri catchment of HP

Plant Species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
BASAL AREA OF SHRUBS													
Adhatoda vasica	-	-	-	-	0.06 ± 0.06	-	-	-	-	-	-	-	-
Aechmanthera gossypina	-	-	-	0.15 ± 0.00	-	-	-	-	-	-	-	-	-
Asparagus adscendens	-	-	-	0.07 ± 0.02	-	-	0.04 ± 0.01	0.04 ± 0.00	-	-	-	-	-
Berberis lycium	0.08 ± 0.07	0.01 ± 0.00	-	0.15 ± 0.07	0.02 ± 0.01	0.06 ± 0.04	0.01 ± 0.00	-	0.05 ± 0.01	-	0.23 ± 0.08	-	-
Carissa carandas	0.20 ± 0.08	0.21 ± 0.03	0.03 ± 0.01	-	0.98 ± 0.14	0.06 ± 0.03	0.02 ± 0.02	-	-	-	-	0.01 ± 0.00	0.33 ± 0.02
Caryopteris wallichiana	-	-	-	-	-	-	-	-	-	-	-	0.01 ± 0.00	-
Colebrookea oppositifolia	-	-	-	-	-	-	-	-	-	-	-	0.38 ± 0.05	0.13 ± 0.01
Hamiltonia suaveolens	-	-	-	-	-	-	-	0.03 ± 0.03	-	-	-	-	-
Indigofera pulchella	-	-	-	0.28 ± 0.14	-	0.01 ± 0.00	-	-	0.14 ± 0.02	-	-	-	-
Lantana camara	0.08 ± 0.04	0.06 ± 0.01	0.15 ± 0.07	-	0.01 ± 0.00	-	-	-	-	-	-	-	-
Meriandra strobilifera	0.03 ± 0.00	-	-	0.01 ± 0.00	0.12 ± 0.03	-	0.08 ± 0.02	-	-	0.06 ± 0.01	-	-	-
Mimosa rubicaulis	-	-	-	-	-	0.04 ± 0.01	0.06 ± 0.00	-	-	-	-	-	-
Myrsine africana	-	0.03 ± 0.00	0.02 ± 0.00	0.01 ± 0.00	0.04 ± 0.00	0.09 ± 0.03	0.01 ± 0.00	0.04 ± 0.00	-	-	0.39 ± 0.01	0.26 ± 0.01	0.01 ± 0.00
Osyris arborea	-	-	-	-	-	-	0.01 ± 0.00	-	-	-	-	-	-
Prunus ceracoides	-	-	-	0.01 ± 0.00	-	0.01 ± 0.01	0.04 ± 0.01	-	0.04 ± 0.01	-	0.02 ± 0.00	0.01 ± 0.00	-
Rabdosia rugosa	-	-	-	-	0.07 ± 0.05	-	-	-	-	-	-	-	-
Randia tetrasperma	-	-	-	-	-	0.03 ± 0.02	0.03 ± 0.00	0.35 ± 0.04	-	-	-	-	-
Rosa moschata	-	-	-	-	-	-	-	0.01 ± 0.00	-	-	-	-	-
Rubus ellipticus	0.01 ± 0.01	-	0.01 ± 0.00	0.01 ± 0.00	-	-	0.01 ± 0.00	0.02 ± 0.02	0.01 ± 0.00	0.02 ± 0.01	0.01 ± 0.00	-	0.01 ± 0.00
Smilex aspera	-	-	-	-	-	-	-	0.02 ± 0.00	-	-	-	-	-
Woodfordia fruticosa	-	-	-	-	0.06 ± 0.00	-	-	-	-	0.03 ± 0.00	-	-	-
Total	**0.40**	**0.31**	**0.22**	**0.70**	**1.36**	**0.30**	**0.30**	**0.38**	**0.25**	**0.11**	**0.65**	**0.68**	**0.48**

The total basal area of shrubs in the grasslands of different sub-watersheds at elevation E_2, varied from 0.15 m^2/ha (SW_5) to 0.80 m^2/ha (SW_6). Among individual species in shrubs higher area contribution was recorded for *Carissa carandus* that varied from 0.04 + 0.00 m^2/ha to 0.52 $\pm$ 0.01 m^2/ha followed by *Rubus ellipticus* 0.01 $\pm$ 0.00 m^2/ha to 0.28 $\pm$ 0.10 m^2/ha and *Berberis lycium* 0.01 $\pm$ 0.00 m^2/ha to 0.15 $\pm$ 0.08 m^2/ha (Table 46).

Similarly, the total basal area of shrubs in grasslands at elevation E_3 of different sub-watersheds varied from 0.18 m^2/ha (SW_2) to 2.43 m^2/ha (SW_{11}). Among different species *Berberis lycuin*, *Robdosia rugosa* and *Rubus ellipticus* were the major contributors to total basal area and their contributions in different sub-watersheds varied from 0.04 $\pm$ 0.01 m^2/ha $\pm$ 0.80 $\pm$ 0.38 m^2/ha, 0.01 $\pm$ 0.00 m^2 ha to 0.25 m^2/ha and 0.01 $\pm$ 0.00 m^2/ha to 0.59 + 0.44 m^2/ha (Table 47).

It was recorded that the interaction effect between sub-watersheds and elevations on basal area of shrubs was found to be significant. Maximum basal area of shrubs was recorded in SW_7E_3 (1.87 m^{2} ha^{-1}), it was statistically at par with SW_5E_1 (1.36 m^2 ha^{-1}), $SW_{13}E_3$ (1.31 m^2 ha^{-1}), SW_8E_3 (1.13 m^2 ha^{-1}) and SW_6E_3 (1.09 ma^2 ha^{-1}) but significantly higher than all other interactions. The effect of sub-watersheds on basal area was found to be non-siognificant (Table 48).

4.5.5 Silvipasture

4.5.5.1 IVI of shrub

The dominant species of shrubs in the silvipasture at elevation E_1 of different sub-watersheds was *Berberis lycium* with highest IVI value varied from 12.02 (SW_7) to 166.59 (SW_{13}) followed by *Carissa carandus* with IVI value of 13.90 (SW_4) to 145.56 (SW_{11}) and *Myrsine africana* 15.67 (SW_5) to 119.21 (SW_6) were the associate species (Table 49).

At elevation E_2, (Table 50) the dominant species of shrubs in different sub-watersheds was *Myrsine africana* with highest IVI value of 43.65 (Sw_8) to 183.15 (SW_5). The co-dominant species was *Carissa carandus* with IVI value of 18.65 (SW_4) to 128.84 (SW_9) and associate species was *Berberis lycium* with IVI value of 28.33 (SW_1) to 103.34 (SW_{13}).

Similarly, at elevation E_3, (Table 51) the dominant species of shrubs in different sub-watersheds was *Berberis lycium* with IVI value ranged 18.61 (SW_3) to 179.73 (SW_9). The co-dominant species was *Rabdosia rugosa* with IVI value of 27.42 (SW_8) to 112.01 (SW_{10}) and the associate species was *Rubus ellipticus* with IVI value of 12.03 (SW_3) to 110.16 (SW_{13}).

Table 46 . Basal area (m^2/ha) of shrub species in grasslands at elevation E2 (1301 – 1700 m) of Giri catchment of HP

Plant Species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
BASAL AREA OF SHRUBS													
Adhatoda vasica	-	-	-	-	-	-	-	-	0.01 ± 0.00	-	-	-	-
Aechmanthera gossypina	-	-	-	-	0.01 ± 0.00	-	-	-	-	-	-	-	-
Asparagus adscendens	-	-	-	0.01 ± 0.00	-	-	-	0.05 ± 0.00	-	-	-	-	-
Berberis lycium	0.01 ± 0.00	0.03 ± 0.01	0.05 ± 0.04	-	0.01 ± 0.00	-	0.05 ± 0.01	0.15 ± 0.08	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.00	-	0.06 ± 0.02
Carissa carandas	0.08 ± 0.01	0.05 ± 0.01	0.15 ± 0.03	-	-	-	-	-	0.52 ± 0.01	-	0.06 ± 0.02	0.05 ± 0.01	0.04 ± 0.00
Caryopteris wallichiana	-	-	-	0.02 ± 0.00	0.02 ± 0.00	-	-	-	-	-	-	-	-
Colebrookea oppositifolia	-	-	-	-	-	-	-	-	-	-	0.02 ± 0.00	-	-
Elaeagnus umbellata	-	-	-	-	0.01 ± 0.00	-	-	-	-	-	-	-	-
Hamiltonia suaveolens	-	-	-	-	-	-	0.07 ± 0.00	0.01 ± 0.00	-	-	-	-	-
Indigofera pulchella	-	-	-	0.48 ± 0.17	-	0.34 ± 0.05	-	-	-	-	-	-	-
Lantana camara	0.03 ± 0.00	-	0.02 ± 0.00	-	-	-	-	-	0.06 ± 0.01	-	-	-	-
Leptodermis lanceolata	-	-	0.08 ± 0.05	-	-	0.07 ± 0.02	-	-	-	-	-	-	-
Meriandra strobilifera	-	-	-	0.03 ± 0.02	-	0.06 ± 0.03	-	0.10 ± 0.00	0.14 ± 0.03	0.04 ± 0.00	0.07 ± 0.02	-	-
Mimosa rubicaulis	-	-	-	-	-	0.01 ± 0.00	-	-	-	-	-	-	-
Myrsine africana	-	0.21 ± 0.03	0.12 ± 0.06	0.08 ± 0.00	0.04 ± 0.00	-	0.15 ± 0.06	0.01 ± 0.00	-	-	-	0.06 ± 0.02	-
Osyris arborea	-	-	-	-	-	-	0.01 ± 0.00	-	-	-	-	-	-
Prinsepia utilis	-	-	-	0.01 ± 0.01	-	-	-	-	-	-	0.04 ± 0.00	-	-
Rabdosia rugosa	-	-	-	-	-	0.04 ± 0.01	0.01 ± 0.00	-	-	0.32 ± 0.05	0.06 ± 0.01	-	0.09 ± 0.02
Randia tetrasperma	-	-	0.08 ± 0.05	-	-	-	0.08 ± 0.02	0.06 ± 0.03	-	0.03 ± 0.01	-	-	-
Rosa moschata	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubus ellipticus	0.09 ± 0.06	0.03 ± 0.01	-	0.05 ± 0.01	0.03 ± 0.00	-	0.03 ± 0.00	0.03 ± 0.01	-	0.25 ± 0.04	0.01 ± 0.00	0.28 ± 0.10	0.01 ± 0.00
Woodfordia fruticosa	-	-	-	0.17 ± 0.00	-	0.28 ± 0.12	-	-	-	-	-	-	-
Zanthoxylem alatum	-	-	-	-	-	-	0.02 ± 0.00	-	-	-	-	0.01 ± 0.00	-
Total	**0.21**	**0.32**	**0.52**	**0.70**	**0.15**	**0.80**	**0.41**	**0.41**	**0.73**	**0.65**	**0.27**	**0.40**	**0.20**

Table 47. Basal area (m^2 ha^{-1}) of shrub species in grasslands at elevation E3 (1701-2100 m) of Giri catchment of HP

Plant Species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
BASAL AREA OF SHRUBS													
Berberis lycium	0.20 ± 0.00	0.03 ± 0.00	0.01 ± 0.01	0.03 ± 0.03	0.08 ± 0.04	0.21 ± 0.29	0.11 ± 0.05	0.80 ± 0.38	0.11 ± 0.04	0.01 ± 0.04	0.11 ± 0.03	0.07 ± 0.00	1.04 ± 0.16
Carissa carandas	-	-	0.05 ± 0.02	0.12 ± 0.12	-	-	0.00 ± 0.05	-	-	-	-	-	-
Hamiltonia suaveolens	-	-	-	-	-	-	-	-	0.06 ± 0.00	-	-	-	-
Hypericum oblongifolium	-	-	-	-	-	0.27 ± 0.29	-	-	-	-	-	-	-
Indigofera pulchella	-	-	-	-	-	-	1.00 ± 0.83	-	-	-	-	-	0.02 ± 0.02
Leptodermis lanceolata	-	-	-	-	-	-	0.15 ± 0.00	-	-	0.06 ± 0.01	-	-	-
Meriandra strobilifera	0.31 ± 0.13	-	0.31 ± 0.10	0.09 ± 0.07	0.17 ± 0.26	-	-	-	-	-	5.90 ± 3.17	-	-
Mimosa rubicaulis	-	-	-	-	-	-	-	0.00 ± 0.06	-	-	-	-	-
Myrsine africana	-	0.01 ± 0.00	-	0.10 ± 0.04	-	0.07 ± 0.05	-	-	-	-	-	-	-
Prinsepia utilis	0.10 ± 0.07	-	-	-	-	0.01 ± 0.01	-	-	-	-	0.03 ± 0.12	-	-
Rabdosia rugosa	0.06 ± 0.02	-	0.02 ± 0.01	0.06 ± 0.03	0.05 ± 0.01	0.06 ± 0.20	-	0.00 ± 0.11	0.05 ± 0.03	0.25 ± 0.09	-	0.02 ± 0.00	0.02 ± 0.01
Randia tetrasperma	-	0.12 ± 0.01	-	0.02 ± 0.00	-	-	-	-	0.11 ± 0.03	0.01 ± 0.01	0.03 ± 0.00	0.21 ± 0.02	-
Rosa moschata	-	-	-	-	-	0.02 ± 0.00	-	0.01 ± 0.00	-	-	-	-	-
Rubus ellipticus	0.07 ± 0.01	0.03 ± 0.01	-	0.01 ± 0.00	0.00 ± 0.06	0.09 ± 0.02	-	0.59 ± 0.44	0.01 ± 0.00	0.22 ± 0.06	-	0.00 ± 0.01	0.02 ± 0.01
Woodfordia fruticosa	-	-	-	-	-	0.00 ± 0.01	0.04 ± 0.00	-	-	-	-	-	-
Zanthoxylem alatum	0.02 ± 0.02	-	-	-	-	-	-	-	-	-	-	-	-
Total	**0.74**	**0.18**	**0.41**	**0.44**	**0.54**	**1.10**	**1.87**	**1.13**	**0.37**	**0.67**	**2.43**	**0.37**	**1.26**

Table 48. Variation in basal area (m^2 ha^{-1}) of shrubs in grassland of different sub-watersheds of Giri catchment

Elevation (E)	SUB-WATERSHED													
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}	Mean
	Basal area													
E_1 (900-1300 m)	0.40	0.31	0.21	0.70	1.36	0.30	0.30	0.38	0.25	0.11	0.65	0.68	0.44	0.47
E_2 (1301-1700 m)	0.20	0.32	0.56	0.70	0.15	0.81	0.41	0.41	0.73	0.65	0.27	0.41	0.20	0.45
E_3 (1701-2100 m)	0.74	0.18	0.41	0.45	0.42	1.09	1.87	1.13	0.37	0.67	2.43	0.37	1.31	0.88
Mean (SW)	0.45	0.27	0.40	0.62	0.64	0.73	0.86	0.64	0.45	0.48	1.12	0.49	0.65	

Factors	$CD_{0.05}$	SEm±
SW	NS	0.203
SW×E	0.990	0.351

Table 49. IVI of shrub species in silvipasture at elevation E_1 (900-1300 m) in Giri-catchment of HP

Plant species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Adhatoda vasica	-	-	-	-	35.46	-	-	-	-	-	-	95.17	-
Asparagus adscendens	-	-	-	14.81	-	17.23	-	57.07	-	-	-	-	-
Berberis lycium	47.16	107.15	-	83.19	14.13	-	12.02	80.37	31.65	44.22	36.86	-	166.59
Carissa carandas	109.38	46.79	42.17	13.90	63.39	50.71	19.81	-	129.33	-	145.56	19.47	-
Colebrookea oppositifolia	-	-	-	-	-	-	-	-	-	-	-	-	27.43
Hypericum oblongifolium	-	-	-	42.65	-	-	-	-	-	-	-	-	-
Indigofera pulchella	-	-	-	-	-	-	-	-	79.80	-	-	-	-
Lantana camara	29.74	67.13	90.27	18.37	-	-	-	-	40.56	-	-	-	44.72
Meriandra strobilifera	48.71	-	-	39.83	105.85	-	48.79	-	-	43.05	-	15.28	-
Mimosa rubicaulis	-	-	-	-	-	48.63	-	-	-	-	-	-	-
Myrsine africana	-	42.59	102.22	-	15.67	119.21	42.12	58.78	-	101.13	41.67	116.28	17.89
Osyris arborea	-	-	-	-	-	-	-	12.75	-	-	-	-	-
Prinsepia utilis	-	-	-	-	-	-	19.65	-	-	-	-	-	-
Prunus ceracoides	-	-	12.31	-	-	14.74	23.92	-	-	-	22.44	11.93	12.28
Rabdosia rugosa	-	-	-	44.10	-	-	25.71	-	-	-	-	-	-
Randia tetrasperma	-	-	-	-	17.47	49.48	75.18	91.03	-	44.06	-	-	-
Rubus ellipticus	15.00	36.34	62.15	-	-	-	22.76	-	18.66	36.94	29.19	41.87	31.09
Woodfordia fruticosa	-	-	-	43.17	48.04	-	-	-	-	-	-	-	-
Zanthoxylem alatum	5-	-	-	-	-	-	10.04	-	-	30.59	24.29	-	-

Table 50. IVI of shrub species in silvipasture at elevation E_2 (1301-1700 m) in Giri-catchment of HP

Plant species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Adhatoda vasica	-	-	-	-	-	-	-	-	17.46	-	132.17	-	-
Asparagus adscendens	-	-	-	14.70	-	-	7.54	-	-	-	-	-	-
Berberis lycium	28.33	66.76	36.69	-	57.38	-	35.85	39.04	56.42	44.22	-	33.00	103.34
Carissa carandas	89.88	57.25	57.88	18.65	-	-	-	-	128.84	-	64.08	54.31	52.83
Hamiltonia suaveolens	-	-	-	-	-	-	47.22	-	-	-	-	-	-
Hypericum oblongifolium	-	-	-	-	-	-	24.60	-	-	-	-	-	-
Indigofera pulchella	-	-	-	93.57	15.25	148.85	-	-	-	-	-	-	-
Lantana camara	34.56	-	23.20	-	-	-	-	-	52.22	-	-	-	-
Leptodermis lanceolata	-	-	-	-	-	20.03	-	-	-	-	-	-	-
Meriandra strobilifera	93.88	-	34.42	30.60	-	-	-	85.49	45.07	43.05	19.93	-	-
Mimosa rubicaulis	-	-	-	-	-	-	50.32	-	-	-	-	-	-
Myrsine africana	-	93.38	93.46	-	183.15	-	-	43.65	-	101.13	-	171.00	-
Osyris arborea	-	-	-	-	-	-	29.45	-	-	-	-	-	-
Prinsepia utilis	-	-	-	10.81	-	-	-	-	-	-	18.85	-	-
Rabdosia rugosa	-	-	-	-	-	57.24	32.83	-	-	-	37.92	-	83.98
Randia tetrasperma	-	-	28.27	-	-	-	72.19	84.23	-	44.06	-	-	-
Rosa moschata	-	-	8.68	-	-	-	-	-	-	-	-	-	-
Rubus ellipticus	17.09	82.61	-	17.55	31.09	-	-	47.58	-	36.94	27.05	41.69	59.85
Woodfordia fruticosa	36.26	-	17.41	114.12	-	73.88	-	-	-	-	-	-	-
Zanthoxylem alatum	-	-	-	-	13.14	-	-	-	-	30.59	-	-	-

Table 51. IVI of shrub species in silvipasture at elevation E_3 (1701-2100 m) in Giri-catchment of HP

Plant species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Berberis lycium	37.97	116.92	18.61	128.88	40.55	78.14	142.31	150.97	179.73	53.48	55.99	46.76	111.57
Carissa carandas	-	-	130.79	26.28	-	-	-	-	-	-	-	-	-
Indigofera pulchella	-	-	-	-	-	-	64.10	-	-	-	-	-	65.25
Inula cuspidata	-	-	-	-	-	39.58	-	-	-	-	-	-	-
Leptodermis lanceolata	-	-	-	-	-	-	22.54	-	-	-	-	-	-
Meriandra strobilifera	116.31	-	76.21	37.41	139.72	-	-	-	-	33.67	160.70	-	-
Myrsine africana	-	35.87	-	29.42	-	51.69	22.21	64.64	-	-	-	-	-
Prinsepia utilis	24.24	-	-	-	-	-	-	-	31.59	-	45.88	14.31	-
Prunus ceracoides	-	-	-	-	-	-	-	-	-	-	-	-	13.01
Rabdosia rugosa	77.68	-	62.36	28.09	76.64	82.42	29.07	27.42	34.93	112.01	-	34.47	-
Randia tetrasperma	-	71.90	-	-	-	-	-	-	39.89	37.95	37.43	172.94	-
Rosa moschata	-	-	-	-	-	-	-	14.36	-	-	-	-	-
Rubus ellipticus	24.08	75.31	12.03	-	43.09	42.18	-	42.61	13.87	62.88	-	31.52	110.16
Woodfordia fruticosa	-	-	-	49.92	-	5.99	19.76	-	-	-	-	-	-
Zanthoxylem alatum	19.72	-	-	-	-	-	-	-	-	-	-	-	-

4.5.6 Grasslands

4.5.6.1 IVI of shrubs

The dominant species of shrubs in the grasslands at elevation E_1 of different sub-watersheds was *Berberis lycium* with highest IVI value varied from 4.20 (SW_3) to 124.59 (SW_9) followed by *Carissa carandus* with IVI value of 3.20 (SW_4) to 85.09 (SW_5) and *Myrsine africana* 9.70 (SW_5) to 88.05 (SW_{11}) were the associate species (Table 52).

At elevation E_2, (Table 53) the dominant species of shrubs in different sub-watersheds was *Rubus ellipticus* with highest IVI value of 7.58 (SW_4) to 153.11 (SW_{12}). The co-dominant species was *Carissa carandus* with IVI value of 7.58 (SW_4) to 152.93 (SW_9) and associate species was *Berberis lycium* with IVI value of 23.30 (SW_9) to 119.51 (SW_{13}).

Similarly, at elevation E_3, (Table 54) the dominant species of shrubs in different sub-watersheds was *Berberis lycium* with IVI value ranged 25.15 (SW_3) to 179.73 (SW_{13}). The co-dominant species was *Meriandra strobilifera* with IVI value of 82.67 (SW_1) to 150.61 (SW_{11}) and the associate species was *Rubus ellipticus* with IVI value of 12.91 (SW_4) to 102.42 (SW_8).

4.6. BIOMASS PRODUCTION OF SYSTEMS (t ha^{-1})

4.6.1. Aboveground biomass (t ha^{-1})

The data presented in the Table 55 revealed that among agroforestry systems the aboveground biomass of vegetation decreased in the order: ASH > AHS > AS > AH. It was recorded that woody components contributions to the aboveground biomass of agroforestry systems varied from 66.40 % (31.10 t ha^{-1}) in AH to 73.65 % (44.89 t ha^{-1}) in AHS. Further, it was noted that fodder trees contributions to the aboveground biomass of vegetation in agroforestry systems ranged from 27.89 % (17.00 t ha^{-1}) in ASH to 66.40 % (31.10 t ha^{-1}) in AHS. It was recorded that crops contribution to the aboveground biomass of vegetation in agroforestry systems varied from 26.35% (AHS) to 33.60 % (AH). Among the six vegetation systems in silvipasture highest aboveground biomass (70.63 t ha^{-1}) was recorded in which trees contributed 95.92 %, shrubs 0.88% and herbs 3.20 % biomass. In grassland herbs contribution to the total aboveground biomass of the system was highest 70.29 % (2.20 t ha^{-1}) and shrubs contributed 29.71 % (0.93 t ha^{-1}).

The data presented in Table 56 reveals that the mean aboveground biomass of vegetation (crops + herbs + shrubs + trees) in system was highest at elevation E_3 (54.92 t ha^{-1}) and it decreased significantly with decrease in elevation to 48.05 t ha^{-1}

Table 52. IVI of shrub species in grasslands at elevation E_1 (900-1300 m) in Giri-catchment of HP

Plant species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Adhatoda vasica	-	-	-	-	17.61	-	-	-	-	-	-	-	-
Aechmanthera gossypina	-	-	-	29.90	-	-	-	-	-	-	-	-	-
Asparagus adscendens	-	-	-	33.33	-	6.69	25.07	26.02	20.61	-	-	-	-
Berberis lycium	49.25	35.49	4.20	88.98	17.61	68.23	68.35	89.91	124.59	28.49	65.57	7.02	112.98
Carissa carandas	67.48	66.08	72.98	3.20	85.09	36.44	15.23	-	14.35	-	-	9.71	37.47
Caryopteris wallichiana	-	-	-	-	-	-	-	-	-	-	-	9.54	-
Colebrookea oppositifolia	-	-	-	-	-	-	-	-	-	-	-	80.51	37.47
Elaeagnus umbellata	-	-	8.46	-	-	-	-	-	-	-	-	-	-
Hamiltonia suaveolens	-	-	-	-	-	-	-	16.89	-	-	-	-	-
Indigofera pulchella	-	-	-	62.86	-	7.13	34.72	-	74.94	-	-	-	18.32
Inula cuspidata	-	-	-	-	-	11.81	-	-	-	-	-	-	-
Lantana camara	47.24	48.03	90.80	-	14.03	-	-	-	-	-	-	9.89	24.98
Leptodermis lanceolata	-	-	-	-	-	-	7.86	-	-	-	-	-	-
Meriandra strobilifera	83.65	-	45.91	19.56	95.13	-	34.87	-	-	89.06	78.61	-	-
Mimosa rubicaulis	-	-	-	-	-	28.98	22.76	-	-	-	-	-	-
Myrsine africana	-	61.31	33.63	12.72	9.70	58.82	11.93	31.90	-	-	88.05	63.17	12.49
Osyris arborea	-	-	-	-	-	-	6.39	11.53	-	-	-	-	-
Prinsepia utilis	8.79	-	-	-	-	-	-	-	4.81	-	13.38	3.00	-
Prunus ceracoides	-	-	8.84	9.66	-	13.93	27.97	-	27.32	-	29.83	18.68	13.23
Rabdosia rugosa	14.95	-	21.43	3.73	43.74	20.38	7.22	4.15	3.06	68.21	-	3.94	-
Randia tetrasperma	-	27.17	-	-	-	25.35	23.74	78.80	6.33	5.29	4.93	82.41	-
Rosa moschata	-	-	-	-	-	-	-	7.45	-	-	-	-	-
Rubus ellipticus	26.19	61.91	13.75	9.20	5.70	19.96	10.38	22.96	23.99	55.57	19.62	12.14	43.05
Smilex aspera	-	-	-	-	-	-	-	10.39	-	-	-	-	-
Woodfordia fruticosa	-	-	-	26.85	11.38	2.28	3.51	-	-	53.38	-	-	-
Zanthoxylem alatum	2.45	-	-	-	-	-	-	-	-	-	-	-	-

Table 53. IVI of shrub species in grasslands at elevation E_2 (1301 – 1700 m) in Giri-catchment of HP

Plant species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Adhatoda vasica	-	-	-	-	-	-	-	-	27.97	-	-	-	-
Aechmanthera gossypina	-	-	-	-	35.52	-	-	-	-	-	-	-	-
Asparagus adscendens	-	-	-	14.09	-	-	6.98	24.58	-	-	-	-	-
Berberis lycium	40.03	58.62	39.98	-	43.85	-	46.03	56.39	23.30	31.65	21.63	-	119.51
Carissa carandas	117.53	55.17	65.18	7.58	-	-	-	-	152.93	-	65.42	63.74	40.95
Caryopteris wallichiana	-	-	-	11.21	39.25	-	-	-	-	-	-	-	-
Colebrookea oppositifolia	-	-	-	-	-	-	-	-	-	-	22.60	-	-
Elaeagnus umbellata	-	-	6.20	-	27.89	-	-	-	-	-	-	-	-
Hamiltonia suaveolens	-	-	-	-	-	-	30.00	36.95	-	-	-	-	-
Hypericum oblongifolium	-	-	-	-	-	-	11.95	-	-	-	-	-	-
Indigofera pulchella	-	-	-	99.29	12.18	91.08	-	-	-	-	-	-	-
Lantana camara	45.32	-	11.96	-	-	-	-	-	40.51	-	-	-	-
Leptodermis lanceolata	-	-	37.87	-	-	45.63	-	-	-	-	-	-	-
Meriandra strobilifera	-	-	-	21.72	-	26.35	-	42.39	55.29	23.83	69.16	-	-
Mimosa rubicaulis	-	-	-	-	-	17.48	-	-	-	-	-	-	-
Myrsine africana	-	129.58	72.88	51.29	91.92	-	90.63	18.19	-	-	-	69.23	-
Osyris arborea	-	-	-	-	-	-	7.95	-	-	-	-	-	-
Prinsepia utilis	-	-	-	15.26	-	-	-	-	-	-	25.78	-	-
Prunus ceracoides	-	-	14.73	-	-	-	-	-	-	-	-	-	-
Rabdosia rugosa	12.34	-	-	-	-	27.99	9.16	-	-	98.29	80.13	-	102.97
Randia tetrasperma	-	-	37.09	-	-	8.95	42.82	48.34	-	43.58	-	-	-
Rosa moschata	-	-	6.59	-	-	-	7.06	-	-	-	-	-	-
Rubus ellipticus	84.78	56.63	7.54	37.06	36.46	-	27.97	59.54	-	95.95	15.28	153.11	36.58
Smilex aspera	-	-	-	-	-	-	-	13.62	-	-	-	-	-
Woodfordia fruticosa	-	-	-	36.14	-	82.52	-	-	-	-	-	-	-
Zanthoxylem alatum	-	-	-	6.35	12.94	-	19.44	-	-	6.70	-	13.91	-

Table 54. IVI of shrub species in grasslands at elevation E_3 (1701-2100 m) in Giri-catchment of HP

Plant species	SUB-WATERSHED												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Berberis lycium	37.42	70.66	25.15	26.68	80.16	75.98	46.57	89.62	79.28	35.55	79.59	69.00	179.73
Carissa carandas	-	-	70.69	52.69	-	-	51.39	-	-	-	-	-	-
Hamiltonia suaveolens	-	-	12.51	-	-	-	-	-	32.82	-	-	-	-
Hypericum oblongifolium	-	-	-	-	-	48.77	-	-	-	-	-	-	-
Indigofera pulchella	-	-	-	-	-	-	152.38	-	-	-	-	-	29.04
Inula cuspidata	-	-	-	-	-	12.32	-	-	-	-	-	-	-
Leptodermis lanceolata	-	-	-	-	-	-	8.82	-	-	25.09	-	-	-
Meriandra strobilifera	82.67	-	126.10	46.72	122.56	-	-	-	-	-	150.61	-	-
Mimosa rubicaulis	-	-	-	-	-	-	-	39.93	-	-	-	-	-
Myrsine africana	-	19.62	18.63	73.39	-	36.65	18.83	-	-	-	-	-	-
Osyris arborea	-	-	-	-	-	-	-	12.46	-	-	-	-	-
Prinsepia utilis	45.05	-	-	-	-	18.12	-	-	-	-	30.08	18.95	-
Rabdosia rugosa	47.75	-	34.37	49.57	40.45	46.74	-	45.92	71.35	98.16	-	50.23	45.28
Randia tetrasperma	-	142.22	-	16.70	-	-	-	-	83.54	46.94	39.72	124.28	-
Rosa moschata	-	-	-	10.67	-	14.61	-	9.65	-	-	-	-	-
Rubus ellipticus	58.18	67.49	-	12.91	56.82	27.26	-	102.42	33.01	94.26	-	37.54	45.94
Woodfordia fruticosa	-	-	-	-	-	19.55	22.01	-	-	-	-	-	-
Zanthoxylem alatum	28.93	-	12.55	10.67	-	-	-	-	-	-	-	-	-

Table 55: Components aboveground, belowground and total biomass (t ha^{-1}) production under different vegetation systems

COMPONENTS				CROPS/HERBS (C)	SHRUBS (S)	TREES (T)		TOTAL (C+S+T)
						FODDER	FRUIT	
				Biomass (t ha^{-1})				
VEGETATION SYSTEMS	AGRO-FORESTRY SYSTEMS	Agri-silvi-culture	AG	15.15± 0.95 (31.15)	-	33.48±7.07 (68.85)	-	48.63±7.01
			BG	5.77±0.59 (39.79)	-	8.73±1.84 (60.21)	-	14.50±1.74
			AG+BG	20.92±1.43 (33.14)	-	42.21±8.91 (66.86)	-	63.13±8.71
		Agri-horticulture	AG	15.74±1.52 (33.60)	-	-	31.10±6.32 (66.40)	46.84±7.05
			BG	5.64±0.74 (41.08)	-	-	8.09±1.68 (58.92)	13.73±2.21
			AG+BG	21.38±2.06 (35.30)	-	-	39.20±7.99 (64.72)	60.57±9.19
		Agri-horti-silviculture	AG	16.06±1.11 (26.35)	-	17.00±5.42 (27.89)	27.89±8.84 (45.76)	60.95±13.87
			BG	6.31±0.61 (35.02)	-	4.25±1.44 (23.58)	7.46±2.34 (41.40)	18.02±3.85
			AG+BG	22.37±1.58 (28.32)	-	21.25±6.85 (26.91)	35.36±11.18 (44.77)	78.98±17.70
		Agri-silvi-horticulture	AG	17.73±1.86 (28.08)	-	29.84±4.51 (47.27)	15.56±2.32 (24.65)	63.13±6.91
			BG	7.02±0.74 (37.22)	-	7.95±1.21 (42.15)	3.89±0.63 (20.63)	18.86±2.07
			AG+BG	24.75±2.51 (30.19)	-	37.78±5.67 (46.08)	19.45±2.92 (23.73)	81.98±8.87
	OTHER SYSTEMS	Silvi-pasture	AG	2.26±0.32 (3.20)	0.62±0.17 (0.88)	67.75±7.26 (95.92)	-	70.63±7.36
			BG	1.61±0.17 (8.65)	0.11±0.04 (0.59)	16.89±2.35 (90.76)	-	18.61±2.37
			AG+BG	3.87±0.46 (4.34)	0.73±0.19 (0.82)	84.64±8.95 (94.85)	-	89.24±9.09
		Grassland	AG	2.20±0.39 (70.29)	0.93±0.27 (29.71)	-	-	3.13±0.45
			BG	1.55± 0.22 (86.59)	0.24±0.05 (13.41)	-	-	1.79±0.21
			AG+BG	3.75±0.53 (76.22)	1.17±0.29 (23.78)	-	-	4.92±0.58

*Values in parenthesis represents per cent values of grand total in the respective row
Mean ± SD (Standard Deviation) values
AG-Aboveground and BG-Belowground

at elevation E_2 and 43.69 t ha^{-1} at elevation E_1. Also, it was evident from the result that the mean aboveground biomass of vegetation in different systems decreased significantly in the order: S_5 (70.63 t ha^{-1}) > S_4 (63.13 t ha^{-1}) > S_3 (60.95 t ha^{-1}) > S_1 (48.63 t ha^{-1}) > S_2 (46.85 t ha^{-1}) > S_6 (3.13 t ha^{-1}).

Table 56: Variation in aboveground biomass (t ha^{-1}) of vegetation relative to elevations and systems in sub-watersheds of Giri catchment

Systems (S)	ELEVATION (E)			
	E_1 (900 - 1300 m)	E_2 (1301 - 1700 m)	E_3 (1701 - 2100 m)	Mean (S)
Aboveground biomass				
S_1	41.45	47.57	56.87	48.63
S_2	41.59	46.83	52.12	46.85
S_3	55.32	59.57	67.97	60.95
S_4	57.49	59.98	71.91	63.13
S_5	62.94	71.33	77.63	70.63
S_6	3.37	3.00	3.02	3.13
Mean (E)	43.69	48.05	54.92	

Factors	$CD_{0.05}$	SEm±
E	0.840	0.302
S	1.187	0.427
E×S	2.057	0.740

S_1	Agrisilviculture	S_4	Agrisilvihorticulture
S_2	Agrihorticulture	S_5	Silvipasture
S_3	Agrihortisilviculture	S_6	Grassland

The interaction effect of elevations and systems on aboveground biomass of vegetation revealed that maximum aboveground biomass occurred in S_5E_3 (77.63 t ha^{-1}) followed by S_4E_3 (71.91 t ha^{-1}) and S_5E_2 (71.33 t ha^{-1}). Minimum biomass was recorded in grasslands S_6E_2 (3.00 t ha^{-1}) followed by S_6E_3 (3.02 t ha^{-1}) and S_6E_1 (3.37 t ha^{-1}). Among the tree based systems significantly low biomass was recorded in agrisilviculture system at elevation E_1 (S_1E_1 = 41.45 t ha^{-1}).

The data presented in Table 57 showed that the mean aboveground biomass of vegetation varied with sub-watersheds and elevations. The mean aboveground biomass was maximum in SW_5 (54.59 t ha^{-1}) which was statistically at par with SW_{12} (54.50 t ha^{-1}) and SW_{13} (54.40 t ha^{-1}) but significantly higher than all other sub-watersheds.

The mean aboveground biomass was minimum in SW_4 (41.52 t ha^{-1}). The interaction effect of sub-watersheds and elevations on aboveground biomass of vegetation revealed that the maximum aboveground biomass occurred in SW_5E_3 (62.02 t ha^{-1}) followed by $SW_{13}E_3$ (61.23 t ha^{-1}). Minimum aboveground biomass was recorded in SW_4E_1 (37.45 t ha^{-1}).

Table 57: Aboveground biomass (t ha^{-1}) of vegetation and its variation at different elevation in sub-watersheds

Elevation (E)	SUB-WATERSHED (SW)													
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}	Mean
Aboveground biomass														
E_1 (900 - 1300 m)	46.56	46.54	41.82	37.45	47.67	43.22	43.08	38.98	41.67	41.91	43.38	46.84	48.88	43.69
E_2 (1301 - 1700 m)	50.24	48.65	44.41	39.63	54.10	44.30	46.70	44.84	48.82	42.05	51.10	56.69	53.09	48.05
E_3 (1701 - 2100 m)	54.74	54.89	50.92	47.47	62.02	53.18	51.38	52.37	58.34	48.86	58.59	59.97	61.23	54.92
Mean (SW)	50.51	50.03	45.72	41.52	54.59	46.90	47.05	45.40	49.61	44.27	51.02	54.50	54.40	

Factors	$CD_{0.05}$	SEm±
SW	1.748	0.629
SW×E	4.282	1.541

Table 58: Variation in aboveground biomass (t ha^{-1}) of vegetation in systems and sub-watersheds

Systems (S)	SUB-WATERSHED (SW)													
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}	Mean
Aboveground biomass														
S_1	49.33	47.66	38.64	48.88	53.37	47.46	49.31	39.93	61.36	38.13	46.47	53.76	57.90	48.63
S_2	50.26	54.14	38.41	40.95	49.66	38.70	37.90	41.95	52.01	41.91	58.49	51.44	53.16	46.84
S_3	56.24	59.23	64.81	39.34	78.47	64.30	52.47	40.87	59.72	45.89	75.07	77.92	78.05	60.95
S_4	66.50	63.84	61.45	57.00	63.69	54.59	65.65	73.34	52.95	68.21	68.36	71.98	53.09	63.13
S_5	77.37	72.60	68.57	59.70	79.11	72.20	73.81	73.52	68.04	68.87	54.54	68.44	81.46	70.63
S_6	3.38	2.69	2.42	3.23	3.26	4.16	3.19	2.78	3.58	2.64	3.20	3.46	2.73	

Factors	$CD_{0.05}$	SEm±
SW×S	3.028	1.089

S_1	**Agrisilviculture**	S_4	**Agrisilvihortic ulture**
S_2	**Agrihorticulture**	S_5	**Silvipasture**
S_3	**Agrihortisilviculture**	S_6	**Grassland**

It was recorded that (Table 58) the aboveground biomass of vegetation in all the systems varied significantly among sub-watersheds. In agrisiliviculture system highest biomass was recorded in SW_9 (61.36 t ha^{-1}) which was statistically at par with SW_{13} (57.90 t ha^{-1}). In agrihorticulture system highest biomass was occurred in SW_{11} (58.49 t $ha^{-1)}$ which was significantly higher than all other systems. Whereas, in agrihortisilviculture system, maximum aboveground biomass was recorded in $SW_5 S_3$ (78.47 t ha^{-1}) which was at par with $SW_{13}S_3$ (78.05 t ha^{-1}) and $SW_{12}S_3$ (77.92 t ha^{-1}). In agrislivihorticulture system highest biomass was recorded in SW_8S_4 (73.34 t ha^{-1}) which was statistically at par with $SW_{12}S_4$ (71.98 t ha^{-1}).

Among the tree based systems highest aboveground biomass of vegetation was recorded in SW_5S_5 (79.11 t ha^{-1}) which was statistically similar with SW_5S_3 (78.47 t ha^{-1}) and $SW_{13}S_3$ (78.05 t ha^{-1}). Minimum aboveground biomass of vegetation was recorded in grasslands SW_3S_6 (2.42 t/ha) Table-58.

4.6.2. Belowground biomass

In case of belowground biomass produced in different agroforestry systems followed the similar trend as aboveground biomass (Table 55). In these systems, the contribution of woody perennials varied from 20.63 % (ASH 3.89 tha^{-1}) to 60.21% (AS 8.09 t ha^{-1}). Whereas, the fodder trees contribution varied from 23.58 % (AHS 4.25 t ha^{-1}) to 60.21% (AS) and contribution of fruit trees ranged between 20.63% in ASH to 58.92% in AH (8.09 t ha^{-1}). The contribution of crop species varied from 35.02 % (5.77 t ha^{-1}) to 41.08 % (7.02 t ha^{-1}) in belowground biomass under AHS and AH, respectively. In other systems, the fodder tree species was the only woody perennials, which contribute highest, and it accounts 90.76 % (16.89 t ha^{-1}) in silvipasture systems. The shrub species present in both the systems viz., SP and grasslands and their contribution varied from 0.59 % to 13.41 %, respectively. However, herb species were the prominent component of grasslands (86.59 % contribution to total belowground biomass) produced lowest belowground biomass (1.55 t ha^{-1}); they also contribute 8.65 % (1.61 t ha^{-1}) in silvipasture system.

Perusal of data in the Table 59 reveals that mean belowground biomass of vegetation in systems was highest at elevation E_3 (16.08 t $ha^{-1)}$ and it decreased significantly with decrease in elevations to 13.56 t ha^{-1} at elevation E_2 and 13.10 t ha^{-1} at elevation E_1. Also, it was exhibited that mean belowground biomass of vegetation in systems S_4 (18.86 t ha^{-1}) was statistically at par with S_5 (18.61 t ha^{-1}).

In the interaction effect of elevations and systems, maximum belowground biomass observed in S_4E_3 (21.38 t ha^{-1}) followed by S_5E_3 (21.17 t ha^{-1}) and S_3E_3 (20.20 t ha^-1) which significantly varied from other system. Minimum belowground biomass was recorded in grasslands at S_6E_3 (1.73 tha^{-1}) followed by S_6E_2 (1.78 t ha^{-1}) and S_6E_1 (1.86 t ha^{-1}) elevation.

Table 59: Variation in belowground biomass (t ha^{-1}) of vegetation in relation to elevations and systems in sub-watersheds of Giri catchment

Systems (S)	ELEVATION (E)			
	E_1 (900 - 1300 m)	E_2 (1301 - 1700 m)	E_3 (1701 - 2100 m)	Mean (S)
Belowground biomass				
S_1	12.66	14.10	16.72	14.50
S_2	12.63	13.27	15.29	13.73
S_3	16.60	17.24	20.20	18.02
S_4	17.46	17.74	21.38	18.86
S_5	17.41	17.25	21.17	18.61
S_6	1.86	1.78	1.73	1.79
Mean (E)	13.10	13.56	16.08	

Factors	$CD_{0.05}$	SEm±
E	0.212	0.076
S	0.300	0.108
E×S	0.520	0.187

S_1 Agrisilviculture **S_4 Agrisilvihorticulture**
S_2 Agrihorticulture **S_5 Silvipasture**
S_3 Agrihortisilviculture **S_6 Grassland**

The data present in Table 60 reveals that the mean belowground biomass of vegetation varied with sub-watersheds and elevations. The highest mean belowground biomass occurred in SW_{13} (15.96 t ha^{-1}) which was statistically at par with SW_{12} (15.83 t ha^{-1}) but significantly higher than all other sub-watersheds. Mean minimum belowground biomass showed by Sw_4 (12.40 t ha^{-1}).

A perusal of data in Table 61 recorded that the belowground biomass of vegetation in all the systems varied significantly among sub-watersheds. In agrisiliviculture system highest biomass was recorded in SW_9 (17.85 t ha^{-1}) which was significantly higher than all other systems. In agrihorticulture system highest belowground biomass occurred in SW_{11} (16.80 t ha^{-1}) which was statistically at par with SW_2 (16.52 t ha^{-1}) and SW_{13} (16.43 t ha^{-1}). Whereas, in agrihortisilviculture system, maximum belowground biomass was recorded in $SW_{12} S_3$ (23.03 t ha^{-1}) which was at par with $SW_{13}S_3$ (22.51 t ha^{-1}) and $SW_{11}S_3$ (22.26 t ha^{-1}). In agrislivihorticulture system highest biomass was recorded in SW_8S_4 (21.47 t ha^{-1}) which was statistically at par with SW_{10} (21.25 t ha^-1) and $SW_{12}S_4$ (21.10 t ha^{-1}).

Table 60: Belowground biomass (t ha^{-1}) of vegetation and its variation at different elevations in sub-watersheds

Elevation (E)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Belowground biomass													
E_1 (900 - 1300 m)	14.02	14.51	12.27	11.56	14.28	12.90	12.93	11.67	12.32	13.23	12.88	13.42	14.35
E_2 (1301 - 1700 m)	12.80	12.00	11.52	11.80	13.49	13.00	14.42	13.31	14.31	12.97	14.36	16.81	15.55
E_3 (1701 - 2100 m)	16.61	16.00	15.19	13.86	17.45	15.77	14.99	15.11	16.85	14.78	17.22	17.27	17.99
Mean (SW)	14.48	14.17	12.99	12.40	15.07	13.89	14.11	13.36	14.49	13.66	14.82	15.83	15.96

Factors	$CD_{0.05}$	SEm±
SW	0.442	0.159
SW×E	0.766	0.275

Table 61: Variation in belowground biomass (t ha^{-1}) of vegetation in systems and sub-watersheds

Systems (S)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Belowground biomass													
S_1	14.61	14.10	11.26	14.32	15.54	14.50	14.85	12.90	17.85	12.09	14.73	15.23	16.45
S_2	15.11	16.52	11.86	11.98	13.81	11.87	10.05	11.68	14.65	12.55	16.80	15.17	16.43
S_3	17.07	17.66	19.24	12.31	21.98	18.77	15.00	11.95	18.47	13.98	22.26	23.03	22.51
S_4	20.09	19.35	18.13	16.98	18.66	16.61	20.99	21.47	15.44	21.25	18.80	21.10	16.30
S_5	17.97	15.72	16.02	16.56	18.62	19.62	21.87	20.41	18.78	20.55	14.79	18.50	22.50
S_6	2.02	1.69	1.47	2.27	1.81	1.99	1.93	1.77	1.74	1.55	1.55	1.95	1.58

Factors	$CD_{0.05}$	SEm±
SW×S	1.083	0.390

S_1 Agrisilviculture **S_4 Agrisilvihorticulture**
S_2 Agrihorticulture **S_5 Silvipasture**
S_3 Agrihortisilviculture **S_6 Grassland**

In silvipasture systems highest belowground biomass of vegetation was recorded in $SW_{13}S_5$ (22.50 t ha^{-1}) which was statistically similar with SW_7S_5 (21.87t ha^{-1}). Minimum belowground biomass of vegetation was recorded in grasslands SW_3S_6 (1.47 t/ha).

4.6.3. Total biomass (Aboveground biomass + Belowground biomass)

The total biomass produced by different agroforestry and other systems followed the same trend as above and belowground biomass production (Table 55). The contribution of fodder and fruit trees varied from 26.91 % (AHS 21.25 t ha^{-1}) to 94.85 % (SP 84.64 t ha^{-1}) and 23.73 % (ASH 19.45 t ha^{-1}) to 64.72 % (AH 39.20 t ha^{-1}), respectively. Shrub species contribute highest under grasslands (23.78 %) followed by silvipasture (0.82 %). In case of crop/or herb species, their contribution to the total biomass varied from 4.34 % (SP 3.87 t ha^{-1}) to 76.22% (Grasslands 3.75 t ha^{-1}). In case of agroforestry systems only, the contribution of crop species varied from 28.32 % to 35.30 % in AHS (22.37 t ha^{-1}) and AH (21.38 t ha^{-1}), respectively.

Data presented in Table 62 reveals that the mean total biomass of vegetation in systems was highest at elevation E_3 (71.00 t ha^{-1}) and it decreased significantly with decrease in elevation to 61.61 t ha^{-1} at elevation E_2 and 56.79 t ha^{-1} at elevation E_1. It reveals from the results that mean total biomass of vegetation in different systems decreased significantly in the order: S_5 (89.24 t ha^{-1}) > S_4 (81.98 t ha-1) > S_3 (78.97 t ha^{-1}) >S_1 (63.13 t ha^{-1}) > S_2 (60.57 t ha^{-1}) > S_6 (4.93 t ha^{-1}).

Table 62: Variation in total biomass (t ha^{-1}) of vegetation relative to elevations and systems in sub-watersheds of Giri catchment

Systems (S)	ELEVATION (E)			
	$E_{1 (900 - 1300 m)}$	$E_{2 (1301 - 1700 m)}$	$E_{3 (1701 - 2100 m)}$	Mean (S)
Total biomass				
S_1	54.11	61.68	73.59	63.13
S_2	54.21	60.10	67.41	60.57
S_3	71.93	76.81	88.17	78.98
S_4	74.95	77.72	93.29	81.98
S_5	80.34	88.58	98.80	89.24
S_6	5.23	4.79	4.76	4.92
Mean (E)	56.79	61.61	71.00	

Factors	$CD_{0.05}$	SEm±
E	1.020	0.367
S	1.443	0.519
E×S	2.499	0.899

S_1 Agrisilviculture
S_2 Agrihorticulture
S_3 Agrihortisilviculture
S_4 Agrisilvihorticulture
S_5 Silvipasture
S_6 Grassland

The interaction effect of elevations and system on total biomass of vegetation revealed that maximum total biomass occurred in S_5E_3 (98.80 t ha^{-1}) which was significantly higher than other systems. Minimum total biomass was recorded in grasslands at S_6E_3 (4.76 t ha^{-1}) followed by S_6E_3 (4.79 t ha^{-1}) and S_6E_1 (5.23 t ha^{-1}).

Among all the tree based systems significantly low total biomass was recorded in agrisilviculture system at elevation E_1S_1 (54.11 t ha^{-1}) followed by S_2E_1 (54.21 t ha^{-1}) in agrihorticulture system.

The data presented in Table 63 showed that the mean total biomass of vegetation varied with sub-watersheds and elevations. The mean total biomass was highest in SW_{13} (70.36 t ha^{-1}) which was at par with SW_{12} (70.33 t ha^{-1}) and SW_5 (69.66 t ha^{-1}) but significantly higher than all other sub-watersheds. The minimum total biomass was recorded in SW_4 (53.92 t ha^{-1}). The interaction effect of sub-watersheds and elevations on total biomass of vegetation revealed that the maximum total biomass was recorded in SW_5E_3 (79.46t ha^{-1}) which was statistically at par with $SW_{13}E_3$ (79.22 t ha^{-1}), $SW_{12}E_3$ (77.24 t ha^{-1})' $SW_{11}E_3$ (75.81 t ha^{-1}) and SW_9E_3 (75.19 t ha^{-1}). The minimum total biomass of vegetation was recorded in SW_4 E_1 (49.00 t ha^{-1}).

It was recorded that the total biomass of vegetation in all the systems varied significantly among the sub-watersheds (Table 64). In agrisilviculture system, the highest biomass was recorded in SW_9 (79.22 t ha^{-1}) which was statistically at par with SW_{13} (74.36 t ha^{-1}). The highest total vegetation biomass in agrihorticulture systems was recorded in SW_{11} (75.29 t ha^{-1}) which was statistically at par with SW_2 (70.66 t ha^{-1}). In agrihortisilviculture systems, maximum total biomass of vegetation was recorded in SW_{12} (100.96 t ha^{-1}) which was statistically at par with SW_{13} (100.56 t ha^{-1}), SW_5 (100.45 t ha^{-1}) and SW_{11} (97.33 t ha^{-1}). In agrisilviculture system, highest biomass was recorded in SW_8 (94.80 t ha^{-1}) which was statistically at par with SW_{12} (93.08 t ha^{-1}).

In silvipasture system, highest total vegetation biomass was recorded in SW_{13} (103.95 t ha^{-1}) which was significantly higher than other systems in all sub-watersheds. Total biomass of vegetation in grasslands was statistically at par in all sub-watersheds.

Table 63: Total biomass (t ha^{-1}) of vegetation and its variation at different elevations in sub-watersheds

Elevation (E)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Total biomass of vegetation													
E_1 (900 - 1300 m)	60.59	61.05	54.09	49.00	61.95	56.12	56.01	50.64	53.99	55.14	56.26	60.25	63.23
E_2 (1301 - 1700 m)	63.04	60.65	55.93	51.43	67.58	57.31	61.12	58.16	63.13	55.03	65.46	73.49	68.63
E_3 (1701 - 2100 m)	71.34	70.90	66.12	61.33	79.46	68.95	66.37	67.48	75.19	63.64	75.81	77.24	79.22
Mean (SW)	64.99	64.20	58.71	53.92	69.66	60.79	61.17	58.76	64.10	57.93	65.84	70.33	70.36

Factors	$CD_{0.05}$	SEm±
SW	2.124	0.764
SW×E	3.678	1.324

Table 64: Variation in total biomass (t ha^{-1}) of vegetation in systems and sub-watersheds

Systems (S)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Total biomass of vegetation													
S_1	63.94	61.76	49.90	63.20	68.91	61.96	64.16	52.83	79.22	50.22	61.20	68.99	74.36
S_2	65.37	70.66	50.26	52.94	63.48	50.57	47.95	53.64	66.66	54.46	75.29	66.61	69.59
S_3	73.30	76.89	84.04	51.64	100.45	83.07	67.47	52.82	78.20	59.86	97.33	100.96	100.56
S_4	86.58	83.19	79.58	73.97	82.35	71.20	86.64	94.80	68.39	89.45	87.16	93.08	69.39
S_5	95.35	88.32	84.59	76.26	97.73	91.82	95.68	93.93	86.82	89.42	69.33	86.94	103.95
S_6	5.40	4.38	3.89	5.50	5.07	6.15	5.12	4.55	5.32	4.19	4.74	5.41	4.31

Factors	$CD_{0.05}$	SEm±
SW×S	5.202	1.872

S_1 Agrisilviculture   **S_4 Agrisilvihorticulture**
S_2 Agrihorticulture   **S_5 Silvipasture**
S_3 Agrihortisilviculture   **S_6 Grassland**

Among the all trees based system, highest total biomass of vegetation was recorded in $SW_{13}S_5$ (103.95 t ha^{-1}) which was at par with $SW_{12}S_3$ (100.96 t ha^{-1}), $SW_{13}S_3$ (100.56 t ha^{-1}) and SW_5S_3 (100.45 t ha^{-1}). Minimum total biomass of vegetation was recorded in grassland SW_3S_6 (3.89 t ha^{-1}) Table-63.

4.6.4. Aboveground biomass carbon of vegetation

The aboveground carbon storage by different agroforestry systems (Table 65) decreased as ASH (31.57 t C ha^{-1}) > AHS (30.48 t C ha^{-1}) > AS (24.32 t C ha^{-1}) > AH (23.43 t C ha^{-1}). The aboveground carbon storage by fodder and fruit trees varied from 8.50 t C ha^{-1} in AHS to 16.74 t C ha^{-1} in AS and 7.78 t C ha^{-1} in ASH to 15.55 t C ha^{-1} AH, respectively. Crop component from different agroforestry systems, aboveground carbon storage ranged from 7.58 t C ha^{-1} in AS to 8.87 t C ha^{-1} in ASH. In case of other systems, silvipasture stored highest carbon in aboveground components followed by grasslands. Where, the carbon storage in aboveground by different components varied from 0.31 t C ha^{-1} (SP) to 0.47 t C ha^{-1} (Grasslands) by shrubs, 1.10 t C ha^{-1} (Grasslands) to 1.13 t C ha^{-1} (SP) by herbs and 33.88 t C ha^{-1} (SP) by fodder trees.

A perusal of data in Table 66 reveals that the mean aboveground biomass carbon was maximum (35.32 t C ha^{-1}) in silvipasture, which was significantly higher than all other systems and followed by S_4 (31.56 t C ha^{-1}), S_3 (30.48 t C ha^{-1}), S_1 (24.32 t C ha^{-1}), S_2 (23.42 t C ha^{-1}) and S_6 (1.57 t C ha^{-1}). The effect of elevation showed significant effect on aboveground biomass carbon of vegetation. The aboveground carbon increased significantly with increasing elevation. Maximum aboveground vegetation carbon was recorded at E_3 (27.48 t C ha^{-1}).

The interaction effect of elevations and systems on aboveground biomass carbon was evident from the result that it increased significantly in all systems along elevation E_1 to E_3 except for S_6. Maximum (38.81 t C ha^{-1}) aboveground biomass carbon was recorded in S_5E_3, it was significantly higher than aboveground biomass carbon of vegetation recorded in other combinations. Minimum (1.50 t C ha^{-1}) aboveground biomass carbon was recorded in S_6E_3, it was found to be statistically alike in S_6E_1 (1.51 t C ha^{-1}) and S_6E_2 (1.69t C ha^{-1}).

Table 65: Aboveground and belowground total carbon density (t C ha^{-1}) under different vegetation systems

COMPONENTS				CROPS/ HERBS (C)	SHRUBS (S)	TREES (T)		TOTAL (A= C+S+T)
						FODDER	FRUIT	
				Carbon density (t ha^{-1})				
VEGETATION SYSTEMS	AGRO-FORESTRY SYSTEMS	Agri-silvi-culture	AG	7.58±0.48	-	16.74±3.54	-	24.32±3.51
			BG	2.89±0.29	-	4.36±0.92	-	7.25±0.87
			AG+BG	10.46±0.72	-	21.11±4.45	-	31.57±4.36
		Agri-horticulture	AG	7.87±0.76	-	-	15.55±3.16	23.43±3.53
			BG	2.82±0.37	-	-	4.05±0.84	6.87±1.10
			AG+BG	10.69±1.03	-	-	19.60±3.99	30.29±4.60
		Agri-horti-silviculture	AG	8.03±0.55	-	8.50±2.71	13.95±4.42	30.48±6.93
			BG	3.16±0.31	-	2.13±0.72	3.72±1.17	9.01±1.93
			AG+BG	11.19±0.79	-	10.62±3.43	17.68±5.59	39.49±8.85
		Agri-silvi-horticulture	AG	8.87±0.93	-	14.92±2.25	7.78±1.16	31.57±3.45
			BG	3.50±0.37	-	3.98±0.61	1.95±0.31	9.43±1.03
			AG+BG	12.38±1.26	-	18.88±2.84	9.73±1.46	40.99±4.43
	OTHER SYSTEMS	Silvi-pasture	AG	1.13±0.16	0.31±0.08	33.88±3.63	-	35.32±3.68
			BG	0.81±0.09	0.06±0.02	8.44±1.17	-	9.31±1.19
			AG+BG	1.94±0.23	0.37±0.10	42.31±4.48	-	44.62±4.55
		Grassland	AG	1.10±0.19	0.47±0.14	-	-	1.57±0.23
			BG	0.78±0.11	0.12±0.03	-	-	0.90±0.11
			AG+BG	1.88±0.27	0.58±0.15	-	-	2.46±0.29

Mean ± SD (Standard Deviation) values
AG-Aboveground and BG-Belowground

Table 66: Variation in aboveground biomass carbon (t C ha^{-1}) of vegetation relative to elevations and systems in sub-watersheds of Giri catchment

Systems (S)	ELEVATION (E)			
	E_1 (900 - 1300 m)	E_2 (1301 - 1700 m)	E_3 (1701 - 2100 m)	Mean (S)
Aboveground carbon				
S_1	20.72	23.79	28.44	24.32
S_2	20.79	23.42	26.06	23.42
S_3	27.66	29.78	33.98	30.48
S_4	28.74	29.99	35.96	31.56
S_5	31.47	35.67	38.81	35.32
S_6	1.69	1.50	1.51	1.57
Mean (E)	21.85	24.02	27.46	

Factors	$CD_{0.05}$	SEm±
E	0.420	0.151
S	0.594	0.214
E×S	1.028	0.370

S_1 Agrisilviculture
S_2 Agrihorticulture
S_3 Agrihortisilviculture
S_4 Agrisilvihorticulture
S_5 Silvipasture
S_6 Grassland

Data presented in Table 67 showed that the aboveground biomass carbon was significantly influenced by sub-watersheds. Maximum (27.30 t C ha^{-1}) aboveground biomass carbon existed in SW_5, it was statistically at par with SW_{12} (27.25 t ha^{-1}) and SW_{13} (27.20 t C ha^{-1}). Minimum (20.76 t C ha^{-1}) aboveground biomass carbon was recorded in SW_4 sub-watershed.

The interaction between sub-watersheds and elevations also effected aboveground biomass carbon significantly. The maximum (31.01 t C ha^{-1}) aboveground biomass carbon was recorded in SW_5E_3, it was statistically at par with SW_9E_3, $SW_{11}E_3$, $SW_{12}E_3$ and $SW_{13}E_3$ with their respective values as: 29.17 t C ha^{-1}, 29.29 tC ha^{-1}, 29.99 t C ha^{-1} and 30.62 t C ha^{-1}, respectively. Minimum (18.72 tC ha^{-1}) aboveground biomass carbon existed in SW_4E_1.

Data presented in Table 68 reveals that the aboveground biomass carbon in all the systems, except for grasslands, varied significantly among sub-watersheds. In agrisilviculture system highest aboveground biomass carbon was recorded in SW_9 (30.68 t C ha^{-1}) which was at par with SW_{13} (28.95 t C ha^{-1}). In agrihorticulture system, the highest aboveground biomass carbon was recorded in SW_{11} (29.25 t C ha^{-1}) which was significantly higher than all other sub-watersheds. In agrihortisilviculture system, the higher aboveground carbon occurred in SW_5 (39.24 t C ha^{-1}) which was at par with SW_{13} (39.03 t C ha^{-1}) and SW_{12} (38.96 t C ha^{-1}).

Table 67: Aboveground biomass carbon (t C ha^{-1}) and its variation at different elevations in sub-watersheds

Elevation (E)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Aboveground carbon													
E_1 (900 - 1300 m)	23.28	23.27	20.91	18.72	23.84	21.61	21.54	19.49	20.84	20.96	21.69	23.42	24.44
E_2 (1301 - 1700 m)	25.12	24.32	22.21	19.82	27.05	22.15	23.35	22.42	24.41	21.03	25.55	28.34	26.54
E_3 (1701 - 2100 m)	27.37	27.45	25.46	23.73	31.01	26.59	25.69	26.19	29.17	24.43	29.29	29.99	30.62
Mean (SW)	25.26	25.01	22.86	20.76	27.30	23.45	23.53	22.70	24.81	22.14	25.51	27.25	27.20

Factors	$CD_{0.05}$	SEm±
SW	0.874	0.314
SW×E	1.514	0.545

Table 68: Variation in aboveground biomass carbon (t C ha^{-1}) in systems and sub-watersheds

Systems (S)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Aboveground carbon													
S_1	24.67	23.83	19.32	24.44	26.68	23.73	24.65	19.97	30.68	19.06	23.24	26.88	28.95
S_2	25.13	27.07	19.21	20.48	24.83	19.35	18.95	20.98	26.01	20.96	29.25	25.72	26.58
S_3	28.12	29.62	32.40	19.67	39.24	32.15	26.24	20.44	29.86	22.94	37.53	38.96	39.03
S_4	33.25	31.92	30.73	28.50	31.84	27.29	32.83	36.67	26.48	34.10	34.18	35.99	26.55
S_5	38.69	36.30	34.29	29.85	39.55	36.10	36.91	36.76	34.02	34.44	27.27	34.22	40.73
S_6	1.69	1.35	1.21	1.62	1.63	2.08	1.59	1.39	1.79	1.32	1.60	1.73	1.37

Factors	$CD_{0.05}$	SEm±
SW×S	2.141	0.770

S_1	Agrisilviculture	S_4	Agrisilvihorticulture
S_2	Agrihorticulture	S_5	Silvipasture
S_3	Agrihortisilviculture	S_6	Grassland

Whereas, in agrisilvihorticulture system, maximum aboveground biomass carbon was recorded in SW_8 (36.67 t ha^{-1}) which was statistically at par with SW_{12} (35.99 t C ha^{-1}). In silvipasture, highest aboveground biomass carbon was recorded in SW_{13} (40.70 t C ha^{-1}) which was statistically at par with SW_5 (39.43 t C ha^{-1}) and SW_1 (38.44 t C ha^{-1}). In grassland system, aboveground biomass carbon was at par in all sub-watersheds.

4.6.6. Belowground biomass carbon (t C ha^{-1})

Belowground carbon followed the same trend as aboveground carbon storage in components of the different vegetation systems as given in Table 65 and decreased as ASH (9.43 t C ha^{-1}) > SP (9.31 t C ha^{-1}) > AHS (9.01 t C ha^{-1}) > AS (7.25 t C ha^{-1}) > AH (6.87 t C ha^{-1}) > Grasslands (0.90 t C ha^{-1}). Where the carbon storage in different components were varied from 2.13 t C ha^{-1} (AHS) to 8.44 t C ha^{-1} (SP) by fodder trees, 1.95 t C ha^{-1} (ASH) to 4.05 t C ha^{-1} (AH) by fruit trees, 0.06 t C ha^{-1} (SP) to 0.12 t C ha^{-1} (grasslands) and crop/herb species stored 0.78 t ha^{-1} in grasslands to 3.50 t C ha^{-1} in ASH.

Data presented in Table 69 reveals that the belowground biomass carbon (t ha^{-1}) was significantly influenced by systems, elevations and their interactions. Maximum belowground biomass carbon (9.43 t C ha^{-1}) accumulated in agrisilvihorticulture, which was found to be statistically at par with silvipasture system (S_5). Minimum belowground biomass carbon (0.90 t C ha^{-1}) was recorded in grassland system. The effect of elevation on belowground biomass carbon of vegetation

Table 69: Variation in belowground biomass carbon (t C ha^{-1}) of vegetation relative to elevations and systems in sub-watersheds of Giri catchment

Systems (S)	ELEVATION (E)			
	E_1-(900-1300 m)	E_2- (1301-1700 m)	E_3- (1701-2100 m)	Mean (S)
Belowground biomass carbon				
S_1	6.33	7.05	8.36	7.25
S_2	6.31	6.63	7.65	6.86
S_3	8.30	8.62	10.10	9.01
S_4	8.73	8.87	10.69	9.43
S_5	8.70	8.62	10.59	9.30
S_6	0.93	0.89	0.87	0.90
Mean (E)	6.55	6.78	8.04	

Factors	$CD_{0.05}$	SEm±
E	0.106	0.038
S	0.150	0.054
E×S	0.260	0.094

S_1 **Agrisilviculture** S_4 **Agrisilvihorticulture**
S_2 **Agrihorticulture** S_5 **Silvipasture**
S_3 **Agrihortisilviculture** S_6 **Grassland**

was evident from the result that it enhanced significantly from elevation E_1 to elevation E_3. Belowground biomass carbon at E_1 (6.53 t C ha^{-1}) was 18.64% and 3.4 % lower than E_3 and E_2, respectively.

The interaction effect of systems and elevations on belowground biomass carbon (Table 69) showed that maximum belowground biomass carbon stock (10.69 t C ha^{-1}) occurred in agrisilvihorticulture system (S_4) at elevation (E_3) followed by (10.59 t C ha^{-1}) and (10.10 t C ha^{-1}) in silvipasture and agrihortisilviculture, respectively. Minimum (0.87 t C ha^{-1}) belowground biomass carbon was recorded in grassland (S_6) at elevation (E_3) which statistically at par with grasslands at elevations E_2 and E_1.

A perusal of data in Table 70 shows that belowground biomass carbon varied significantly in sub-watersheds The mean belowground biomass carbon was maximum in SW_{13} (7.98 t C ha^{-1}) which was at par with SW_{12} (7.92 t C ha^{-1}) but significantly higher than all other sub-watersheds. Minimum belowground biomass carbon was recorded in SW_4 (6.20 t C ha^{-1}). The interaction effect of elevations and sub-watersheds on belowground biomass carbon revealed that maximum belowground carbon occurred in SW_{12} E_3 (9.00 t C ha^{-1}) which was stastically at par with SW_5E_3 (8.72 t C ha^{-1}). Minimum belowground biomass carbon was recorded in SW_3 E_2 (5.76 t C ha^{-1}).

The data presented in Table 71 reveals that the belowground biomass carbon in vegetation varied significantly among sub-watersheds in all the systems except grasslands. In agrisilviculture system highest belowground biomass carbon was recorded in SW_9 (8.93 t C ha^{-1}) which was significantly higher than all other sub-watersheds. In agrihorticulture system the highest belowground biomass carbon was recorded in SW_{11} (8.40 t C ha^{-1}) which was spastically at par with SW_2 (8.26 t C ha^{-1}) and SW_{13} (8.22 t C ha^{-1}). In agrihortisilviculture system the higher belowground biomass carbon was recorded in SW_{11} (11.52 t C ha^{-1}) which was at par with SW_{13} (11.26 t C ha^{-1}) and SW_{11} (11.13 t C ha^{-1}). Whereas, in agrisilvihorticulture system maximum belowground biomass carbon was recorded in SW_8 (10.73 t C ha^{-1}) which was statistically at par with SW_{10} (10.62 t C ha^{-1}), SW_{12} (10.55 t C ha^{-1}) and SW_7 (10.49 t C ha^{-1}). In silvipasture highest belowground biomass carbon was recorded in SW_{13} (11.25 t C ha^{-1}) which was significantly higher than all other sub-watersheds. In grassland the belowground biomass carbon was statistically similar in all sub-watersheds.

Table 70: Belowground biomass carbon (t C ha^{-1}) and its variation at different elevations in sub-watersheds

Elevation (E)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Belowground biomass carbon													
E_1 (900 - 1300 m)	7.01	7.26	6.14	5.78	7.14	6.45	6.47	5.83	6.16	6.61	6.44	6.71	7.18
E_2 (1301 - 1700 m)	6.40	6.00	5.76	5.90	6.74	6.50	7.21	6.66	7.15	6.49	7.18	8.40	7.77
E_3 (1701 - 2100 m)	8.30	8.00	7.60	6.93	8.72	7.89	7.50	7.56	8.42	7.39	8.61	8.64	9.00
Mean (SW)	7.24	7.09	6.50	6.20	7.54	6.95	7.06	6.68	7.24	6.83	7.41	7.92	7.98

Factors	$CD_{0.05}$	SEm±
SW	0.221	0.080
SW×E	0.383	0.138

Table 71: Variation in belowground biomass carbon (t C ha^{-1}) in systems and sub-watersheds

Systems (S)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Belowground biomass carbon													
S_1	7.30	7.05	5.63	7.16	7.77	7.25	7.43	6.45	8.93	6.05	7.37	7.61	8.23
S_2	7.55	8.26	5.93	5.99	6.91	5.93	5.03	5.84	7.32	6.27	8.40	7.59	8.22
S_3	8.53	8.83	9.62	6.15	10.99	9.38	7.50	5.97	9.24	6.99	11.13	11.52	11.26
S_4	10.04	9.67	9.06	8.49	9.33	8.31	10.49	10.73	7.72	10.62	9.40	10.55	8.15
S_5	8.99	7.86	8.01	8.28	9.31	9.81	10.93	10.20	9.39	10.27	7.39	9.25	11.25
S_6	1.01	0.85	0.73	1.13	0.91	0.99	0.96	0.89	0.87	0.78	0.77	0.98	0.79

Factors	$CD_{0.05}$	SEm±
SW×S	0.541	0.195

S_1 Agrisilviculture | **S_4 Agrisilvihorticulture**
S_2 Agrihorticulture | **S_5 Silvipasture**
S_3 Agrihortisilviculture | **S_6 Grassland**

4.6.7. Total carbon of vegetation (t C ha^{-1})

Total carbon is the addition of above and belowground carbon stored in components of different vegetation systems and varied with same trend (Table 65). In case of agroforestry systems, total carbon storage by fodder tree species varied from 10.62 t ha^{-1} (AHS) to 21.11 t ha^{-1} (AS), whereas 9.73 t C ha^{-1} (ASH) to 19.60 t C ha^{-1} (AH) stored by fruit tree species, which were the major woody perennials contribute highest than crop species. However, total carbon stored by crop species varied from 10.46 t C ha^{-1} (AS) to 12.38 t C ha^{-1} (ASH). In case of other systems, fodder trees stored 42.31 t C ha^{-1} total carbon in silvipasture system. Whereas, shrub species stored 0.37 t C ha^{-1} total carbon in silvipasture and 0.58 t C ha^{-1} in grassland; 1.88 t C ha^{-1} in grassland and 1.94 t C ha^{-1} in silvipasture stored by herbage species.

Data presented in Table 72 reveals that the mean total carbon of vegetation in systems was highest at elevation E_3 (35.50 t C ha^{-1}) and it decreased significantly with decrease in elevation to 30.81 t C ha^{-1} at elevation E_2 and 28.40 t C ha^{-1} at elevation E_1. It revealed from the results that mean total carbon of vegetation in different systems decreased significantly in the order: S_5 (44.62 t C ha^{-1}) > S_4 (40.99 t C ha-1) > S_3 (39.48 t C ha^{-1}) >S_1 (31.56 t C ha^{-1}) >S_2 (30.29 t C ha $^{-1}$) > S_6 (2.46 t C ha^{-1}).

Table 72: Variation in total carbon (t C ha^{-1}) of vegetation relative to elevations and systems in sub-watersheds of Giri catchment

Systems (S)	ELEVATION			
	E_1-(900-1300 m)	E_2- (1301-1700 m)	E_3- (1701-2100 m)	Mean (S)
Total carbon				
S_1	27.05	30.84	36.80	31.56
S_2	27.11	30.05	33.71	30.29
S_3	35.96	38.41	44.09	39.48
S_4	37.47	38.86	46.64	40.99
S_5	40.17	44.29	49.40	44.62
S_6	2.62	2.39	2.38	2.46
Mean (E)	28.40	30.81	35.50	

Factors	$CD_{0.05}$	SEm±
E	0.510	0.184
S	0.721	0.260
E×S	1.249	0.450

S_1 Agrisilviculture S_4 Agrisilvihorticulture
S_2 Agrihorticulture S_5 Silvipasture
S_3 Agrihortisilviculture S_6 Grassland

The interaction effect of elevations and systems on total carbon of vegetation showed that maximum total carbon of vegetation occurred in S_5E_3 (49.62 t C ha^{-1}) which was significantly higher than other systems. Minimum total carbon of vegetation was recorded in grasslands at S_6E_3 (2.38 t C ha^{-1}). Among the tree based systems significantly low total carbon was recorded in agrisilviculture system at elevation E_1S_1 (27.05 t C ha^{-1}) followed by S_2E_1 (27.11 t C ha^{-1}) in agrihorticulture system.

Data presented in Table 73 reveals that the total vegetation carbon was significantly influenced by sub-watersheds and elevations. The maximum total vegetation carbon (35.18 t C ha^{-1}) was recorded in SW_{13}, which was significantly at par with SW_{12} (35.17 t C ha^{-1}) and SW_5 (34.83 t C ha^{-1}). Minimum total vegetation carbon (26.96 t C ha^{-1}) recorded in SW_4 sub-watershed.

Total vegetation carbon was found to be maximum (39.73 t C ha^{-1}) in SW_5E_3 (39.73 t C ha^{-1}) and it was significantly higher than all other interactions except $SW_{13}E_3$ (39.61 t C ha^{-1}), $SW_{12}E_3$ (38.62 t C ha^{-1}) and $SW_{11}E_3$ (37.91 t C ha^{-1}) with which it was statistically at par. Minimum total vegetation carbon was recorded in SW_4E_1 (24.50 t C ha^{-1}).

A perusal of data in Table 74 reveals that the total carbon of vegetation of vegetation in all the systems varied significantly among the sub-watersheds. In agrisilviculture system highest total carbon of vegetation was recorded in SW_9 (39.61 t C ha^{-1}) which was at par with SW_{13} (37.18 t C ha^{-1}). In agrihorticulture system, the maximum total carbon of vegetation was recorded in SW_{11} (37.65 t C ha^{-1}) which was significantly higher than all other sub-watersheds. In agrihortisilviculture system, the higher total carbon of vegetation was recorded in SW_{12} (50.48 t C ha^{-1}) which was at par with SW_{13} (50.28 t C ha^{-1}) and SW_5 (50.23 t C ha^{-1}). Whereas, in agrisilvihorticulture system, maximum total carbon of vegetation was recorded in SW_8 (47.40 t C ha^{-1}) which was statistically at par with SW_{12} (46.54 t C ha^{-1}). In silvipasture, highest total carbon of vegetation was recorded in SW_{13} (51.98 t C ha^{-1}) which was significantly higher than all other systems. In grassland system, maximum total carbon of vegetation was recorded in SW_5 (2.75 t C ha^{-1}) which was significantly at par with all other systems.

Table 73: Total carbon (t C ha^{-1}) of vegetation and its variation at different elevations in sub-watersheds

Elevation (E)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Total carbon of vegetation													
E_1 (900 - 1300 m)	30.29	30.52	27.04	24.50	30.98	28.06	28.01	25.32	26.99	27.57	28.13	30.13	31.61
E_2 (1301 - 1700 m)	31.52	30.33	27.96	25.71	33.79	28.65	30.56	29.08	31.56	27.51	32.73	36.75	34.32
E_3 (1701 - 2100 m)	35.67	35.45	33.06	30.66	39.73	34.47	33.19	33.74	37.59	31.82	37.91	38.62	39.61
Mean (SW)	32.50	32.10	29.36	26.96	34.83	30.40	30.58	29.38	32.05	28.97	32.92	35.17	35.18

Factors	$CD_{0.05}$	SEm±
SW	1.062	0.382
SW×E	1.839	0.662

Table 74: Variation in total carbon (t C ha^{-1}) of vegetation in systems and sub-watersheds

Systems (S)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Total carbon of vegetation													
S_1	31.97	30.88	24.95	31.60	34.45	30.98	32.08	26.42	39.61	25.11	30.60	34.49	37.18
S_2	32.69	35.33	25.13	26.47	31.74	25.28	23.98	26.82	33.33	27.23	37.65	33.31	34.80
S_3	36.65	38.44	42.02	25.82	50.23	41.54	33.74	26.41	39.10	29.93	48.66	50.48	50.28
S_4	43.29	41.59	39.79	36.99	41.18	35.60	43.32	47.40	34.20	44.73	43.58	46.54	34.70
S_5	47.67	44.16	42.29	38.13	48.86	45.91	47.84	46.96	43.41	44.71	34.66	43.47	51.98
S_6	2.70	2.19	1.95	2.75	2.54	3.07	2.56	2.27	2.66	2.10	2.37	2.71	2.15

Factors	$CD_{0.05}$	SEm±
SW×S	2.601	0.936

S_1 Agrisilviculture   **S_4 Agrisilvihorticulture**
S_2 Agrihorticulture   **S_5 Silvipasture**
S_3 Agrihortisilviculture   **S_6 Grassland**

4.7 SOIL ORGANIC CARBON (%)

A perusal of data presented in the Table 75 revealed that soil organic carbon was significantly influenced by systems and elevations. A significantly higher mean soil organic carbon (2.22 %) was recorded in agrihorticulture (S_2) followed by (S_3) agrihortisilculture (2.20 %) and (S_6) grassland (2.19 %). The minimum soil organic carbon was recorded in (S_5) silvipasture system (2.08 %). However, the value obtained in agrisilviculture and agrisilvihorticulture systems were statistically at par. The effect of elevations was evident from the finding that the mean soil organic carbon increased with increasing elevation. Maximum soil organic carbon (2.19 %) was observed at elevation E_2 which was significantly different from soil organic carbon at elevation E_3 and E_1, where it was at par. The interaction effect of systems and elevations on the soil organic carbon per cent revealed that maximum soil organic carbon was occurred in S_2E_3 (2.29 %) which was at par with S_3E_3, S_3E_1 and S_6E_1. Minimum (1.98 %) soil organic carbon was recorded in S_5E_1 (1.98%).

Table 75: Variation in soil organic carbon (%) relative to elevations and systems in sub-watersheds of Giri catchment

Systems (S)	ELEVATION (E)			
	$E_{1 (900-1300\ m)}$	$E_{2 (1301-1700\ m)}$	$E_{3 (1701-2100\ m)}$	Mean (S)
Soil Organic Carbon (%)				
S_1	2.17	2.22	2.10	2.16
S_2	2.22	2.16	2.29	2.22
S_3	2.21	2.12	2.27	2.20
S_4	2.12	2.21	2.17	2.17
S_5	1.98	2.16	2.10	2.08
S_6	2.26	2.26	2.06	2.19
Mean (E)	2.16	2.19	2.16	

Factors	$CD_{0.05}$	SEm±
E	NS	0.020
S	0.078	0.028
E×S	0.136	0.049

S_1	Agrisilviculture	S_4	Agrisilvihorticulture
S_2	Agrihorticulture	S_5	Silvipasture
S_3	Agrihortisilviculture	S_6	Grassland

The data presented in Table 76 showed that the mean organic carbon of soil varied with sub-watersheds and elevation. The mean maximum soil organic carbon was SW_1 (2.47 %) which was significantly higher than all other internactions sub-watersheds. Minimum soil organic was recorded in SW_{10} (2.03 %). The interaction effect sub-watersheds and elevation on soil organic carbon revealed that the maximum soil organic carbon was occurred in SW_1E_3 (2.89 %). Which was significantly higher than all other watersheds. Minimum soil organic was recorded in SW_8 E_3 (1.85%).

Table 76: Soil organic carbon (%) and its variation at different elevations in sub-watersheds

Elevation (E)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Soil Organic Carbon													
E_1 (900-1300 m)	2.24	2.18	2.33	1.88	2.17	2.02	2.23	2.20	2.22	2.07	2.23	2.21	2.08
E_2 (1301-1700 m)	2.28	2.27	2.16	2.14	2.32	2.38	2.29	2.21	2.17	2.05	1.79	2.23	2.16
E_3 (1701-2100 m)	2.89	2.19	1.89	2.16	2.29	1.95	2.05	1.85	1.94	1.98	2.50	2.48	1.97
Mean (SW)	2.47	2.22	2.13	2.06	2.26	2.12	2.19	2.09	2.11	2.03	2.17	2.31	2.07

Factors	$CD_{0.05}$	SEm±
SW	0.115	0.041
SW×E	0.200	0.072

Table 77: Variation in soil organic carbon (%) relative to vegetation systems in sub-watersheds

Systems (S)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Soil Organic Carbon													
S_1	2.25	2.14	2.09	2.16	2.30	2.25	2.30	2.04	2.11	2.05	2.11	2.27	2.07
S_2	2.65	2.55	1.96	2.04	2.50	2.03	2.26	2.29	2.20	1.82	2.35	2.31	1.92
S_3	2.47	2.07	2.22	2.05	2.25	1.99	2.05	2.50	2.20	2.19	2.28	2.32	2.01
S_4	2.40	2.26	2.19	1.99	2.24	2.17	2.31	2.02	2.26	2.07	1.92	2.26	2.08
S_5	2.44	2.19	2.15	1.97	2.06	1.76	2.14	1.92	1.83	2.03	2.31	2.32	1.89
S_6	2.60	2.08	2.15	2.14	2.24	2.49	2.08	1.75	2.05	2.04	2.06	2.36	2.46

Factors	$CD_{0.05}$	SEm±
SW×S	0.282	0.102

S_1	**Agrisilviculture**	S_4	**Agrisilvihorticulture**
S_2	**Agrihorticulture**	S_5	**Silvipasture**
S_3	**Agrihortisilviculture**	S_6	**Grassland**

It was recorded that (Table 77) soil organic carbon in all systems varied significantly among sub-watersheds. In agrisiliviculture system, highest soil organic carbon was recorded in SW_5 (2.30 %) which was statistically at par with $SW_{12}S_1$ (2.27 %). In agrihorticulture system highest soil organic carbon occurred in SW_1S_2 (2.65 %) which was statistically at par with SW_2S_2 (2.55 %) and SW_5 S_2 (2.50 %). Whereas, in agrihortisilviculture system maximum soil organic carbon was recorded in SW_8S_3 (2.50 %) which was at par with SW_1S_3 (2.47 %). In agrislivihorticulture system, highest soil organic carbon was recorded in SW_1S_4 (2.40 %) which was significantly higher than all other sub-watersheds. In silvipasture system, maximum soil organic carbon was recorded in SW_1S_5 (2.44 %) which was statistically at par with $SW_{12}S_5$ (2.32 %) and $SW_{11}S_5$ (2.31 %). In grassland highest soil organic carbon was recorded SW_1S_6 (2.60 %) which was statistically at par with SW_5S_6 (2.49 %), $SW_{13}S_5$ (2.46 %) and $SW_{12}S_6$ (2.36 %).

4.8 BULK DENSITY (g/cm^3)

A perusal of the data in Table 78 revealed that mean maximum bulk density of soil was recorded in grassland (1.27) which was significantly higher than all other systems. Minimum mean bulk density of soil was obtained in agrisilvicutlure systems (1.20). Mean maximum bulk density (1.28) of soil was observed at elevation E_3 which was significantly higher than elevation E_1 (1.26) and elevation E_2 (1.14).

Table 78: Variation in soil bulk density (g/cm^3) relative to elevations and systems in sub-watersheds of Giri catchment

Systems (S)	ELEVATION (E)			
	E_1-(900-1300 m)	E_2- (1301-1700 m)	E_3- (1701-2100 m)	Mean (S)
Soil Bulk Density (g/cm^3)				
S_1	1.24	1.10	1.26	1.20
S_2	1.24	1.12	1.26	1.21
S_3	1.26	1.13	1.27	1.22
S_4	1.24	1.12	1.27	1.21
S_5	1.27	1.15	1.30	1.24
S_6	1.29	1.19	1.33	1.27
Mean (E)	1.26	1.14	1.28	

Factors	$CD_{0.05}$	SEm±
E	0.007	0.003
S	0.010	0.004
E×S	NS	0.006

S_1 Agrisilviculture
S_2 Agrihorticulture
S_3 Agrihortisilviculture
S_4 Agrisilvihorticulture
S_5 Silvipasture
S_6 Grassland

The interaction between systems and sub-watersheds exhibited non-significant effect on soil bulk density.

The data pertaining to the Table 79 showed that mean bulk density of soil varied with sub-watersheds and elevations. Among the different sub-watersheds, mean bulk density of soil was maximum (1.29) in SW_9 and SW_{10} which was statistically at par with SW_{12} but higher than the bulk density in other sub-watersheds. Mean minimum bulk density of soil was recorded in SW_{11} which was at par with $SW_{4.}$

The interaction effect of sub-watersheds and elevations on bulk density revealed that maximum bulk density was recorded in $SW_{12}E_3$ (1.37) which was significantly higher than other sub-watersheds. Minimum bulk density was recorded in SW_3 E_2 and SW_{11} E_2 (1.07). The effect of interaction of systems and sub-watersheds on soil bulk density was non-significant (Table 80).

4.8.1 Soil carbon density (t C ha^{-1})

A perusal of data in the Table 81 revealed that mean maximum soil carbon density (53.45 t C ha^{-1}) was in grassland followed by agrihortisilviculture, agrihorticulture, Agrisilvihorticulture, agrisilviculture with their respective values 52.57 t C ha^{-1}, 51.88 t C ha^{-1} and 50.02 t C ha^{-1}, respectively in the descending order. Minimum, soil carbon density (49.76 tha^{-1}) was recorded in silvipasture system. Also, it was evident from the result that mean soil carbon density in systems was maximum at elevation E_3 (53.91 t C ha^{-1}) which was significantly higher than mean soil carbon density at elevations E_1 (52.37 t C ha^{-1}) and E_2 (48.15 t C ha^{-1}).

The interaction effect of elevation and systems on soil carbon density revealed that maximum soil carbon density occurred in S_3E_3 (56.70 t C ha^{-1}), it was statistically alike with S_6E_1 (56.02 t C ha^{-1}), S_2E_3 (55.64 t C ha^{-1}), S_4E_3 (54.06 t C ha^{-1}) and S_3E_1 (54.04 t C ha^{-1}). Minimum soil carbon density was recorded in S_2E_2 (47.02 t C ha^{-1}).

Data presented in the Table 82 revealed that maximum soil carbon density was occurred in SW_1 (59.09 t C ha^{-1}). It was significantly different from all other sub-watersheds. The minimum (47.29 t C ha^{-1}) soil carbon density was found in SW_4 which was statistically at par with SW_{10}, (49.87 t C ha^{-1}), SW_{11} (48.90 t C ha^{-1}), SW_3 (48.41 tha^{-1}) and SW_{13} (48.39 tha^{-1}).

Table 79: Soil Bulk density (g/cm^3) and its variation at different elevations in sub-watersheds

Elevation (E)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Soil Bulk Density (g/cm^3)													
E_1 (900-1300 m)	1.26	1.24	1.20	1.25	1.20	1.25	1.24	1.31	1.30	1.33	1.19	1.30	1.24
E_2 (1301-1700 m)	1.12	1.13	1.07	1.08	1.12	1.17	1.16	1.17	1.21	1.19	1.07	1.17	1.11
E_3 (1701-2100 m)	1.27	1.28	1.22	1.24	1.22	1.27	1.28	1.32	1.36	1.34	1.23	1.37	1.26
Mean (SW)	1.22	1.22	1.17	1.19	1.18	1.23	1.22	1.27	1.29	1.29	1.16	1.28	1.20

Factors	$CD_{0.05}$	SEm±
SW	0.015	0.005
SW×E	0.025	0.009

Table 80: Variation in soil bulk density (g/cm^3) relative to systems and sub-watersheds

Systems (S)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Soil Bulk Density (g/cm^3)													
S_1	1.21	1.19	1.11	1.10	1.18	1.21	1.21	1.29	1.15	1.25	1.11	1.34	1.22
S_2	1.14	1.30	1.16	1.15	1.15	1.25	1.22	1.15	1.39	1.20	0.94	1.44	1.22
S_3	1.26	1.24	1.13	1.20	1.21	1.22	1.33	1.21	1.27	1.13	1.22	1.29	1.18
S_4	1.23	1.13	1.25	1.19	1.22	1.28	1.14	1.25	1.20	1.23	1.20	1.19	1.26
S_5	1.27	1.22	1.14	1.21	1.10	1.23	1.14	1.41	1.33	1.41	1.26	1.31	1.10
S_6	1.20	1.26	1.20	1.29	1.22	1.18	1.31	1.30	1.39	1.52	1.26	1.13	1.25

Factors	$CD_{0.05}$	SEm±
SW×S	NS	0.006

S_1	**Agrisilviculture**	S_4	**Agrisilvihorticulture**
S_2	**Agrihorticulture**	S_5	**Silvipasture**
S_3	**Agrihortisilviculture**	S_6	**Grassland**

Table: 81: Variation in soil carbon density (t C ha^{-1}) relative to elevations and systems in sub-watersheds of Giri catchment

Systems (S)	ELEVATION (E)			
	E_1-(900-1300 m)	E_{2}- (1301-1700 m)	E_{3}- (1701-2100 m)	Mean (S)
Soil Carbon Density				
S_1	51.66	47.20	51.19	50.01
S_2	52.97	47.02	55.64	51.88
S_3	54.04	46.96	56.70	52.57
S_4	51.27	48.20	54.06	51.18
S_5	48.25	47.92	53.12	49.76
S_6	56.02	51.57	52.75	53.45
Mean (E)	52.37	48.15	53.91	

Factors	$CD_{0.05}$	SEm±
E	1.42	0.51
S	2.01	0.72
E×S	3.49	1.25

S_1 Agrisilviculture; S_2 Agrihorticulture; S_3 Agrihortisilviculture; S_4 Agrisilvihorticulture; S_5 Silvipasture; S_6 Grassland

The interaction effect of sub-watersheds and elevations on soil carbon density revealed that maximum carbon density occurred in SW_1E_3 (72.45t ha^{-1}). It was significantly higher than all other interaction combinations. The minimum soil carbon density was recorded in SW_{11} E_2 (36.88 t C ha^{-1}).

It was recorded that the soil carbon density in all the systems varied significantly among sub-watersheds (Table 83). In agrisiliviculture system highest soil carbon density was recorded in SW_7 (54.73 t C ha^{-1}) which was statistically at par with SW_1 (54.03 t C ha^{-1}), SW_{12} (53.21 t C ha^{-1}), SW_8 (50.90 t C ha^{-1}), SW_2 (50.35 t C ha^{-1}), SW_{13} (49.39 t C ha^{-1}). Soil carbon density in agrihorticulture system was recorded maximum in SW_2 (65.35 t C ha^{-1}) which was statistically at par with SW_{12} (62.48 tha^{-1}) and SW_1 (59.94 t C ha^{-1}). Whereas, agrihortisilviculture system showed maximum soil carbon density in SW_1 (62.45 t C ha^{-1}) which was at par with SW_8 (59.43 t C ha^{-1}). In agrislivihorticulture system SW_1 displayed highest (58.02 t C ha^{-1}) soil carbon density which was at par with SW_5 (54.02 t C ha^{-1}), SW_6 (53.64 t C ha^{-1}), SW_9 (52.59 t C ha^{-1}) and $SW_{12}S_4$ (52.23 t C ha^{-1}). Silvipasture system exhibited maximum soil carbon density in SW_1 (61.24 t C ha^{-1}) which was statistically at par with SW_{12} (57.52 t C ha^{-1}). Grassland system in SW_1 displayed maximum (60.72 t C ha^{-1}) soil carbon density which was statistically at par with SW_{13} (59.45 t C ha^{-1}), SW_{10} (57.89 t C ha^{-1}) and SW_6 (57.72 t C ha^{-1}).

Table 82: Soil carbon density (t C ha^{-1}) and its variation at different elevations in sub-watersheds

Elevation (E)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Soil Carbon Density (t C ha^{-1})													
E_1 (900-1300 m)	55.43	53.31	54.71	45.59	50.84	48.90	54.22	56.10	55.49	52.14	49.92	53.88	50.24
E_2 (1301-1700 m)	50.32	50.84	45.12	44.62	51.36	53.98	51.41	50.22	50.18	46.86	36.88	47.91	46.21
E_3 (1701-2100 m)	72.45	55.62	45.41	51.66	54.65	48.45	50.51	47.43	50.29	50.62	59.92	65.09	48.73
Mean (SW)	59.40	53.26	48.41	47.29	52.29	50.44	52.05	51.25	51.98	49.87	48.90	55.63	48.39

Factors	$CD_{0.05}$	SEm±
SW	2.96	1.06
SW×E	5.13	1.84

Table 83: Variation in soil carbon density (t C ha^{-1}) relative to systems and sub-watersheds

Systems (S)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Soil Carbon Density (t C ha^{-1})													
S_1	54.03	50.35	45.43	44.60	53.02	53.08	54.73	50.90	47.21	48.65	45.60	53.21	49.39
S_2	59.94	65.35	44.50	45.47	55.72	49.09	53.74	51.49	57.51	42.13	41.03	62.48	45.94
S_3	62.45	50.34	49.46	48.34	54.08	47.43	53.48	59.49	54.10	47.68	54.46	55.85	46.20
S_4	58.02	49.45	53.79	45.79	54.02	53.64	51.37	49.44	52.59	48.99	45.40	52.23	50.58
S_5	61.24	52.80	47.81	46.59	43.33	41.71	47.32	52.72	46.89	53.91	56.29	57.52	38.78
S_6	60.72	51.24	49.48	52.95	53.57	57.72	51.65	43.45	53.61	57.89	50.64	52.46	59.45

Factors	$CD_{0.05}$	SEm±
SW×S	7.26	2.614

S_1 Agrisilviculture **S_4 Agrisilvihorticulture**
S_2 Agrihorticulture **S_5 Silvipasture**
S_3 Agrihortisilviculture **S_6 Grassland**

4.8.2 Total carbon density of systems (t C ha^{-1})

A critical review of data in Table 84 reveals that the total carbon density (vegetation + soil) was significantly influenced by sub-watersheds and elevations. The mean total carbon density of system at elevation E_3 (89.41 t C ha^{-1}) was significantly higher than other elevations and it was found increasing from E_1 through E_3. Irrespective of elevation, systems also differed in total soil carbon density significantly. It was also evident from the results that mean total carbon density in different systems decreased significantly in the order: S_5 (94.38 t C ha^{-1}) > S_4 (92.17 t C ha^{-1}) > S_3 (92.05 t C ha^{-1}) > S_2 (82.16 t C ha^{-1}) > S_1 (81.58 t C ha^{-1}) > S_6 (55.91 t C ha^{-1}).

The interaction effect of elevations and systems on total carbon density of systems revealed that maximum total carbon density (102.52 t C ha^{-1}) occurred in S_5-E_3 which was statistically at par S_3E_3 (100.79 t C ha^{-1}) and S_4E_3 (100.70 t C ha^{-1}). Minimum total carbon density was recorded in grasslands at S_6E_2 (53.97 t C ha^{-1}).

It was evident from the figures in Table 85 that among the tree-based systems, significantly low total carbon density of system was recorded in SW_4 at elevation E_2 (74.25 t C ha^{-1}).

Table 84: Variation in total carbon density (t C ha^{-1}) of systems relative to elevations and systems in sub-watersheds of Giri catchment

Systems (S)	ELEVATION (E)			
	E_1-(900-1300 m)	E_2- (1301-1700 m)	E_3- (1701-2100 m)	Mean
Total carbon density of system (t C ha^{-1})				
S_1	78.71	78.04	87.98	81.58
S_2	80.07	77.07	89.35	82.16
S_3	90.00	85.36	100.79	92.05
S_4	88.74	87.06	100.70	92.17
S_5	88.42	92.21	102.52	94.38
S_6	58.63	53.97	55.13	55.91
Mean	80.76	78.95	89.41	

Factors	$CD_{0.05}$	SEm±				
E	1.53	0.55	S_1	Agrisilviculture	S_4	Agrisilvihorticulture
S	2.16	0.78	S_2	Agrihorticulture	S_5	Silvipasture
E×S	3.75	1.35	S_3	Agrihortisilviculture	S_6	Grassland

The maximum mean total carbon density of systems was recorded in in the sub-watershed SW_1 (91.90 t C ha^{-1}) which was statistically similar with SW_{12} (90.79

t C ha^{-1}) but significantly higher than all other sub watersheds (Table 85). In the interaction, effect of sub-watersheds and elevations on total carbon density was found to be significant. It was observed that, maximum total carbon density of system (108.13 t C ha^{-1}) occurred in SW_1E_3 which was statistically similar with $SW_{12}E_3$ (103.71 t C ha^{-1}) but significantly higher from all other interactions. Minimum total carbon density was obtained in SW_4E_1 (70.09 t C ha^{-1}).

It was recorded that the total carbon density of systems varied significantly among sub-watersheds (Table 86). In agrisiliviculture system highest total carbon density of system was recorded in $SW_{12}S_1$ (87.71 t C ha^{-1}) which was statistically at par with SW_5S_1 (87.47 t C ha^{-1}), SW_7S_1 (86.81 t C ha^{-1}), SW_9S_1 (86.82 t C ha^{-1}), $SW_{13}S_1$ (86.57 t C ha^{-1}), SW_2S_1 (81.23 t C ha^{-1}) and SW_1S_1 (86.00 t C ha^{-1}). In agrihorticulture system maximum total carbon density of system occurred in SW_2S_2 (100.68 t C ha^{-1}) which was statistically at par with $SW_{12}S_2$ (95.79 t C ha^{-1}). Whereas, in agrihortisilviculture system maximum total carbon density of system was recorded in $SW_{12}S_3$ (106.33 t C ha^{-1}) which was statistically at par with SW_5S_3 (104.30 t C ha^{-1}), $SW_{11}S_3$ (103.13 t C ha^{-1}) and SW_1S_3 (99.10 t C ha^{-1}). In agrislivihorticulture system highest total carbon density of systemwas recorded in SW_1S_4 (101.31 t C ha^{-1}) which was statistically at par with $SW_{12}S_4$ (98.77 t C ha^{-1}) and SW_8S_4 (96.84 t C ha^{-1}). Maximum total carbon density in silvipasture system was recorded at SW_1S_5 (108.92 t C ha^{-1}) which was significantly higher than all other interactions, whereas minimum total carbon density of system was recorded in SW_4S_5 (84.72 t C ha^{-1}). In grasslands maximum total carbon density of system was recorded in $SW1S_6$ (63.42 t C ha^{-1}) which was statistically at par with $SW5S_6$ (56.10 t C ha^{-1}), SW_6S_6 (60.80 t C ha^{-1}), SW_9S_6 (56.27 t C ha^{-1}), $SW_{10}S_6$ (59.99 t C ha^{-1}), $SW_{12}S_6$ (55.17t C ha^{-1}) and $SW_{13}S_6$ (61.60 t C ha^{-1}).

4.9 ECONOMIC ANALYSIS

4.9.1 Gross return

The mean gross returns from agrisilviculture (Rs 352600.00 $ha^{-1}yr^{-1}$), agrihorticulture (Rs 344555.00 $ha^{-1}yr^{-1}$) and agrisilvihorticulture (328964.00 Rs $ha^{-1}yr^{-1}$) systems were at par but significantly higher than agrihortisilviculture (S3) (Rs 271883.00 $ha^{-1}yr^{-1}$). Also, the gross return from silvipasture (Rs 22,377.00 ha^{-1} yr^{-1}) and grassland (Rs 15150.00 $ha^{-1}yr^{-1}$) were at par, but significantly low than the other

Table 85: Total carbon density (t C ha^{-1}) of systems and its variation at different elevations in sub-watersheds

Elevation (E)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Total carbon density of system (t C ha^{-1})													
E_1 (900-1300 m)	85.72	83.83	81.75	70.09	81.82	76.97	82.23	81.42	82.48	79.71	78.05	84.00	81.85
E_2 (1301-1700 m)	81.84	81.17	73.08	70.33	85.16	82.63	81.97	79.30	81.74	74.37	69.61	84.66	80.53
E_3 (1701-2100 m)	108.13	91.06	78.47	82.32	94.38	82.93	83.70	81.17	87.88	82.44	97.82	103.71	88.34
Mean (SW)	91.90	85.35	77.77	74.25	87.12	80.84	82.63	80.63	84.03	78.84	81.83	90.79	83.57

Factors	$CD_{0.05}$	SEm±
SW	3.193	1.149
SW×E	5.530	1.990

Table 86: Variation in total carbon density (t C ha^{-1}) of systems relative to systems and sub-watersheds

Systems (S)	SUB-WATERSHED (SW)												
	SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8	SW_9	SW_{10}	SW_{11}	SW_{12}	SW_{13}
Total carbon density of system (t C ha^{-1})													
S_1	86.00	81.23	70.38	76.20	87.47	84.05	86.81	77.32	86.82	73.76	76.20	87.71	86.57
S_2	92.63	100.68	69.63	71.94	87.45	74.37	77.72	78.30	90.84	69.35	78.68	95.79	80.73
S_3	99.10	88.79	91.48	74.16	104.30	88.96	87.22	85.90	93.19	77.61	103.13	106.33	96.49
S_4	101.31	91.04	93.58	82.78	95.19	89.24	94.68	96.84	86.79	93.72	88.98	98.77	85.28
S_5	108.92	96.96	90.11	84.72	92.19	87.62	95.15	99.69	90.30	98.62	90.96	100.99	90.76
S_6	63.42	53.43	51.42	55.69	56.10	60.80	54.21	45.72	56.27	59.99	53.01	55.17	61.60

Factors	$CD_{0.05}$	SEm±
SW×S	7.821	2.814

S_1 Agrisilviculture
S_2 Agrihorticulture
S_3 Agrihortisilviculture
S_4 Agrisilvihorticulture
S_5 Silvipasture
S_6 Grassland

agroforestry systems (Table 87). However, it was found that gross returns from the systems decreased in the order: $S_1 > S_2 > S_4 > S_3 > S_5 > S_6$. It was recorded that gross return from silvipasture was less than 8 % and from grassland less than 5% of what we get from agrihotisilviculture system, the least remunerative amongst agroforestry systems i.e., S_1, S_2, S_3 and S_4. Gross returns from systems was significantly higher at elevation E_3 but was at par on elevations E_1 and E_2.

The interaction between elevations and systems showed that maximum (Rs 540110.00 $ha^{-1}yr^{-1}$) gross return was obtained from agrihorticulture system (S_2E_3) at elevation E_3 and minimum gross return (Rs 14,175.00 $ha^{-1}yr^{-1}$) was obtained from grassland (S_6E_3) at elevation E_3.

Table. 87 Gross return (Rs $ha^{-1}yr^{-1}$) from systems in Giri catchment of HP

Systems (S)	Elevation			Mean (S)
	E_1 (900 -1300 m)	E_2 (1301 - 1700 m)	E_3 (1701 - 2100 m)	
S_1	3,80,814.00	3,30,788.30	3,46,197.70	**3,52,600.00**
S_2	2,93,563.30	1,99,991.70	5,40,110.00	**3,44,555.00**
S_3	1,90,291.70	2,85,825.00	3,39,532.70	**2,71,883.10**
S_4	2,46,940.80	3,34,671.70	4,05,281.70	**3,28,964.70**
S_5	20,531.60	24,691.60	21,908.33	**22,377.18**
S_6	15,750.00	15,525.00	14,175.00	**15,150.00**
Mean (E)	**1,91,315.20**	**1,98,582.20**	**2,77,867.60**	

	C.D.	SEm ±
Elevation (E)	41,707.00	14,449.00
System (S)	58,983.00	20,435.00
Interaction E X S	102,162.00	35,394.00

S_1	**Agrisilviculture**	S_4	**Agrisilvihorticulture**
S_2	**Agrihorticulture**	S_5	**Silvipasture**
S_3	**Agrihortisilviculture**	S_6	**Grassland**

4.9.2 Total expenses

Data presented in Table 88 revealed that mean maximum total expenses incurred in agrihorticulture system (Rs 174690.00 ha^{-1} yr^{-1}) were statistically at par with agrisiviculture system (Rs 168017.00 ha^{-1} yr^{-1}) but significantly higher than other systems. Minimum expenditure incurred in grassland (Rs 6000 ha^{-1} yr^{-1}).The f expenditure incurred in systems at different elevations revealed that maximum total expenses were done in systems at elevation E_3 (Rs 115698.00 ha^{-1} yr^{-1}) which was significantly higher than the expenses done at elevations E_1 and E_2.

Table. 88 Total expenses (Rs $ha^{-1}yr^{-1}$) incurred in systems in Giri catchment of HP

Systems (S)	Elevation			Mean (S)
	E_1 (900 -1300 m)	E_2 (1301 - 1700 m)	E_3 (1701 - 2100 m)	
S_1	1,80,802.10	1,47,126.90	1,76,124.90	**1,68,017.90**
S_2	1,71,935.40	1,30,746.40	2,21,391.00	**1,74,690.90**
S_3	99,173.19	1,30,360.60	1,41,902.90	**1,23,812.30**
S_4	128660.00	139836.60	142303.90	**136933.50**
S_5	6466.67	7166.67	6466.67	**6700.00**
S_6	6000.00	6000.00	6000.00	**6000.00**
Mean (E)	**98,839.57**	**93,539.54**	**1,15,698.20**	

	C.D.	SE(m) ±
Elevation (E)	14,465.00	5,011.00
System (S)	20,457.00	7,087.00
Interaction E X S	35,434.00	12,276.00

S_1 Agrisilviculture **S_4 Agrisilvihorticulture**
S_2 Agrihorticulture **S_5 Silvipasture**
S_3 Agrihortisilviculture **S_6 Grassland**

The interaction between systems and elevations revealed that highest cost (Rs 221391.00 $ha^{-1}yr^{-1}$) was incurred in agrihorticulure system (S_2) at elevation E_3. It was significantly higher than all other interactions. Minimum (Rs 6000.00 $ha^{-1}yr^{-1}$) cost was recorded in grasslands at all the three elevations.

4.9.3 Net return (Rs $ha^{-1}yr^{-1}$)

A perusal of data in Table 89 revealed that mean maximum net return was obtained from agrisilviculture system (Rs 277415.00 ha^{-1} yr^{-1}) which was statistically at par with agrisilvihorticulture (270747.00 Rs ha^{-1} yr^{-1}) and agrihortisilviculture (Rs 269033.00 ha^{-1} yr^{-1}) systems. Minimum (Rs 13150.00 ha^{-1} yr^{-1}) net return was obtained from grassland system it was significantly lower than all other systems except silvipasture system (Rs 20143.00 $ha^{-1}yr^{-1}$). The variation of net return obtained from systems at different elevations revealed that maximum net return was obtained at elevation E_3 (Rs 229452.00 $ha^{-1}yr^{-1}$) which was significantly higher than the net return obtained at elevations E_1 and E_2.

The interaction of elevations and systems exhibited that maximum net return was obtained from agrihorticulture system at elevation E_3 (Rs 449682.00 ha^{-1} yr^{-1}). However, it was statistically at par with agrisilvihorticulture at elevation E_3 (Rs 342278.00 ha^{-1} yr^{-1}). Minimum net return of was obtained from grassland (S_6) at elevation E_3 (Rs 12175.00 ha^{-1} yr^{-1}).

Table. 89 Net return (Rs $ha^{-1}yr^{-1}$) from systems at different elevations in Giri catchment of HP

Systems (S)	Elevation			Mean (S)
	E_1 (900 -1300 m)	E_2 (1301 - 1700 m)	E_3 (1701 - 2100 m)	
S_1	2,81,576.90	2,69,458.80	2,81,211.70	**2,77,415.80**
S_2	2,17,976.90	1,39,439.80	4,49,682.40	**2,69,033.00**
S_3	1,52,431.80	2,54,152.50	2,71,056.60	**2,25,880.30**
S_4	1,86,308.80	2,83,654.70	3,42,278.40	**2,70,747.30**
S_5	18,931.60	21,191.60	20,308.33	**20,143.84**
S_6	13,750.00	13,525.00	12,175.00	**13,150.00**
Mean (E)	**1,45,162.70**	**1,63,570.40**	**2,29,452.10**	

	C.D.	SEm ±
Elevation (E)	48,972.00	16,966.00
System (S)	69,257.00	23,994.00
InteractionE X S	119,957.00	41,559.00

S_1 Agrisilviculture **S_4 Agrisilvihorticulture**
S_2 Agrihorticulture **S_5 Silvipasture**
S_3 Agrihortisilviculture **S_6 Grassland**

4.9.4 Benefit-Cost ratio

The Benefit-Cost ratio in silvipasture system was significantly higher (3.34) than all other systems. However, it was found that mean benefit-cost ratio of the systems decreased in the order: $S_6 > S_5 > S_4 > S_3 > S_1$. Mean minimum benefit-cost ratio (1.87) was recorded in agrihorticulture system, which was significantly lower

Table. 90 Benefit-cost ratio of vegetation systems at different elevations in Giri catchment of HP

Systems (S)	Elevation			Mean (S)
	E_1 (900 -1300 m)	E_2 (1301 - 1700 m)	E_3 (1701 - 2100 m)	
S_1	2.08	2.24	1.97	**2.10**
S_2	1.70	1.52	2.40	**1.87**
S_3	1.93	2.16	2.43	**2.17**
S_4	1.93	2.40	2.83	**2.38**
S_5	3.19	3.45	3.38	**3.34**
S_6	2.63	2.59	2.36	**2.53**
Mean (E)	**2.24**	**2.39**	**2.56**	

	C.D.	SEm ±
Elevation (E)	0.15	0.05
System (S)	0.21	0.07
InteractionE X S	0.38	0.13

S_1 Agrisilviculture **S_4 Agrisilvihorticulture**
S_2 Agrihorticulture **S_5 Silvipasture**
S_3 Agrihortisilviculture **S_6 Grassland**

than all other systems. The variation of mean benefit- cost ratio recorded in systems at different elevations revealed that mean maximum benefit-cost ratio were recorded at elevation E_3 (2.56) which was significantly higher than the Benefit- Cost ratio recorded at elevations E_1(2.24) and E_2 (2.56).

The interaction of systems and elevations exhibited that maximum benefit-cost ratio (3.45) was recorded in silvipasture (S_5) at elevation E_2 and it was statistically at par with silvipasture (S_5) at elevation E_3 (3.38) and silvipasture (S_5) at elevation E_1 (3.49). The benefit-cost ratio of silvipasture system at all three elevations was significantly higher than other interactions (Table 90).

Chapter-5

DISCUSSION

The results emerged out of the present investigation entitled "Pattern, composition and vegetation dynamics of traditional agroforestry systems in Giri catchment of H.P." have been discussed in this chapter by establishing cause and effect relationships, wherever necessary or feasible in the focus of pertinent available literature under the following headings:

5.1 SOCIOECONOMIC CONDITIONS IN THE CATCHMENT

The integrated watershed management of the late 1980s was a forerunner of sustainable rural development, as advocated at the 1992 Rio summit. Both approaches share a systemic view of biophysical and social interactions, a concern for the on- and off-site and the short and long-term effects of change, and a fundamental belief that appropriate social management can optimize the functioning of human ecosystems. Both aim to generate benefits for people and environments.

Every watershed has distinct physical and social identities. There are many indicators in it, which can help managers to predict the likely changes that may occur here over the time. They are measured through appropriate methodologies to ascertain likely changes. Table 91 depicts some indicators and measures that were considered important in the perspective of Giri catchment in Himachal Pradesh (India) relative to its socioeconomic conditions.

Socioeconomic status (SES) is an economic and sociological combined total measure of a person's work experience and of an individual's or family's economic and social position in relation to others, based on income, education, and occupation. When analyzing a family's SES, the household income, earners' education, and occupation is examined, as well as combined income versus with an individual are assessed. Socioeconomic status is used to identify family categories of individuals.

Table 91. Socioeconomic indicators and measures in Giri catchment of HP.

Indicators	Measures
Land use	Area owned by each household Area used for cultivation Area under other land uses
Demographics	Household heads Qualification of family members Male and female population Professional competence
Unique characteristics	Uses of natural resources Cropping - seasonal variation in cropping pattern (Rabi and Kharif crops), marketing of agricultural produce, income from agriculture Fodder demand- fodder resources, plant species utilized for fodder Fuelwood demand – types of energy used, fuelwood plant species, methods of fuelwood collection Animal rearing – type and numbers Agricultural inputs – nursery preparation, fertilisers used, plant protection etc.

The Giri-catchment in Himachal Pradesh is characterized by fragmented land holdings, marginal farmers, undulating terrain, rainfed subsistence agriculture, low-income resources and sparse population. Land is a part of man's natural heritage. The level of skills within the population and attitudes towards economic and social development are associated with the increased literacy rates and availability of education facilities. In Giri catchment, households' characteristics summarized in Tables 1 to 4 reflect the subsistence socioeconomic condition of villages. The agricultural sector alone was employing most of the active population, and the area was relying on subsistence agriculture. Socio-demographic characteristics showed no striking differences across villages. Literacy rate varied marginally at different elevations and in sub-watersheds. Overall literacy rate is around 85 % and this figure is very close to the literacy rate of 83.78 % for the state of Himachal Pradesh (GOHP, 2011). However, it was pertinent to note that only 10 % population is graduate or higher. Other workers who have worked on 'socioeconomic status' in other parts of H.P. reported that literacy percent varied from 88.09 % in Karganoo and to 75.79 % in Katli panchayat in Rajgarh and Sarah block of district Sirmour (Joshi, 2011). While, Nisha (2013) reported overall level of literate person in a family as 92.23% in mid-hills of Sirmour district. Likewise, in other parts of India, Kareemulla et al. (2002) reported 77 % literacy in Budelkhand region of Uttar Pradesh; Sharma et al. (2009a) recorded 80% literacy in villages of Garhwal, Uttarakhand and Mughal et al., (2000) reported 31 % literacy in rural Srinagar of Kashmir valley. In general, education in socioeconomically strong families is stressed as an important topic in the household and local community, while in poorer areas where food and safety are priority, education can take a backseat. The same is true for Giri catchment as the people residing here are not rich, hence their main efforts focuses to earn both ends meal for their family members rather than achieving higher education which otherwise can bring them good employment opportunities.

Education also plays a role in family income. Medium earnings increase with each level of education. The higher education brings out professionalism in an individual and makes him better adapted to its surrounding. Thus, always there are chances that he may make higher earnings. Higher levels of education are associated with better economic and psychological outcomes (i.e.: more income, more control and, greater social support and networking). Education plays a major role in skill sets for acquiring jobs. Families with low socioeconomic status often lack the financial, social, and educational supports. In Giri catchment, though the literacy rate is comfortable but around 90 per cent villagers have education below graduation and that entitles them for small jobs that too many a times are not permanent. Thus, in current scenario the people living here seems to keep higher education at the back seat. Démurger and Martin (2010) also noted that average schooling level of household heads did not exceed primary school in their study on socio-demographic status of some villages in China.

The other pertinent demographic factor in an area that determine the intensity of dependence of population on natural resources is the sex ratio, because if the males are destined to do jobs away from their homes females are given the responsibility to seek various household needs from nearby natural resources. The sex ratio in the Giri catchment is not dwindling (947 females to the 1000 males) but definitely less than the sex ratio recorded for Himachal Pradesh i.e., 974 females for 1000 males (GOHP, 2011). Sharma, (2012) has reported higher sex ratio of 988 female to 1000 male in one of the sub-watersheds (Sd4e) of Giri Catchment. Household heads are mostly men, this observation is consistent with Heltberg et al. (2000); Chen et al. (2006) and Démurger and Martin (2010). The complacent gender ratio in the catchment perhaps is good for households as most of the activities of agro-ecosystem are women centered in this area. All the agricultural operations in this catchment are performed by women except ploughing. Women have been food growers, processor and storers from the beginning of recorded history (Rawat and Adhikari, 2005; Eneh and Nkamnebe, 2011).

Household size is a parameter that determines the quantity of products required from neighbouring natural resources. In Giri catchment, the average household size is 6.97 with a maximum of 12. The result corroborates to the findings of Masoodi (2010) and Sharma, (2012) who reported average family size of 5 persons in Solan (HP). Joshi (2011) reported average family size of 6.5 persons at Karganoo and 7.0 persons at Katli at Rajgarh and Pacchad block of Sirmour (HP). Nisha (2013) reported average family size of 5.53 persons in mid-hills of HP. Sharma et al. (2009) recorded family size of 5.3 to 5.8 persons in Garhwal, Uttarakhand; Kareemulla et al. (2002) and Mughal et al., (2000) reported an average of 9 persons in a family in Budelkhand region of Uttar Pradesh and in rural Srinagar of Kashmir valley, respectively Démurger and Martin (2010) reported the average household size of 3.3 persons with a maximum of 6 in their study in some villages of China.

The land utilization pattern determines the type of farming system prevailing in an area. The agriculture income is dependent upon availability of arable land, its proper use, cropping schedule, transportation cost and market value of the agricultural produce. Unscientific use of land, lowers the efficiency of other factors of production such as labour and capital used on it. The extent of landholdings with people in the Giri catchment restricts the possibilities of extensive cultivation as the average landholding size per household is 1.10 ha. Cultivated land in the catchment accounted for around 77% of the total landholding of a household. The percentage of land under orchards was higher at elevation E_3 (1701 – 2100 m) perhaps due to suitable climate for temperate fruits.

Fuelwood is the most common and primary energy source among rural populations in developing countries (Allen et al., 1998), and is used for cooking and heating rooms and water during the winter season. Other forms of commercial energy are beyond the reach of ordinary people because of poor socioeconomic conditions (Chettri et al., 2002). Today, India still relies on fuelwood to satisfy 24% of total energy consumption. India's forests can sustainably provide 41 x 10^6 m^3 of fuelwood per year, though current annual demand for wood remains at 241 x 10^6 m^3 (World Resources Institute, 1994). In India, in the house sector, bulk of energy is spent on cooking, according to 1991 census; about 30% of urban population relies on fuelwood and twigs, whereas, about 78% of the population relies on fuelwood and twigs in rural sector, the situation is similar in Giri catchment of HP. The average per capita consumption of the fuelwood in the Giri catchment is 3.79 kg/day. The consumption of fuelwood per household showed increasing trend with decrease in elevation with 30.92 kg/household/day at E_3 (1701 – 2100 m), 25.63 kg/household/day at elevation E_2 (1301-1700 m) and 22.77 kg/household/day at elevation E_1 (900-1300 m). Similar variation in fodder requirement with change in elevation was also noted by Sharma, (2012) in Sd4e sub-watershed of Giri catchment with consumption of 40 Kg/household/day at elevation E_3 (1600 & above); 30 kg/household/day at elevation E_2 (1150-1600m) and 20 kg/household/day at elevation E_1 (860-1150m).

The quantity of fuelwood used per household in Giri catchment, as recorded in the present study, is considerably higher than the figures quoted by Khanduri et al. (2002), Bhatt and Sachan (2004) and Chandra et al. (2008) for Garhwal in Central Himalaya; Shaheen et al. (2011) for Bagh district in western Himalaya in Pakistan; Donovan, (1981) for western south-east Asia and Mahat et al. (1987) for trans-Himalayan Nepal, But, it is very less as compared to the fuelwood consumption of 40-60 kg/household/day recorded by Sharma (2012) for the Sd4e sub-watershed of Giri catchment in Solan, HP. Mughal et al. (2000) reported 12.02 q/ha fuelwood consumption per household of 9 persons in rural Srinagar of Kashmir valley. However, it is certainly lower than the finding of Sundriyal and Singh (2009) for Central Himalaya in India; Chen et al. (2006) and, Démurger and Martin (2010) for China. The fuelwood consumption is regulated by climate and, socio-demographic features of any area like personal income, prices of fuelwood and kerosene oil and household size (Onoja and Idiko, 2012). It was noted in the present study that consumption of wood increases in winters which reflects the importance of firewood use for heating. Zhou et al. (2008) and Démurger and Martin (2010) also reported the similar results on their studies in villages of China. The later has even estimated that the fuelwood consumption increases three times in winters.

Trees in forests and cultivable land are the prime source of fuelwood for the agrarian people of any area. Fuelwood consumption and forest degradation mostly focuses on India, Nepal, or African countries (Adhikari et al., 2004; Amacher et al., 1993; 1996; 1999; Baland et al., 2010; Heltberg et al., 2000; Mekonnen, 1999). Environmental impact of fuelwood collection on forest degradation rather than deforestation is emphasized because the former is deeply linked to the behavior of local population, including fuelwood collection, over-grazing, fires, whereas the latter is mostly due to forest exploitation and commercial logging (Duraiappah, 1998; Trossero, 2002; Wunder, 2001).

The fuelwood collection is correlated to forest degradation for the reasons like, income, poverty, opportunity costs, preferences, market imperfections, institutional weaknesses, family time used in collection and credit constraints (Arnold et al., 2003; 2006; Cooke et al., 2008; Duraiappah, 1998; Wunder, 2001; Démurger and Martin, 2010). Some workers argued that increasing firewood consumption is threatening the sustainable development of forest resources (Anderson & Fishwick, 1984; Eckholm, 1975). Not only that, Bruce et al. (2000) debated the adverse health consequences of indoor air pollution generated by burning wood, animal dung or agricultural residues. Agroforestry, on the other hand, is considered as an alternative to provide fuelwood and thereby curtail forest degradation. Geography or climate variations jointly affect fuelwood availability (Baland *et al.* 2010). In Giri catchment the trees like, *Grewia optiva*, *Acacia catechu*, *Celtis australis*, *Pinus roxburghii*, *Bauhinia variegata*, *Bombax ceiba*, *Quercus leucotrichophora, Albizzia lebbek,* and *Toona ciliata* are widely used for fuelwood extraction. Almost the same species has been referred as important fuelwood species in mid-hill Himalaya of HP by Masoodi, (2010), Joshi (2011), Farooq (2012) and Nisha (2013). Beside these species, Sharma, (2012) has reported *L. leucocephala* and *Quercus incana* as other common fuelwood species in SD4e sub-watershed of Giri catchment. Whereas, in Central Himalaya, Chandra et al. (2008) and Sharma et al.(2009) has reported that similar species are used for fuelwood extraction. It was noted that women or children were mainly involved in fuelwood collection which is usually a practice found in Nepal (Baland et al., 2010; Cooke, 1998) or India (Heltberg et al., 2000; Negi et al., 1999; Bhatt and Sachan, 2004; Singh et al., 2009 and Sharma et al., 2009) or China (Zhou et al., 2008; Démurger and Martin, 2010)

In the Himalayan region, domestic animals provides main draught power for agriculture system. They process crop residues, provide essential organic manure and generate farm income when they are sold (Thapa et al., 1991). Trees and shrubs often contribute substantial amount of leaf fodder during lean period through lopping/pruning activities. In India, demand of green fodder during 2010 was 1061 million tonnes but the supply of green fodder was 395 million tonnes, so there is deficit of 666 million tonnes (Dhyani et al., 2009). There is huge gap between demand and supply of fodder in country. The fodder scarcity could be reduced through fodder cultivation on farmlands and through silvipasture on wastelands. Promotion of silvipasture contributes in two form namely additional fodder supply that ensures proper rearing of livestock and environmental protections. The most serious problem is the unavailability of green forage, particularly in winter, causing deficiency of protein and vitamins, resulting in low milk production, shortened breeding span and decreased working capacity of bullocks (Palni et al., 1998). The fodder trees are integral part of the cultivable land of the farmers in Giri catchment and they act as buffer stock to feed their cattle in lean periods of the year. The animals are fed upon leaf fodder from trees like *Grewia optiva*, *Bauhinia variegata*, *Celtis australis, Morus alba* and *Quercus leucotrichophora* during lean period in Giri catchment. The same findings are reported by Joshi (2011), and Nisha (2013) in mid-hills of Sirmour, HP and Rawat et al. (2011) for north-western Himalaya in H.P. Grasslands, silvipastures and forests land uses are the main fodder resources in this area.

Almost everywhere in the mountains, agriculture is widely based on livestock power. Mountain communities are fully dependent on natural resources as well. Traditional agriculture is a socioeconomic symbiosis of crop and livestock production and, man power. In this type of system, besides human activities, livestock play a crucial role in strengthening the economy. Livestock power is a capital asset in this catchment. Common livestock species domesticated by people in the study area are cows, calves, goats, sheep, and buffaloes.

Fodder consumption in an area reflects the dependency of people on livestock rearing. Amount of fodder consumption however changes with the type of animal reared. In Giri catchment, average fodder consumption per household was 55.44 kg/day. This figure is considerably higher to the findings of Khanduri et al., (2002), Bhatt et al. (2004), Sharma et al. (2009) and Bagwari and Todaria (2011) for villages in Garhwal Himalaya and, Chandra et al. (2008) for Mussoorie hills Uttarakhand. Shaheen et al. (2011) have also quoted less fodder consumption in Bagh district in western Himalaya in Pakistan and likewise, Thapa et al. (1997) and Adhikari et al. (2007) quoted less fodder consumption in Nepal. Sharma, (2012) has recorded average fodder consumption of 45 kg/day in Sd4e sub-watershed of Giri catchment.

It was observed that green fodder consumption per household increased with the increase in elevation (Table 4). Sharma, (2012) however, reported least fodder consumption at the lowest elevation (860-1150 m) in Sd4e sub-watershed of Giri catchment. The fodder consumption at any place is directly correlated to number and type of animals reared by household. The fodder trees are integral part of the cultivable land of the farmers in this region and they act as buffer stock to feed their cattle in lean periods of the year. While, grasslands, silvipastures and forests are used mainly as regular fodder resources.

5.2 IDENTIFICATION OF AGROFORESTRY SYSTEMS

Although agroforestry is being practiced for thousands of years, it has been a focus scientific research for only 20-30 years. During this period research on different agroforestry systems from many regions have been reported (Gold and Hanover, 1987; Nair, 1987; Steppler and Nair, 1987; Zou and Stanford, 1990; Zhao hua et al. 1991, Clarke and Thaman, 1993, Nair, 2007; Nair et al. 1990). In India, there are several forms of agroforestry practices in vogue in different agro-ecological situations (Tejwani, 1987; Nair and Dagar, 1991; Chauhan and Dhyani, 1989; Khosla and Tokey, 1990; Dhadwal et al. 1995; Mazumdar, 1991). The Himalayan state of Himachal Pradesh has highly diverse agro-ecological conditions due to wide altitudinal range varying from 300 m to 6530 m above mean sea level accompanied by variation in properties of edaphic strata i.e., soil pH, fertility, soil structure, slope, aspect etc. Rainfall too exhibits a wide variability from 400 mm in extremely cold and dry conditions to 2000 mm in sub-humid and sub-tropical conditions. These ecological variations have resulted in high plant biodiversity and consequently variations in agroforestry systems existing here.

In Giri catchment, types of agroforestry systems at different elevations were same but the systems units in each agroforestry systems varied with elevation. At elevation E_1, 26 system units were recognized in agrisilviculture, 17 in agrihorticulture and 11 each in agrihortisilviculture and agrisilvihorticulture. At elevation E_2, agrisliviculture had 12 system units, agrihorticulture 12 system units, agrihortisilviculture 9 system units and agrisilvihorticulture 4 system units. Likewise, at elevation E_3, in agrisilviculture 12 system units were identified, in agrihorticulture 12 system units, in agrihortisilviculture 9 system units and in agrisilvihorticulture 4 system units were recognized (Tables 5 to 7). Such variations in the system units of an agroforestry at different elevations can be attributed to climatic variation and socioeconomic status of inhabitants where farmers' preference for species type, amount of income generated, agricultural inputs and access to government extension agencies play key role in selecting the components in agroforestry system.

The similar agroforestry systems have been reported by many workers in Himachal Pradesh. Kachru (1997) reported eight agroforestry systems namely, agrisilviculture (Maize, Wheat, Blackgram and Grewia, Morus), agrihorticulture (Wheat, Mustard and Pear), agri-silvihorticulture (Wheat, Mustard, Grewia and Apricot), pastoralsilviculture (Grewia, Bauhinia and grasses), pastoralhortisilviculture (Pear, Plum, Grewia and grasses), agrihortisilviculture (Maize, Blackgram Pear and Grewia), pastoralsilviculture (Chir pine, Acacia and grasses), and pasture in mid-hills of Himachal Pradesh. Likewise, Upadhyaya (1997) reported six agroforestry systems types namely, agrisiliviculture, agrisilvihorticulture, pastoralsilvihorticvultural, pastoralhortisilviculture and silvipasture in Balh valley of Himachal Pradesh. Goswami (2008) reported five agroforestry systems viz., agrisilvihorticulture (Maize, Wheat, Blackgram, Grewia, Ficus and Pear), agrohortisilviculture (Wheat, Rajmah, 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. Kumari et al., (2008) reported five agroforestry systems in Lahaul and Kinnuar in Himachal Pradesh viz., agrihorticulture (Pea, Potato and Apple), agrisilviculture (Pea, Potato, Rajmah and Salix), agrisilvipastoral (Pea, Salix and grasses), pastoralsilviculture (grasses and Salix) and pastoralhorticulture (grasses and Apple). Rajput (2010) reported that four agroforestry system viz, agrihorticulture (Maize, Blackgram, Cauliflower and Apple), agrisilviculture (Maize, Wheat, Grewia and Celtis), agrihorticulture (Maize, Wheat, Tomato, Apple and Grewia) and silvipasture (Grewia, Chir pine, Bauhinia and grasses) in Kullu valley of Himachal Pradesh (Table 92).

5.3 FLORAL DIVERSITY AND PHYTOSOCIOLOGY OF VEGETATION IN SYSTEMS

Plant community structure and its diversity patterns are important ecological attributes that correlates with prevailing environment as well as anthropogenic variables Each species plays a particular role in an ecosystem, limited by its ecological tolerances, that defines its ecological niche. The range of niche available and occupied in turn determines the biotic range within the ecosystem. Its diversity, in other words (Goodall, 1979). Diversity has been quantified in a wide variety of ways (Simpson, 1949; Macarthur and Macarthur, 1961; Pielou, 1969; Hill, 1973; Peet, 1974). Two basic components of species diversity are total number of species actually present and the degree to which they are equally important.

In Himachal Pradesh, agroforestry systems beside silvipasture and grasslands are vital to sustain livelihoods of rural people. Many workers have highlighted their importance in biodiversity conservation, biomass production, carbon sequestration and environmental amelioration. In Himalayan region, most of the farming systems are at the subsistence level (Fonzen and Oberholzer, 1984; Misra and Ramakrishnan 1982; Toky and Khosla, 1989 and Sundriyal et al., 1994) and have evolved over the years from trial and error by the farmers to meet out their demand for food, fodder, fuelwood and timber and present a wide spectrum of flora of distinct utility.

In Giri catchment land use under agroforestry exhibited that four agroforestry systems viz., agrisliviculture (AS), agrisilvihorticulture (ASH), agrihortisilviculture (AHS) and agrihorticulture (AH) were adopted by farmers. These systems varied in spatial and temporal arrangement of components. In AS the major crop component were cereals (maize, wheat and barley), pulses (black gram and rajmah) and oil seeds (mustard). The woody components in the form of *Grewia*, *Celtis*, *Bauhinia*, *Ficus* and *Morus* trees were intentionally retained on the bunds of the fields to provide fodder, fuelwood and minor timber. As compared to AS in AH the vegetables (tomato, cauliflower, capsicum and beans) and cereal crops (maize, wheat and barley) were grown with fruit trees of peach, plum, pear and apricot. While, in AHS beside cereals (maize, wheat and barley), pulses (blackgram and rajmah), vegetables (tomato, beans, capsicum and pea) and fruit trees (peach, plum, pear and apricot) with few fodder trees (*Grewia, Celtis* and *Ficus*) were also the integral part of the system. In ASH the components were similar to AHS except for higher density of fodder trees (Tables 5-7). The similar components of the four agroforestry systems in Himachal Pradesh have also been reported by other workers (Toky and Khosla 1990; Mazumdar, 1991; Rana, 1995; Kachru, 1997; Upadhyaya, 1997; Singh et al., 2002; Kumar, 2004; Thakur et al., 2004; Kumar, 2007 and Kumari et al., 2008). However, others have reported the similar agroforestry systems with different components in other parts of India (Dadhwal et al., 1989; Mughal et al., 2000; Chauhan and Dhyani, 1989, Kala, 2010 and Bijalwan, 2012).

Beside agroforestry systems, other land uses important for sustained rural livelihood in Giri catchment were chir pine silvipasture and grasslands that are rich source of fodder and fuel wood. These systems nurtured variety of grasses, sedges, legumes, forbs and shrubs in them. Chir pine (*Pinus roxburghii*) was a major tree component in silvipasture beside it, some fodder and fuelwood trees like *Bauhinia variegata, Bombax ceiba, Albizzia lebbek*, *Pyrus pashia* and *Toona ciliata* were intermittently seen. It was recorded that number of forbs was more in grasslands as compared to chir pine silvipasture. Common plant species in these systems were *Chrysopogon montanus, Heteropogon contortus, Cymbopogon martini, Themeda anathera, Arundinella nepalensis* and *Apluda mutica.* Many workers have reported similar species composition in these types of systems in Himachal Pradesh (Thakur et al., 2004; Toky et al., 1989, Gupta and Bhardwaj, 1993; Gupta, 2001; Thakur et al., 2002; Sharma and Gupta, 2005 Masoodi, 2010; Farooq, 2012; Sharma, 2012 and Mahato, 2013).

Chir pine silvipasture and grasslands systems showed little variation in their species composition at different elevations. In these systems floral spectrum comprised of angiospermic plants and only gymnosperm *P. roxburghii* (Table 9-10). In silvipasture systems, 85 genera with 93 species while in grassland 87 genera with 93 species were recorded. These plants belonged to 37 families among which Poaceae, Asteraceae, Lamiaceae and Fabaceae were the most represented, similar to the findings of Uniyal et al. (2010), Sharma, (2012) and Farooq, (2012) for similar plant communities in Himalaya. The number of species in different plant categories in these systems decreased in the order: forbs > grasses > sedges > legumes (Tables 9 -10). This result is contrasting to the findings of Sharma and Gupta, (2005); Farooq, (2012); Sharma, (2012) and Mahato, (2013) for chir pine forests and grasslands of north-west Himalaya as they have reported more number of species of grasses as compared to forbs or legumes or sedges in these communities.

The plant richness in chir pine silvipasture and grasslands of Giri catchment was very low as compared to findings of Chawla et al. (2012) who reported 832 species belonging to 427 genera and 128 families of plants in conifer forest communities of great national Himalayan Park of H.P.; Chandrasekar and Srivastava (2009), they reported 513 species belonging to 243 genera in Pin valley National Park, HP and Chawla et al., (2008), who recorded 313 plant species in Bhabha valley in Western Himalaya (HP). Since these workers investigated least disturbed areas so high number of plant species can be expected in them.

Table. 92 Biomass production and carbon storage potential of agroforestry systems and natural vegetation in Himachal Pradesh.

Land use system	Components	Biomass (t ha^{-1})			Carbon stock/ density(t ha^{-1})			References
		Above ground	Below ground	Total	Above ground	Below ground	Total	
Agrihorticulture (1500-2400m)	Maize/Jowar/Potato/*Amaranthus* + Apple	73.46	30.06	103.7	36.73	15.03	51.85	Sanneh, 2007
Silvipasture (1500-2400m)	*Robinia Pseudoacacia/ Pinus wallichiana/Cedrus deodara* +grasses	103.20	34.42	137.5	51.60	17.21	68.75	Sanneh, 2007
Agrisilviculture (1500-2400m)	Maize/Jowar/*Amaranthus*/ *Fagopyrum* + *R. pseudoacacia / Morus serrata/Quercus semecarpifolia*	89.59	24.58	105.9	40.29	12.29	52.95	Sanneh, 2007
Horticulture (1500-2400m)	Apple	71.51	29.04	100.48	35.75	14.52	50.24	Sanneh, 2007
Forest (1500-2400m)	*Pinus wallichiana, Cedrus deodara, Abies pindrow, Picea smithiana*	308.96	62.09	371.06	154.48	31.04	185.00	Sanneh, 2007
Agriculture (1500-2400m)	Maize, Jowar, Potato, *Amaranthus, Fagopyrum*	5.91	1.04	6.95	3.12	0.52	3.90	Sanneh, 2007
Grassland (1500-2400m)	Pure natural grasses	2.47	16.05	18.52	1.23	8.03	9.27	Sanneh, 2007
Hortipastoral (468m & 1250m)	*Mangifera indica/Prunus salicina* + grasses	38.73	11.19	49.92	17.43	5.04	22.47	Minj, 2008
Silvi-pastoral (468m & 1250m)	*Leucaena leucocephala/Populus deltoids* + grasses	50.30	15.63	65.93	22.63	7.18	29.82	Minj, 2008
Agrisilviculture (468m & 1250m)	Wheat-paddy/ wheat-soybean +*Populus deltoides/Bauhinia variegata/ Grewia optiva*	67.86	20.98	88.84	30.54	9.43	39.97	Minj, 2008
Agrihorticulture (468m & 1250m)	Wheat-paddy/ wheat-soybean + *Mangifera indica /Prunus persica*	36.01	12.92	48.93	16.19	5.81	22.01	Minj, 2008
Agrihortisilviculture (468m & 1250m)	Wheat-paddy/ wheat-soybean + *Mangifera indica/ Prunus salicina + Populus deltioides/ Morus alba*	44.81	15.27	60.09	20.17	6.87	27.04	Minj, 2008
Pure agriculture (468m & 1250m)	Wheat-paddy/ wheat-soybean	14.88	3.77	18.65	6.93	1.70	8.63	Minj, 2008
Grassland (468m & 1250m)	Berseem- sorghum/*Panicum maximum*	8.90	1.63	10.53	4.01	0.73	4.74	Minj, 2008
Plantation	*Populus deltioides*	188.60	49.04	237.70	84.88	22.07	107.00	Minj, 2008
Agriculture (1100 - 2300m)	Maize - wheat/ pea/garlic	13.75	6.60	20.28	6.87	3.30	10.01	Rajput, 2010
Agrihorticulture (1100 -2300m)	Maize - wheat/ pea/garlic + plum/apple	73.92	23.35	97.51	36.31	11.49	49.05	Rajput, 2010
Horticulture (1100 -2300m)	Plum/apple	71.22	21.18	91.32	35.82	10.75	46.13	Rajput, 2010
Silvipasture (1100 - 2300m)	*Pinus roxburhii/ P. wallichiana/ Cedrus deodara* + grasses	102.00	21.23	123.31	51.15	10.63	61.66	Rajput, 2010
Pine forest (1100 - 2300m)	*Pinus roxburhii/ P. wallichiana/ Cedrus deodara/ Abies pindrow/ Picea smithiana*	336.40	67.90	404.35	168.20	33.95	202.2	Rajput, 2010
Agrihorticulture (1200m)	*Withania somnifera – Ocimum sanctum- Andrographis paniculata + Peach*	4.71	1.08	5.79	2.34	0.53	2.87	Tripathi, 2012

Agriculture/ medicinal plant (1200m)	*Withania somnifera – Ocimum sanctum- Andrographis paniculata*	1.47	0.38	1.85	0.67	0.17	0.84	Tripathi, 2012
Agriculture (1600m)	Maize - wheat	7.75	0.74	8.49	-	-	-	Sunita, 2012
Horticulture (1600m)	Apple	80.43	26.54	106.97	-	-	-	Toppo, 2012
Agrihorticulture (1600m)	Maize- wheat- apple	82.68	26.05	108.73	-	-	-	Toppo, 2012
Traditional Agroforestry (1600m)	Maize- wheat- oak	14.88	2.50	17.37	-	-	-	Toppo, 2012
Pasture (1600m)	Grasses	3.24	20.81	24.04	-	-	-	Toppo, 2012
Silvipastoral (1600m)	Blue pine-grasses	86.84	30.76	117.60	-	-	-	Toppo, 2012
Hortipastoral system (338m)	Mango+ Litchi + natural grasses	15.26	5.37	20.63	6.86	2.41	9.28	Khaki and Wani, 2011
Silvipastoral system (338m)	*Dalbergia* + natural grasses	32.72	11.50	44.22	14.72	5.17	19.89	Khaki and Wani, 2011
Agrisiliviculture system (338m)	Sal + wheat	34.05	11.97	46.02	15.32	5.38	20.70	Khaki and Wani, 2011
Hortisilvipastoral system (338m)	Mango+ Litchi + poplar + natural grasses	18.20	6.40	24.60	8.19	2.88	11.07	Khaki and Wani, 2011
Pure forest (338m)	Sal	134.18	47.16	181.34	60.38	21.22	81.60	Khaki and Wani, 2011
Natural grassland (338m)	-	3.44	1.03	4.47	1.54	0.46	2.01	Khaki and Wani, 2011
Agrisilviculture (900 - 2100 m)	Maize-Wheat/ Barley- Mustard/ *Grewia*, Ficus, Morus	41.45 – 56.87	12.66 - 16.72	54.11- 73.59	20.72 – 28.44	6.33 – 8.36	27.05 – 36.88	Matber, 2014
Agrihorticulture (900 - 2100 m)	Maize-Wheat/ Barley- Mustard/ *Grewia*, Ficus, Morus	41.4- 56.87	12.66 - 16.72	54.11- 73.59	20.72 – 28.44	6.33 -8.36	27.05 – 36.80	Matber, 2014 (Present study)
Agrihortisilviculture (900 - 2100 m)	Maize-Wheat/ Pea/Barley/Blackgram/ Mustard + Grewia, Ficus, Morus/Bauhinia	41.5- 52.12	12.63- 15.29	54.21- 67.41	20.79- 26.06	6.31- 7.65	27.11- 33.71	
Agrisilvihorticulture (900 - 2100 m)	Maize-Wheat/ Capsicum/Tomato + Peach/Pear/Plum/Apricot	55.3- 67.97	16.60- 20.20	71.93- 88.17	27.66- 33.98	8.30- 10.10	35.96- 44.09	
Silvipasture (900 - 2100 m)	Maize-Wheat/ Capsicum/Pea/Tomato + Peach/Pear/Plum/Apricot/Grewia/Celtis/Ficus	57.4- 71.91	17.46- 21.38	74.95- 93.29	28.74- 35.96	8.73- 10.69	37.47- 46.64	
Grassland (900 - 2100 m)	Wheat-Maize/ Mustard/Capsicum/Tomato + /Grewia/Celtis/Ficus/Peach/Pear/Plum/Apricot	62.9- 77.63	17.41- 21.17	80.34- 98.80	31.47- 38.81	8.70- 10.59	40.17- 49.40	

Further, they surveyed big areas as compared to 13 sub-watersheds studied in the present investigation and, the plant distribution at a place is also governed by an area surveyed beside time of sampling and season (Malik, 2005).

The plant categories in ground vegetation of grassland and silvipasture were similar but the number of plant species in these categories was more in grasslands as compared to silvipastures. The result suggests that chir pine trees in silvipasture can be held responsible for low species diversity of understory vegetation as many workers have reported adverse effect of trees on understorey vegetation (Anderson et al., 1968; Gupta et al., 2007; Yadav, 1999; Hazra and Patil, 1986; Vockenhuber et al., 2011).

It was observed that the density and basal area of herbage in grasslands and chir pine silvipasture varied with sub-watersheds and elevations in them. This can be attributed to difference in microclimatic conditions which led to the differential growth of the constituent species. In chir pine silvipasture density and basal area of herbage at different elevations of sub-watersheds ranged from 513.33 to 984.67 tillers/m^2 and 25.05 to 63.00 cm^2/m^2, respectively and in grasslands they varied from 543.33 to 1147.33 tillers/m^2 and 23.21 to 68.41 cm^2/m^2, respectively (Tables 14,18, 25 and 29). The range of the values of density and basal area of herbage recorded in these systems falls within the range reported by Mahmoud, (2009); Gupta *et al.,* (2009); Kharkwal and Rawat, (2010); Masoodi, (2010); Farooq, (2012) and Mahato, (2013) for herbage under chir pine forests (606 to 1525 tillers/m^2 for density and 36.08 to 82.87 cm^2/m^2 for basal area) and grasslands (845 to 1360 tillers/m^2 for density and 50.38 to 98.23 cm^2/m^2 for basal area) of Solan in HP. Mahato, (2013) has recorded density of herbage in chir pine forests of Giri catchment ranging from 420 to 1279 tillers/m^2 and in grasslands 603 to 1445 tillers/m^2. Likewise, he has reported that basal area of herbage in chir pine forests of Giri catchment varied from 25.23 to 49.48 cm^2/m^2 and in grasslands from 25 to 56 cm^2/m^2.

It was recorded that in these communities only few species like *Themeda anathera*, *Chrysopogon montanus*, *Arundinella nepalensis* and *Heteropogon contortus* contributed handsomely to the density and basal area of herbage which confirms their better growth performance in the prevailing environment due to their better adaptability to it. Such variations in growth behavior of constituent species in the herbage communities in different parts of India have been reported by Chaturvedi et al. (1988); Guleria et al. (1999); Gupta et al. (2000); Kumar, (2001); Gupta et al. (2002); Sah, (2002); Sharma and Gupta, (2005); Lehria et al. (2006); Mahmoud, (2009); Gupta *et al.,* (2009); Kharkwal and Rawat, (2010); Rashid, (2010); Farooq, (2012), Sharma, (2012), Mahato, (2013) and Prenil, (2014).

It was also observed that the density and basal area of herbage in chir pine silvipasture and grassland communities at different elevations differed slightly, but it was non-significant. Thus, the adverse effect of chir pine trees on growth of understory vegetation was not perceptible as contended by many workers in chir pine forests (Sharma and Gupta, 2005; Gupta et al., 2007; Gupta et al., 2009; Mahmoud, 2009 and Farooq, 2012).

Each species in a community plays specific role and there is definite quantitative relationship between abundant and rare species (Bhandari et al., 1999). The high IVI of a species suggests its dominance, good ecological adaptation, good power of regeneration and greater ecological amplitude. In the present study IVI of different species in chir pine silvipastures and grasslands of different sub-watersheds at three elevations E_1, E_2 and E_3 presented in Tables and 19-21 and 30-32 showed that there were irregular increase and decrease in IVI in them. Perhaps the continuous change in inter and intra-specific interactions among plants, as their growth progresses, result in their different competitive ability with time and thereby different growth leading to such irregular pattern. But it always happen in a community that one or two species excels other due to their better competitive ability or better adaptation to the prevailing climate. Biological dominance of vegetation are used to describe species composition and spatial patterns of vegetation in different plant communities (Chen et al., 2008). The higher value of IVI of a species indicates that all the available resources are being utilized by that species and left over are being trapped by another species as its competitors and associates.

The IVI of constituent species of the herbage in chir pine silvipastures and grasslands showed that few species exhibited higher values of IVI in all samplings done in different sub-watersheds at elevations E1, E_2 and E_3. These were: *Themeda anathera*, *Heteropogon contortus, Arundinella nepalensis* and *Chrysopogon montanus.* The dominance of species also varied with elevation in these systems and grasses accounted about 75% of total IVI of herbage. In silvipasture at elevation E_1, *Chrysopogon-Themeda* type of community was identified. At elevation E_2 herbage community was *Themeda-Chrysopogon* type and at elevation E_3 it was *Themeda- Arundinella* type (Tables 19-21). In grasslands at elevation E_1, *Heteropogon-Chrysopogon* herbage community was recognized, at elevation E_2 *Themeda-Heteropogon* type and at elevation E_3 *Chrysopogon-Themeda* type community was identified.

The dominance of *Themeda anathera*, *Heteropogon contortus, Panicum maximum and Chrysopogon montanus* in grasslands and herbage communities in chir pine of Himachal Pradesh have been earlier reported by Guleria et al. (1999); Gupta et al. (2000); Gupta et al. (2002); Sharma and Gupta, (2005); Mahmoud, (2009); Gupta *et al.,* (2009); Rashid, (2010); Farooq, (2012), Sharma, (2012), Mahato, (2013) and Prenil, (2014). The variation in the dominance of plant types is associated with difference in microclimate and edaphic conditions (Sharma and Upadhyaya, 2002).

The number of shrubs in silvipasture and grasslands was comparatively high as compared to the number of shrubs reported by other workers for similar ecosystems of mid-Himalaya chir pine forest zone (Guleria et al., 1999; Gupta et al., 2000; Sharma and Gupta 2005; Gupta et al., 2009; Masoodi, 2010; Kumar and Thakur 2008; Siddiqui et al., 2009; Dangwal et al., 2012; Farooq 2012 and Sharma 2012). The environmental variables like, altitude, moisture regime, aspect etc. are responsible for such differences (Sakya and Bania, 1998; Adhikari et al., 2009).

5.4 BIOMASS PRODUCTION IN SYSTEMS

Biomass estimation of any plant community is one of the few characteristics that establishes its suitability to the prevailing environmental conditions. Management of its constituent components on Mans' knowledge is often done to enhance his socioeconomic condition beside environment amelioration. The importance of vegetation as carbon sink is highlighted under Kyoto protocol. Thus, biomass analysis is given priority to ascertain carbon cycle and carbon sequestration. Moreover, the recent impetus on LULUCF by international organisations makes it more pertinent to study biomass fluctuations in agroforestry systems.

Agroforestry systems (AFS) spread over one billion ha in diverse ecoregions around the world have a special relevance in this respect (Kumar and Nair, 2011). These woody perennial-based land use systems have relatively high capacities for capturing and storing atmospheric CO_2 in vegetation, soils, and biomass products. The biomass production depends upon a number of factors viz., growth habit of the species, site quality, soil on which trees are growing, stand age, management practices and their interactions with belowground components (Grahan et al., 1992; Niu and Duiker, 2006; Jana et al., 2009).

In the present study, aboveground biomass production in agrisilvihorticulture (ASH) was around 3.6 % higher than agrihortisilviculture (AHS), 29.9 % than agrisilviculture (AS) and 34.8 % than agrihorticulture (AH). The overall production of any system is a manifestation of the potential production of its inherent components in a set of environment, number and types of constituent species, age and, their management (Swamy and Puri, 2005; Oelbermann et al., 2002). In ASH, the fruit and fodder trees contribution to the system biomass was 72.92 %, higher than in any other agroforestry system, resulted in maximum biomass. On the similar analogy, maximum aboveground biomass in silvipasture (SP), 11.8 % more than ASH, can be attributed to *P. roxburghii* trees that contributed 95.9 % biomass to the total. Least aboveground biomass in grasslands thus can be expected due to absence of trees. It was 3.34 % of the aboveground biomass of chir pine trees in silvipasture, whereas, herbage aboveground biomass in grasslands was only 3.24% of the aboveground biomass of chir pine trees in silvipasture. The extent of herbage biomass in grasslands and silvipasture recorded in Giri catchment in the present study is comparable to the findings of Masoodi (2010) and Mahato (2013) who reported that herbage aboveground biomass in chir pine forests in HP represents 1.9 - 4.57 % of the aboveground biomass of chir pine trees in them. However, these values are much higher compared to finding of Sharma et al. (2008). They reported that grasslands accounted for 0.45 % of total tree biomass. Tree based agroforestry systems have been reported to produce more biomass as compared to grasslands (Sanneh, 2007; Minj, 2008; Gupta and Chib, 2011 and, Khaki and Wani, 2011)

The similar decrease in belowground and total biomass of vegetation as the aboveground biomass, among the six systems can also be related to the proportion of tree components in them. It emanated from the results that in agroforestry systems ground flora or crops accounted for less than 21 % of total biomass, in silvipasture (SP) less than 4.1 %, while in grasslands their contribution was 76.2 %. Among agroforestry systems, agrisilvihorticulture (ASH) can be rated as most efficient with highest total biomass production of 81.98 t ha^{-1}. However, among the six vegetation systems, silvipasture (SP) produced the highest biomass (94.85 t ha^{-1}). The similar range of total biomass production in agroforestry systems, chir pine forests and grasslands in Himachal Pradesh has been reported by Kumar (2003); Minj (2000); Sanneh (2007); Goswami (2008); Rajput (2010) as given in Table 92 beside Chisanga (2012); Gupta and Sharma (2012) and Mahato (2013).

The results indicated that the biomass production of systems was influenced by their structure, especially the species and density of woody components, dominant species and management of components and, species richness. The similar reasons for biomass variations in agroforestry systems have been given by Nayak (1996), Gupta and Singh (1981) and, Deshmuk (1998). Though other reasons have also been assigned by other workers for difference in biomass production like, soil condition and phenology (Gupta and Singh, 1981), better root net working as well as efficient and economical use of limited resources for maintaining higher photosynthetic activities, leaf area index, better light interception and water use efficiency (Sehgal, 1999 and Huxley, 1983).

In the present study biomass production of herbage under chir pine trees was slightly more than grasslands (Table 55) which is in contrast to the findings of various workers who have reported up to 34% decrease in aboveground biomass of herbage under chir pine trees as compared to grasslands (Chib, 2005; Dalai, 1997; Sharma, 1999; Sah, 2002; Farooq, 2012; Sharma, 2012 and Mahato, 2013). The slightly higher biomass of herbage under chir pine trees can be attributed to slightly higher density of herbage under chir pine as compared to grasslands (Table 11-13 and 22-24). Also, the production of any ecological system is governed by climatic conditions, edaphic characteristics, phenology and floristic diversity (Bahar, 2003). Nair, (1993) contended that trees benefit understory by producing unique environment that reduces evapotranspiration, conserve moisture in plants, buffers understory from extreme temperature and suppress many invasive problem weeds. These attributes might have enhanced the growth of herbage under trees.

Further, it was recorded that in chir pine silvipastures and grasslands at different elevations in different sub-watersheds only few species like *Themeda anathera*, *Chrysopogon montanus*, *Arundinella nepalensis* and *Heteropogon contortus* contributed more to the total biomass as compared to other plant species. These species also contributed more to density and basal area of the herbage as discussed earlier. It suggests that these species has better adaptability under prevailing ambient environment in comparison to other associate herbage species. The major contribution towards total community biomass by only few species has also been reported by Blaisdell, (1958); Gupta, (1993); Pearson, (1965); Sharma and Gupta, (2005); Mahmoud, (2009); Rashid, (2010); Farooq, (2012); Sharma, (2012); Mahato, (2012) and Prenil, (2014).

5.5 BIOMASS CARBON STORGAE IN SYSTEMS

Concentration of CO_2 and other atmospheric greenhouse gases (GHGs) has considerably increased over the last century and is set to rise further. Carbon is accumulating in the atmosphere at a rate of 3.5 Pg. Scientific evidences suggest that increased atmospheric CO_2 could have some positive effects such as improved plant productivity (Centritto et al., 1999 a & b; Idso and Imball, 2001; Keutgen and Chen, 2001). However, negative changes in global climate are often most consequential processes associated with an increased concentration of CO_2 in the atmosphere (USDA NRCS 2000). Agroecosystems play a central role in the global C cycle and contain approximately 12% of the world terrestrial C (Smith et al., 1993; Dixon et al., 1994; Dixon, 1995). The carbon sequestration potential of agroforestry systems has been established by IPCC third assessment report on climate change to increase carbon stock in farm lands and mitigate greenhouse gas problems through economic, environmental and socioeconomic benefits (Rizvi et al., 2011; Ajit et al., 2013). IPCC is of the view that, agroforestry systems offer important opportunities of creating synergies between both adaptation and mitigation actions with a technical mitigation potential of 1.1–2.2 Pg C in terrestrial ecosystems over the next 50 years (Kumar and Nair, 2011). In agroforestry systems, C sequestration primarily involves the uptake of atmospheric CO_2 during photosynthesis and the transfer of fixed C into vegetation, detritus, and soil pools for long-term storage in aboveground and belowground major segments (Nair et al. 2010).

In the present study aboveground biomass carbon in agrisilvihorticulture system (31.56 t C ha $^{-1}$) was highest followed by agirihortisilviculture (30.48 t C ha $^{-1}$), agrisilviculture (24.32 t C ha $^{-1}$) and agrihorticulture (23.42 t C ha $^{-1}$) systems. The biomass and, thereby the biomass carbon, of aboveground components depends upon a number of factors like, growth habit of the species, site quality, soil on which trees are growing, stand age, management practices and their interactions with belowground components (Graham et al., 1992; Niu and Duiker, 2006; Jana et al., 2009). Belowground biomass carbon was also was highest in agrisilvihorticulture (9.43 t C ha $^{-1}$) followed by agrihortisilviculture system (9.01 t C ha $^{-1}$) agrisilviculture (7.25 t C ha $^{-1}$) and agrihorticulture (6.86 t C ha $^{-1}$). Likewise, total biomass carbon was highest agrisilvihorticuture (40.99 t ha $^{-1}$) followed by agrihortisilviculture (39.49 t C ha $^{-1}$), agrisilviculture (31.57 t C ha $^{-1}$) and agrihorticulture (30.29 t C ha $^{-1}$).

The carbon density in vegetation is reflection of its biomass accumulation hence the difference in carbon density of vegetation amongst agroforestry systems can be attributed to the reasons as described earlier for biomass variation. Thus, the species and number of trees in agroforestry systems played lead role in defining the carbon storage in them confirming that woody perennials have relatively high capacities for capturing and storing atmospheric CO_2 in vegetation. In AHS system, tree species (fodder and/or fruit) were more in number and thus accounted for 73.65 % aboveground biomass carbon in it followed by 71.90 % in ASH, 68.83% in AS and 66.36 % in AH and their contributions to the belowground biomass carbon and total biomass carbon also followed the similar trend in the agroforestry systems. The amount of C sequestered largely depends on the agroforestry system put in place, the structure and function of which are, to a great extent, determined by environmental and socio-economic factors.

In ASH, fodder and fuel wood trees contributed 69.79 % to total carbon density of vegetation, in AHS trees contributed 71.66 %, in AH the contribution of trees was 60.20 % and in AS 67 % of total carbon was stored in trees. In India, Sathaye and Ravindranath, (1998) reported 25 tonnes carbon per ha over 96 million ha average sequestration potential in agroforestry, which is higher than the results obtained in present study. But, Ramnewaj and Dhyani (2008) and Dhyani et al. (2009) contended that there is a considerable variation in different regions depending upon the biomass production. The C sequestration potential of tropical agroforestry systems in recent studies is estimated between 12 to 228 Mg ha^{-1} with a median value of 95 Mg ha^{-1} (Pandey, 2007).

In chir pine silvipastures trees stored 95.92 % of aboveground biomass carbon. The belowground biomass carbon was 9.30 t C ha^{-1}, in which trees contributed 90.76 %, shrubs contributed 0.59 % and herbage vegetation contributed 8.65 % and, in total biomass carbon trees contributed 94.82 % carbon. Tree incorporation on crop and pasture lands results in greater net aboveground as well as belowground carbon sequestration (Palm et al., 2004 and Haile et al., 2008). In grasslands 70.06 %, 86.59 % and 76.42 % of carbon was locked in aboveground, belowground and total biomass of herbage (Table 87).

It emanated from findings that carbon sequestration was controlled by structural components and management of agroforestry systems similar to the findings of Minj, (2008); Goswami, (2008); Rajput, (2010); Kumar, (2003); Sanneh, (2007) and Mahato, (2013). The carbon storage in vegetation is dependent upon their management practices and prevailing ecological variations (Nair et al., 2010; Rizvi et al., 2011; Nair, 2011 and Ajit et al., 2013). Beside these factors, the decision making process of selecting land use systems and management practices influenced by socioeconomic factors also resulted in differences in productivity and carbon sequestration potential of systems (Williams, 1999; Anjichi et al. 2007; Seabrook et al. 2008; Matata et al. 2008). It was evident from the results that less than 25% carbon was stored in aboveground parts of the agroforestry systems while in chir pine silvipasture it was considerably high in aboveground parts (> 95 %). It was quite different from the finding of Lal, (2010) who reported that on an average, the aboveground parts hold roughly one-third of the total C stored in tree-based systems.

Range of carbon storage in agroforestry systems, chir pine forests and grasslands of Giri catchment was low as compared to the findings of other workers in Himachal Pradesh (Sanneh (2007); Minj, (2008); Rajput, (2010), Khaki and Wani, (2011); Toppo, (2012) and Tripathi, (2012) given in Table 92. Such differences can be attributed to structural differences in systems, prevailing environmental conditions and their management. Tree based systems stored more carbon than grasslands or field crops growing under similar ecological conditions is consonant to the findings of Roshetko et al. (2002) and Kirby and Potvin, (2007).

5.6 SOIL ORGANIC CARBON, BULK DENSITY AND SOIL CARBON STORAGE IN SYSTEMS

Soil is the most effective sequestration reservoir for C in any ecosystems because of the long turnover time of soil organic matter compared with most plant tissues, and because of less inter-annual variability or disturbance-driven losses (Lal, 2004). Generally, soil carbon shares two-third in the total carbon stored by tree based systems. Most of carbon enters into the ecosystem through process of photosynthesis. After litter fall, the detritus material decomposed and forms soil organic carbon through microbial process. IPCC (2000) has recognized soil organic carbon as one of the five major carbon pools for LULUCF (Land Use Land Use Change and Forestry). Soil organic carbon is sensitive to the impacts of anthropogenic activities. Conversion of natural vegetation to crop based land uses results in rapid decline in soil organic matter (Post and Kwon, 2000; Toky et al., 1989b).

In the present vegetation systems the SOC varied between 2.08% to 2.22 %. The range of SOC in soils ranging from 1.16 to 3.49 % in grasslands and 1.68 to 3.83 % in chir pine forests have been reported by Dutt, (1999); Chib, (2005); Sanneh, (2007); Goswami, (2008); Minj, (2008); Mahmoud, (2009); Masoodi (2010); Mahato (2013), Farooq (2012) and Prenil (2013) in Himachal Pradesh. While, in the similar agroforestry systems, Sanjeev (2003); Minj, (2008) and Goswami, (2008); Rajput, (2010), Sanneh, (2007) have reported SOC ranging from to 0.89 to 1.22%. The intensive management of agroforestry systems by the use farm yard manure to enrich soil with nutrients and organic matter improves its carbon content and bulk density.

The results indicated that SOC in the soils of different systems did not vary significantly (Table 73). Thus, the higher SOC reported in tree based systems as compared to pasture or field crops as reported by Kaushal, (1992); Kang et al., (1999); Oelberman, (2002); Singh, (2009); Kumar, (2007); Sanneh, (2007); Minj, (2008); Rajput, (2010); Negi et al., (2010); Chisanga, (2012) and Kanime et al., (2012) was not recorded in the present study. Soil organic carbon in grasslands equivalent to tree based systems, can be related to its intensive root cycling system, which has great content of lignin (Lugo and Brown, 1992; Tornquist et al., 1999; Martens, 2000). In the long-term, areas under grasslands have similar potential to store total organic carbon as areas under tree-based systems (Franzluebbers et al., 2000).

It also emanated from results that in chir pine silvipasture SOC was less as compared to other systems. This can be due to two reasons; one, in Giri catchment, like in whole Himachal Pradesh, the grasslands and chir pine forests are subjected to frequent fire every year to enhance the forage yield. Hence, the litter in these ecosystems is often burnt and second, in chir pine silvipastures, people collect pine needle litter lying on forest floor every year for its domestic and industrial use. Hence, there is depleted organic matter turnover in these forests, which might have reduced soil organic carbon in chir pine silvipasture. Murthy et al., 2006 also reported more carbon storage (3.94 t C ha^{-1}) in pure pasture as compared to silvipasture (1.89-3.45 t C ha^{-1}) and assigned the high diversity of vegetation as the reason for it.

The soil organic carbon (%) and carbon density in agroforestry systems decreased in the order: agrihorticulture (2.22%) > agrihortisilviculture (2.20%) > agrisilvihorticulture (2.17%) > agrisilviculture (2.16%). The difference in soil carbon among agroforestry systems can be related to difference in structure and composition of vegetation, climatic variation and management inputs.

The bulk density refers to the weight of a given volume of soil per unit volume (Singer and Munns 2002). In the present study, bulk density of soil in different agroforestry systems (Table 74) decreased in the order: AHS (1.22 g cm^{-3}) > ASH (1.21 g cm^{-3})> AH (1.21 g cm^{-3}) > AS (1.20 g cm^{-3}). The bulk density of soil was more in grasslands (1.27 g cm^{-3}) and silvipasture (1.24 g cm^{-3}). Similar range of bulk density (0.97 to 1.25 g cm^{-3}) in agroforestry systems of Himachal Pradesh have been reported by Sanneh, (2007); Minj, (2008); Gowsami, (2008); Chisanga, (2012); Bhardwaj et al. (2013) and Mahato (2013). They have also reported that bulk density in grassland varies from 1.07 to 1.22 g cm^{-3} and in silvipasture systems from 0.94 - 1.22 g cm^{-3}.

The soil carbon density (t C ha^{-1}) up to 30 cm soil layer under agroforestry systems (Table 79) showed the decreasing precedence as: agrihortisilviculture (52.57 t C ha^{-1}) > agrihorticulture (51.88 t C ha^{-1}) > agrisilvihorticulture (51.18 t C ha^{-1}) > agrisilviculture (50.01 t C ha^{-1}). In Giri catchment Negi and Gupta (2010) have reported SOC in agriculture lands to range between 31.33 to 91.46 t C ha^{-1} with an average value of 53.62 t C ha^{-1}.The effectiveness of agroforestry systems in storing carbon depends on both environmental and socio-economic factors. In humid tropics, agroforestry systems have the potential to sequester over 70MgC/ha in the top 20 cm of the soil and in degraded soils of the sub-humid tropics, agroforestry practices can increase top soil carbon stocks up to 1.6Mg C $ha^{-1}yr^{-1}$ (Mutuo et al., 2005). The soil carbon storage in an agroforestry system is regulated by its structural components and their management (Singh et al., 1989; Samra and Singh, 2000), soil type (Gupta et al., 2009) and age of the agroforestry plantations (Maikhuri, et al., 2000 and Saha, et al., 2007). Soil carbon density range of 41.05 to 51.04 t C ha^{-1} in agroforestry systems have been recorded by Kumar (2003); Minj (2008); Goswami (2009); Rajput (2010); Tripathi (2012) and Kanime et al. (2012).

The soil carbon density in grasslands (53.45 t C ha^{-1}) was higher than chir pine silvipastures (49.76 t ha^{-1}). In Giri catchment Negi and Gupta, (2010) have reported SOC (up to 30 cm depth) under chir pine forests to range between 29.71 – 89.03 t C ha^{-1} with average value as 57.33 t C ha^{-1}. Likewise, Kumar (2003); Minj (2008); Goswami (2009); Rajput (2010); Sharma (2009); Masoodi (2010); Farooq (2012); Sharma (2012) and Mahato (2013) recorded SOC in chir pine silvipasture and in grasslands in Himachal Pradesh to range between 26.37 to 78.57 t C ha^{-1} 31.10 to 43.71 t C ha^{-1}, respectively.

5.7 TOTAL CARBON STORAGE IN SYSTEMS

Agroforestry systems show significant carbon accumulation in living biomass, as well as soil carbon, demonstrating the potential to offer the environmental service of carbon sequestration. Agroforestry has a huge potential as mitigation strategy to the changing climate because of its potential to sequester carbon in its multiple plant species and soil (Albrecht and Kandji, 2003; Montagnini and Nair, 2004). The average carbon sequestered by these practices has been estimated to be 9, 21, 50, and 63 Mg C ha^{-1} in semiarid, sub-humid, humid, and temperate regions. In tropics, for small agroforestry systems, it has been found to be ranging from 1.5 to 3.5 $MgCha^{-1}yr^{-1}$ and thus can be a viable strategy for carbon storage (Montagnini and Nair, 2004; Roshetko, 2007). Thus, proper designing and managing of agroforests can make them effective carbon sinks.

In the present study carbon stock inventory of vegetation systems was prepared by the addition of soil organic carbon stock (up to 30 cm depth) and net carbon stock in plant components (Table 80). In agroforestry systems it decreased in the order: ASH (92.17 t C ha^{-1}) > AHS (92.05 t C ha^{-1}) > AH (82.16 t C ha^{-1}) > AS (81.58 t C ha^{-1}). Different agroforestry systems sequestered varied amount of carbon based on the type of system, species composition, density and age of tree component, tree density and carbon concentration in different components, soil and climate (Swamy and Puri, 2005; Oelbermann et al., 2004; Nair et al., 2009). It was recorded that SP (94.38 t C ha^{-1}) stored 58.92 % more net carbon than grassland (55.61 t C ha^{-1}). The findings suggest that tree based systems stored more carbon as compared to grasslands and the carbon storage in systems was regulated by type of the tree species and their management in them. Similar range of carbon storage in agroforestry systems, chir pine silvipastures and grasslands were also reported by Kumar, (2003); Sanneh, (2007); Minj, (2008); Rajput, (2010); Goswami, (2009) and Chauhan et al., (2010) in Himachal Pradesh (Table 92).

The amount of carbon stored in agroforestry systems of Giri catchment (81.58 to 92.17 t C ha^{-1}) is within the range reported by Krankina and Dixon (1994) for agrosilviculture systems of humid tropical regions of southeast Asia (12-228 Mg C $ha-^{1}$) and far above the range recorded for silvopastoral systems of low humid tropical regions of northern Asia (15-18 Mg C ha^{-1}) by Winjum et al., (1992).

Carbon stock varying from 82.40 to 89.73 t/ha in chir pine forests near Solan (HP) was reported by Sharma, (2012). Rashid, (2010) reported 86.88 to 160.35 t/ha carbon stock in trees of chir pine forest at different elevations in Solan (HP). Syed et al. (2009) reported carbon stock in plant in two forest sites of sub-tropical pines (*P. roxburghii*) as 126 t/ha in Ghoragali and 99 t/ha in Lehterar, Pakistan. They further said that on an average basis sub-tropical pine (*P. roxburghii*) forest ecosystems has 112.5 ± 2.26 t/ha carbon which comprises of 94% from plant material and 6% from top soils. Likewise a range of carbon stock from 91.5 to 239.9 t/ha in Garhwal Himalaya has been reported by Chaturvedi and Singh, 1987; Rana et al. (1989); Singh and Singh, (1992); Jina, et al. (2008) and, Sharma and Singh, (2010) reported carbon stock to vary from 250-300 t/ha in forest of Central Himalaya. Manhas et al. (2006) has estimated carbon stock in conifers of temperate region in India between 28.88 to 65.21 t/ha and these are well below the present estimates.

5.8 ECONOMIC RETURNS FROM SYSTEMS

The gross and net returns were higher from agroforestry systems as compared to traditional chir pine based silvipasture and grasslands. It is pertinent to mention here that, in tree based agroforestry systems, the economic value of trees was calculated for fuel wood only. Among agroforestry systems economic returns were governed by the arrangement of components, their management, yield and market value. The returns (gross and net) were highest from agrisilviculture system because vegetable crops like tomato, capsicum, garlic and beans are cultivated in large area that fetch more capital to the farmers from market. The returns from agrihorticulture, agrihortisilviculture and agrisilvihorticulture were slightly less, though statistically non-significant, than agrisilviculture because the cash crops mentioned above are grown in lesser areas in these systems. Very low returns from chir pine based silvipasture and grasslands were due to low market value of fuelwood and fodder taken from them.

Rajput 2010, has reported very high return, to the tune of 7.32 lakhs/ha/year from agrihorticulture (apple + pea & cauliflower) and 0.70 lakhs/ha/year from silvipasture (mixed conifer forests) systems in Kullu valley of Himachal Pradesh. Sood (1999) also reported that agrihorticulture system provides more return as compared to sole crop. Tomar and Bhatt (2004), contended that maximum net monetary benefit per hectare can be obtained when peach is intercropped with rice (Rs, 40,404) as compared to rice cultivation with guava (Rs, 27.087) or Assam lemon.

In the present study benefit-cost ratio of the agroforestry systems decreased in the order: agrisilvihorticulture (2.38) > agrihortisilviculture (2.17) > agrisilviculture (2.10) > agrihorticulture (1.87). In silvipastures benefit cost ratio was calculated as 3.58 while in grasslands it was 2.53. Rajput (2010) reported benefit-cost ratio of 2.94 for agrihorticulture in Kullu valley of Himachal Pradesh, Verma et al. (2002) reported benefit cost ratio ranging from 1.99 to 2.34 for agrisilvihorticulture systems in Solan (HP). A range of benefit cost ratio from 1.87-5.7 have been reported by Dhyani et al. (1996) for sericulture based agroforestry systems in Meghalaya; Kumar et al. (2002) for hortipastoral systems at Jhansi; Bhatt and Mishra (2003) for Assam lemon and Guava based agroforestry systems in Meghalaya and Sharma (2007) for cardamom based in Sikkim.

Chapter-6

SUMMARY AND CONCLUSIONS

The present investigation entitled "Pattern, composition and vegetation dynamics of agroforestry systems in Giri catchment, Himachal Pradesh" was carried out in Giri catchment, a component of Giri river in Himachal Pradesh, located between 30^{o} 33′ 48″ and 31^{o} 16′ 08″ N latitude and 77^{o} 02′ 32″ to 77^{o} 38′ 22″ E longitude. Out of the 135 sub-watersheds in Giri catchment, 13 sub-watersheds viz., SW_1 to SW_{13} were selected randomly to study the socio-economic status and vegetation composition of the land uses which are important for rural upliftment by stratifying each sub-watershed into three elevations E_1 (900-1300 m), E_2 (1301-1700 m) and E_3 (1701-2100 m).

6.1 SOCIOECONOMIC CONDITIONS IN THE CATCHMENT

The number of villages in sub-watersheds selected for study varied from 5 to 10 at elevation E_1, 4 to 12 at elevation E_2, and 4 to 8 at elevation E_3. The average number of households in villages at elevations E_1, E_2 and E_3 was 52, 54 and 51, respectively. The average family size of sampled households was 6.85, 6.97 and 7.09 at elevations E_1, E_2 and E_3, respectively. Sex ratio at elevation E_1, E_2 and E_3 was 929, 971 and 941, respectively. Average sex ratio in Giri catchment was 947 (Table 1).

Literacy rate at elevation E_2 was 87.24% people while at elevation E_3 it was 85.70%, and 85.91% at elevation E_1 (Table 2).

The land holding per household in the selected sub-watersheds at elevation E_3, was higher (1.23 ha) as compared to elevation E_1, (1.09 ha) and E_2 (0.99 ha). At these elevations, 77 to 79 per cent of land holding per household was under cultivated land (Table 3).

The fodder consumption was highest at elevation E_3 (60.20 ± 1.54 kg/household/day) followed by elevation E_2 (56.78 ± 1.40 kg/household/day) and elevation E_1 (49.34 ± 2.00 kg/household/day).

The fuelwood consumption per household was highest at elevation E_3 i.e., 30.92 kg/day while it was 25.65kg/day at elevation E_2 and 22.77 kg/day at elevation E_1 (Table 4).

6.2 IDENTIFICATION OF AGROFORESTRY SYSTEMS

Six types of vegetation systems are prevailent in Giri catchment viz., a) agrisilviculture (AS), b) agrihorticulture (AH), c) agrihortisilviculture (AHS), d) agrisilvihorticulture (ASH), e) silvipastures (SP) and f) grasslands (Gr). In rabi season, wheat, mustard, barley and pea and, in kharif season, maize blackgram, rajmah, capsicum, tomato and beans were the major crops. Prominent trees in agroforestry systems were *Grewia optiva*, *Toona ciliata*, *Morus alba*, *Celtis australis* and *Bauhinia variegata* and, mainly retained on the bunds of agriculture fields. Fruit trees in the agroforestry systems were pear, peach and plum (Tables 6-8).

6.3 FLORAL DIVERSITY AND PHYTOSOCIOLOGY OF VEGETATION IN SYSTEMS

In agroforestry systems the diversity of species was less as compared to chir pine silvipastures and grasslands. The agroforestry systems had 15 genera of crop (cereals, pulses and oil seeds) and vegetables, 14 genera of fuelwood and fodder trees and 4 genera of fruit trees. In silvipasture systems, in the selected sub-watersheds, 88 plant genera with 93 species were recorded which comprised of 7 genera of trees, 27 genera of shrubs, 17 genera of grasses, 30 genera of forbs and 3 genera of sedges and 4 genera of herbaceous legumes (Table 5). In grasslands, 86 genera with 94 species with 19 genera of grasses, 3 sedges, 33 forbs, 4 legumes (herbaceous) and 27 shrubs (Table 6).

At elevation $E_{1,}$ in silvipasture systems, total density and basal area of herbage ranged from 657.73 to 984.67 tillers/m^2 and 25.53 to 46.79 cm^2/m^2, respectively. At elevation E_2 they ranged from 513.33 to 947.33 tillers/m^2 and 31.38 to 46.33 cm^2/m^2, respectively while at elevation E_3, their values varied between 613.33 to 884.67 tillers/m^2 and 25.05 to 60.10 cm^2/m^2, respectively (Tables 14 and 18). In grasslands at elevation E_1 total density and basal area of herbage varied from 543.33 to 1147.33 tillers/m^2 and 23.34 to 72.89 cm^2/m^2, respectively. At elevation E_2 their values ranged from 481.33 to 1002.0 tillers/m^2 and 28.05 to 64.61 cm^2/m^2, respectively while at elevation E_3 they varied from 513.33 to 996.67 tillers/m^2 and 23.21 to 53.98 cm^2/m^2, respectively (Tables 25 and 29).

The herbage communities in silvipasture and grassland systems showed that *Heteropogon contortus*, *Themeda anathera Chrysopogon montanus* and *Arundinella nepalensis* were dominant as compared to other species at all the elevations. Further grasses accounted about 75% of total IVI of herbage. In silvipasture at elevation E_1, *Chrysopogon-Themeda* type of community was identified. At elevation E_2 herbage community was *Themeda-Chrysopogon* type and at elevation E_3 it was *Themeda-Arundinella* type (Tables 19-21). In grasslands at elevation E_1, *Heteropogon-Chrysopogon* herbage community was recognized, at elevation E_2 *Themeda-Heteropogon* type and at elevation E_3 *Chrysopogon-Themeda* type community was identified.

In silvipasture system, at elevation, E_1 total density and basal area of shrubs in different sub-watersheds ranged from 1666.67 to 2466.67 plant ha^{-1} and 0.08 to 0.49 m^2/ha, respectively. The shrub density and basal area of silvipasture system at elevation E_2, varied from 1466.67 to 2166.67 plant ha^{-1} and 0.11 to 0.67 m^2/ha, respectively. At elevation E_3, total density and basal area of shrubs in silvipasture system of different sub-watersheds varied between 1533.33 to 2600.00 plant ha^{-1} and 0.20 to 0.79 m^2/ha, respectively (Tables 36 & 44). In grasslands at elevation E_1, total density and basal area of shrubs in different sub-watersheds varied from 2133.33 to 4100.00 plant ha^{-1} and 0.11 to 1.36 m^2/ha respectively. Whereas, at elevation E_2 in different watersheds the total density and basal area of shrubs ranged from 1733.33 and 3700.00 plant ha^{-1} and 0.20 to 0.80 m^2/ha respectively. At elevation E_3, the total density and basal area of shrubs ranged from 1633.33 to 3133.33 plant ha^{-1} and 0.18 to 1.87 m^2/ha, respectively (Tables 40 and 48).

In silvipasture systems, the dominated species of shrub was *Berberis lycium* with its IVI values ranging from 12.02 to 166.59 at elevation E_1, *Myrsine africana* with IVI values of 43.65 to 183.15 was dominating shrub at elevation E_2 and *Berberis lycium* with IVI values ranging from 18.61 to 179.73 was dominating species at elevation E_3. In grasslands dominant species of shrubs at elevation E_1 of different sub-watersheds was *Berberis lycium* with IVI values ranging between 4.20 to 112, *Rubus ellipticus* with IVI value of 7.54 to 153.11 was dominating at elevation E_2 and *Berberis lycium* with IVI values of 26.68 to 179.73 was dominant shrub at elevation E_3 (Tables 49 to 54).

6.4 BIOMASS PRODUCTION IN SYSTEMS

The total aboveground biomass of vegetation (crops + herbs + shrubs + trees) in systems decreased in the order: S_5 (70.63 t ha^{-1}) > S_4 (63.13 t ha^{-1}) > S_3 (60.95 t ha^{-1}) > S_1 (48.63 t ha^{-1}) > S_2 (46.85 t ha^{-1}) > S_6 (3.13 t ha^{-1}). Likewise, the belowground biomass of vegetation in systems decreased in the order: S_4 (18.86t ha^{-1}) > S_5 (18.61t ha^{-1}) > S_3 (18.02t ha^{-1}) > S_1 (14.50t ha^{-1}) > S_2 (13.73t ha^{-1}) > S_6 (1.79t ha^{-1}). Whereas total biomass of vegetation in different systems decreased in the order: S_5 (89.24 t ha^{-1}) > S_4 (81.98 t ha^{-1}) > S_3 (78.97 t ha^{-1}) >S_1 (63.13 t ha^{-1}) > S_2 (60.57 t ha^{-1}) > S_6 (4.93 t ha^{-1}).

6.5 CARBON STORAGE IN VEGETAIONS AND SOILS OF SYSTEMS

The aboveground biomass carbon was maximum (35.32 t C ha^{-1}) in S_5, which was significantly higher than all other systems. In other systems it showed decreasing precedence as S_4 (31.56 t C ha^{-1}) > S_3 (30.48 t C ha^{-1}) > S_1 (24.32 t C ha^{-1}) > S_2 (23.42 t C ha^{-1}) > S_6 (1.57 t C ha^{-1}). Likewise maximum belowground biomass carbon (9.43 t C ha^{-1}) accumulated in S_4, which was statistically at par with S_5 system (9.30 t C ha^{-1}). Minimum belowground biomass carbon occurred in S_6 system (0.90 t C ha^{-1}). The total carbon stored in vegetation, decreased significantly, in different systems in the order: S_5 (44.62 t C ha^{-1}) > S_4 (40.99 t C ha^{-1}) > S_3 (39.48 t C ha^{-1}) > S_1 (31.56 t C ha^{-1}) > S_2 (30. t C ha^{-1}) > S_6 (2.46 t C ha^{-1}).

Highest Soil organic carbon (2.22 %) was recorded in agrihorticulture (S_2) followed by (S_3) agrihortisilculture (2.20 %) and (S_6) grassland (2.19 %). The minimum soil organic carbon (2.08 %) occurred in (S_5) silvipasture system. Maximum bulk density of soil was recorded in grassland (1.27 g/cm^3) which was significantly higher than all other systems. Minimum mean bulk density of soil was recorded in agrisilvicutlure systems (1.20 g/cm^3).

Maximum carbon (53.45 t C ha^{-1}) was stored in the soils of grasslands followed by agrihortisilviculture, agrihorticulture, agrisilvihorticulture, agrisilviculture (Table 81) with their respective values as 52.57 t C ha^{-1}, 51.88 t C ha^{-1} and 50.02 t C ha^{-1}, respectively. The total carbon stored, decreased significantly, in different systems in the order: S_5 (94.38 t C ha^{-1}) > S_4 (92.17 t C ha^{-1}) > S_3 (92.05 t C ha^{-1}) > S_2 (82.16 t C ha^{-1}) > S_1 (81.58 t C ha^{-1}) > S_6 (55.91 t C ha^{-1}).

6.6 ECONOMIC RETURNS FROM SYSTEMS

The expenses incurred on managing a system was maximum for agrihorticulture (Rs 174690.00 ha^{-1} yr^{-1}) which was statistically at par with agrisiviculture system (Rs 168017.00 ha^{-1} yr^{-1}) but significantly higher than other systems. Minimum expenditure incurred in grassland (Rs 6000 ha^{-1} yr^{-1}). It was found that gross returns from the systems decreased in the order: agrisilvihorticulture (S_4) >agrisilviculture (S_1) > agrihortisilviculture (S_3) > agrisilviculture (S_1) > silvipasture (S_5) > grassland (S_6). Maximum net return was recorded in agrisilviculture system (Rs 277415.00 ha^{-1} yr^{-1}) which was statistically at par with agrisilvihorticulture (Rs 270747.00 ha^{-1} yr^{-1}) and agrihortisilviculture (Rs 269033.00 ha^{-1} yr^{-1}) systems. Minimum (Rs 13150.00 ha^{-1} yr^{-1}) net return was obtained from grassland and it was significantly lower than all other systems except silvipasture (S_5) system (Rs 20143.00 $ha^{-1}yr^{-1}$). The benefit-cost ratio of different agroforestry systems varied with elevations. The benefit-cost ratio of systems varied from 1.87 (S_2) to 3.34 (S_5). It was recorded that benefit-cost ratio was higher in chir pine silvipasture (S_5) and grasslands (S_6) as compared to agroforestry systems.

CONCLUSIONS

1. Traditional agroforestry systems *viz*., Agrislviculture, Agrihorticulture, Agrihortisilviculture and Agrisilvihorticulture are widely practiced in Giri catchment of Himachal Pradesh. Beside them, extensive area is covered by chir pine natural silvipastoral system. In traditional agroforestry systems, *Grewia*, *Toona*, *Morus*, *Celtis*, *Ficus* and *Bauhinia* trees are retained on farm bunds for fodder, fibre and fuelwood, whereas *Pyrus*, *Prunus* tree species are grown for fruits.

2. Floral diversity in agroforestry system was less than grassland and chir pine silvipasture system. In agroforestry systems, 23plant species were recorded, while in chir pine silvipasture and grassland comprised 93 plant species were recorded.
3. The density, basal area and biomass of herbage was not affected by overgrowing chir pine trees. This system was dominated by *Chrysopogon mantanus, Heteropogon contortus, Themeda anathera* and *Arundinella nepalensis* in this region.
4. Aboveground, belowground, total biomass and carbon storage (crop + trees) was significant higher in Agrisilvihorticulture compared to other agroforestry systems. However, chir pine silvipasture systems had maximum aboveground, belowground, total biomass (crop + trees) and carbon storage of vegetation among the six vegetation systems.
5. 36.87 to 44.47% of total carbon was stored in vegetation and 55.53 to 63.13% in soil (up to 30 cm depth) in agroforestry systems. In chir pine silvipasture, 52.72% of total carbon was stored in soil whereas 95.58% of total carbon was stored in soils of grasslands.
6. Agrisilviculture system was most renumerative (Rs 2.77 lakhs) among four agroforestry systems. Benefit-cost ratio of agroforestry systems ranged between 1.87 and 2.38 for agroforestry systems.

Chapter-7

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Title of Thesis	:	**Pattern, composition and vegetation dynamics of agroforestry systems in Giri catchment, Himachal Pradesh**
Name of the Student	:	**Matber Singh**
Admission Number	:	F-09-01-D
Major Advisor	:	Dr. B. Gupta
Major Field	:	Agroforestry
Minor Field	:	i) Silviculture
	:	ii) Soil Science
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ABSTRACT

The present investigation entitled "Pattern, composition and vegetation dynamics of agroforestry systems in Giri catchment, Himachal Pradesh" was carried out in Giri catchment in located between 30^o 33′ 48″ and 31^o 16′ 08″ N latitude and 77^o 02′ 32″ to 77^o 38′ 22″ E longitude in Himachal Pradesh. The climate in this area is sub-humid and sub-tropical in lower parts of the track lying in the Shivaliks and wet-temperate in the upper parts in north-west Himalaya. The mean annual precipitation is 1250 mm. Out of 135 sub-watersheds in Giri catchment, 13 sub-watersheds were selected for study and stratified into three elevations, six vegetation systems viz., agrisilviculture (S_1), agrihorticulture (S_2), agrihortisilviculture (S_3), agrisilvihorticulture (S_4), silvipasture (S_5) and grasslands (S_6) at each elevation were selected to study vegetation composition, phytosociology, biomass, carbon stock and their economic viability. The average family size of sampled households was 6.97 persons/household with average 86.28 % literacy. Average fodder and fuel wood consumption was 55.44 and 26.44 kg/household/day, respectively. Wheat, pea, mustard, barley and pea were rabi crops, whereas maize blackgram, rajmah, capsicum, tomato and beans were cereal crop of kharif season. Prominent tree components in agroforestry systems were *Grewia*, *Toona, Morus, Celtis, Ficus* and *Bauhinia* which were retained on the bunds of agriculture fields, whereas fruit trees of pear, apricot, peach and plum were planted at specified spacing in agriculture fields. In silvipasture systems record 88 genera with 93 species, whereas 86 genera with 93 species in grasslands. The number of species of grasses, sedges, forbs, legumes and shrubs in silvipasture systems were 20, 4, 31, 4 and 27, respectively, whereas in grasslands they were 22, 4, 36, 5 and 27, respectively. At elevation E_1, in silvipasture and grasslands, density (tillers/m^2) of herbage vegetation was highest than other elevations and their values ranged from 657.73 to 984.67 and 543.63 to 1250.67, respectively. Mean aboveground biomass of vegetation in different systems decreased significantly in the order: S_5 (70.63 t ha^{-1}) > S_4 (63.13 t ha^{-1}) > S_3 (60.95 t ha^{-1}) > S_1 (48.63 t ha^{-1}) > S_2 (46.85 t ha^{-1}) > S_6 (3.13 t ha^{-1}). The belowground and total biomass followed the trend of aboveground biomass. Total biomass of vegetation in different systems decreased significantly in the order: S_5 (89.24 t ha^{-1}) > S_4 (81.98 t ha^{-1}) > S_3 (78.97 t ha^{-1}) > S_1 (63.13 t ha^{-1}) > S_2 (60.57 t ha^{-1}) > S_6 (4.93 t ha^{-1}). The mean aboveground carbon was significantly higher (35.32 t C ha^{-1}) in silvipasture than all other systems, whereas agrisilvihorticulture store maximum belowground biomass carbon (9.43 t ha^{-1}) which was statistically at par with silvipasture system (S_5). The total carbon stored by vegetation in systems was highest at elevation E_3 (35.50 t C ha^{-1}ha^{-1}) and it decreased significantly with decrease in elevation. In different systems, total carbon stored in systems decreased significantly in the order: S_5 (44.62 t C ha^{-1}ha^{-1}) > S_4 (40.99 t C ha^{-1}ha^{-1}) > S_3 (39.48 t C ha^{-1}ha^{-1}) >S_1 (31.56 t C ha^{-1}ha^{-1}) >S_2 (30.29 t C ha^{-1}ha^{-1}) > S_6 (2.46 t C ha^{-1}ha^{-1}). Mean soil organic carbon (2.22 %) was highest in agrihorticulture (S_2) followed by agrihortisilviculture (S_3) and grassland (S_6). Maximum soil carbon density (53.45 t ha^{-1}) was recorded in grassland that was followed by agrihortisilviculture, agrihorticulture, agrisilvihorticulture, agrisilviculture with their respective values 52.57, 51.88 and 50.02 t C ha^{-1}, respectively. The net returns from agroforestry systems decreased, though statistically insignificant, in the order agrisilviculture system (277415.00 Rs. ha^{-1} yr^{-1}) > agrisilvihorticulture system (270747.00 Rs. ha^{-1} yr^{-1}) > agrihortisilviculture (269033.00 Rs. ha^{-1} yr^{-1}) > agrihortisilviculture (225880.30 Rs. ha^{-1} yr^{-1}) systems. The benefit-cost ratio in silvipasture system was significantly higher (3.34) than all other systems and it decreased in the order: S_6 (2.53) > S_4 (2.38) > S_3 (2.17) > S_1 (2.10) > S_1 (1.87).

Signature of Major Advisor **Signature of Student**

Countersigned

Professor and Head
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APPENDIX-1

QUESTIONNAIRE FOR THE BASELINE SURVEY

Thesis Title: "Pattern, composition and vegetation dynamics of agro forestry systems in Giri catchment of Himachal Pradesh."

1. SOCIOECONOMIC STRUCTURE OF HOUSEHOLDS

i) Address

- Village :
- Panchayat :

ii) Personal Information
- Name :
- Age :
- Sex :
- Qualification:

iii) Occupation

- Main :
- Subsidiary :

iv) Type of household:
(Kutcha/Pucca/Semi pucca)

2. TYPE AND SIZE OF FAMILY

i) Nuclear/Joint :

ii) Head of the family :

iii) Family structure :

	TOTAL	**MALE**	**FEMALE**
No. of Family member			
Illiterate			
Primary			
Middle			
High school			
Intermediate			
Graduate			
Post graduate			

3. LAND UTILIZATION PATTERN

S.No.	Particulars of land (Area) ha.	Total	Irrigated	Un- irrigated	Source of irrigation
1.	Land holding				
2.	Forest land				
3.	Barren land				
4.	Cultivated land				
5.	Under cereal crops				
6.	Under vegetable crops				
7.	Under fruit crops				
8.	Tree on risers				
9.	Cultivated				
10.	On the bunds				
11.	Orchard				
12.	Ghasini/ Pasture land				
13.	Any other				

4. CROPPING PATTERN AND PRODUCTION

Name of crop	Area (bigha)	Production(qtls)		Marketable surplus(qtls)	Return		Type of farming
Kharif crop		**Grain**	**Straw**		**Gross return**	**Net return**	
Maize							
Rajmash							
Urd							
Mung							
Tomato							
Capsicium							
Ginger							
Colocasia							
Mustard							
Beans							
Rabi crop							
Wheat							
Barley							
Pea							
Cabbage							
Fruit trees (no)							
Peach							
Plum							
Pear							
Apricot							
Others							

5. WHAT SORT OF AGROFORESTRY SYSTEMS DO YOU HAVE?

Type of system	Crop	Trees (nos)	Fuel&fodder (kg/tree)	Production	Area (bigha)
Agrisilviculture					
Agrihorticulture					
Agri-horti-siviculture					
Agri-silvi-horticulture					
Silvipasture					
grassland					

6. WHY HAVE YOU ADOPTED THIS SYSTEM?

7. COST OF CULTIVATION

Particular	Crops					
	maize	wheat	tomato	pea	capsicum	other
Cost of seed						
Nursery preparation						
Ploughing						
Transplanting						
Manure&fertilizer						
Fym						
Urea						
Ssp						
Can						
Cultural practices						
Weeding						
Irrigation						
Stacking						
Plant protection						
Harvesting						
Miscellaneous						
Total cost						

12.5 bigha=1 ha.

APPENDIX-II

Root shoot ratio of crops

Crop	R:S	Reference
Hordeum vulgare	0.60	Rajala &Pelloncn-Sainio, 2001
Solanum melongena	0.35	Baynelo-Jimenez *el al.,* 2002
Vigna mungo	0.062	Vanaja *et al.,* 2006
Capsicum annum	0 4 1	Matheron, 2000
Zea mays	0.50	Kanchikenmath & Singh, 2001
Pisum sativum	0.55	McPhce, 2005
Lvcopersion esculantum	0.36	Jaja & Odoemena, 2004
Triticum aesttvum	0.30	Kanchikcrimath & Singh, 2001

APPENDIX III

Average wood density (g/cm^2) of different tree species

Tree species	Wood density	Reference
Acacia catechu	0.53	Shanavas & Kumar, 2006
Albizia lebbek	0.55	AF Tree Database, ICRAF
Bauhinia variegata	0.72	AF Tree Database, ICRAF
Celt is australis	0.66	AF Tree Database, ICRAF
Ficus palmata	0.41	AF Tree Database, ICRAF
Grewia optiva	0.82	AF Tree Database, ICRAF
Morus alba	0.71	AF Tree Database, ICRAF
Pinus roxburghii	0.59	AF Tree Database, ICRAF
Prinus armenica	0.63	AF Tree Database, ICRAF
Prunus domestica	0.63	AF Tree Database, ICRAF
Pruns padus	0.7.1	AF Tree Database, ICRAF
Prunus persica	0.63	AF Tree Database, ICRAF
Pyrus pashia	0.71	AF Tree Database, ICRAF
Pyrus pyrifolia	0.72	AF Tree Database, ICRAF
Toona ciliata	0.33	AF Tree Database, ICRAF

APPENDIX IV

Volume equations

S.No.	Species	Volume equattion
1.	*Pinus roxburghii*	$V = 0.167095/D^2-2.08594/D+9.929936$
2.	*Acacia catechu*	$V = 0.048535-0.183567x\sqrt{D}+5.7825xD^2$
3.	*Toona ciliata*	$V = 0.12483 + 0.284996 \text{ x } D^2 \text{ x } H$
4.	*Morus Alba*	$V = 0.167174 – 1.735312 \text{ x } D + 12.039017 \text{ x } D^2$
5.	*Grewia optiva*	$V/D^2 = 0.007602xD^2-0.033037/D+1.868567+4.48454xD$
6.	*Albizzia lebbek*	$\sqrt{V} = 0.07109 + 2.99732 \text{ x } D – 0.26953 \sqrt{D}$

(Source: FSI, 1996)

APPENDIX V

Biomass expansion factor

S.No.	Species	Biomass expansion factor	Reference
1.	*Pinus roxburghii*	1.91	Rawat and Tondon, 1993
2.	*Acacia catech*	2.51	Gurumurthi *et al*., 1986
3.	*Toona ciliata*	1.40	IPCC, 2003
4.	*Grewia optiva*	2.01	Behera and Misra 2006
5.	*Albizia lebbek*	2.90	Rai *et al*., 2000
6.	*Morus alba*	1.40	IPCC, 2003

APPENDIX VI

Scientific and common name of tree species and crops

Scientific name	Local name / English name	Scientific name	Local name / English name
Albizia chinensis	Chui, Siris	*Brasica campestris*	Sarson / Mustard
Bauhinia variegata	Kachnar / Bauhinia	*Hordeum vulgare*	Jau / Barley
Bombax ceiba	Semal		Black gram
Celtis australis	Kharik / Celtis	*Phaseolus vulgaris*	Bean
Ficus palmata	Fegra	*Solanum melongena*	Baingan / Brinjal
Grewia optiva	Buel	*Capsicum annum*	Capsicum
Melia azedarach	Dreak	*Triticum aestivum*	Gehun / Wheat
Morus alba	Toot/ Mulberry	*Coriandrum sativum*	Dhaniya / Coriander
Pinus roxburghii	Chir / Pine	*Vigna umbellata*	Cowpea
Prunus armeniaca	Khumani / Apricot	*Dolichos uniflorus*	Kulti / Housegram
Prunus domestica	Plum	*Zea mays*	Makka / Maize
Prunus padam	Paza	*Avena sativa*	Oat
Prunus persica	Aadu / Peach	*Pisum sativum*	Matar / Pea
Punica granatum	Anar / Pomegranate	*Glycine max*	Soybean
Pyrush pashia	Kainth	*Lycopersion esculantum*	Tamatar / Tomato
Pyrus pyrifolia	Nashpati / Pear	*Vigna mungo*	Urd
Quercus leucotricophora	Ban / Oak	*Brassica spp*	Cabbage
Toona ciliata	Tooni / Toon	*Allium sativum*	Lahsun / Garlic

APPENDIX VII

Variation in density (tillers/m^2) of herbage in silvipasture system of different sub-watersheds in Giri catchment

Density silvi-pasture

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**5**	1,090,508.788			
Factor A	**2**	191,040.868	95,520.434	1.746	0.17732
Factor B	**12**	1,439,511.005	119,959.250	2.192	0.01357
Intraction A X B	**24**	1,412,928.346	58,872.014	1.076	0.37465
Error	**190**	10,396,570.062	54,718.790		
Total	**233**	14,530,559.068			

Variation in basal area (cm^2/m^2) of herbage in silvipasture of different sub-watersheds in Giri catchment

Basal area silvipasture

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**5**	3,185.971			
Factor A	**2**	355.524	177.762	0.781	0.45954
Factor B	**12**	12,554.829	1,046.236	4.595	0.00000
Intraction A X B	**24**	7,577.539	315.731	1.387	0.11741
Error	**190**	43,261.628	227.693		
Total	**233**	66,935.491			

Aboveground biomass (t ha^{-1}) of vegetation and its variation at different elevation in sub-watersheds

ANOVA Table for AGB

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**2**	678.613			
Factor A	**12**	11,262.834	938.569	43.938	0.00000
Factor B	**2**	14,995.489	7,497.744	351.001	0.00000
Int A X B	**24**	1,526.515	63.605	2.978	0.00000
Factor C	**5**	341,518.773	68,303.755	3,197.588	0.00000
Int A X C	**60**	31,278.903	521.315	24.405	0.00000
Int B X C	**10**	3,977.821	397.782	18.622	0.00000
Int A X B X C	**120**	8,187.691	68.231	3.194	0.00000
Error	**466**	9,954.237	21.361		
Total	**701**	423,380.876			

ANOVA Table for BGB

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**2**	49.377			
Factor A	**12**	692.690	57.724	42.257	0.00000
Factor B	**2**	1,205.728	602.864	441.327	0.00000
Int A X B	**24**	350.488	14.604	10.691	0.00000
Factor C	**5**	24,557.855	4,911.571	3,595.517	0.00000
Int A X C	**60**	2,830.710	47.178	34.537	0.00000
Int B X C	**10**	322.992	32.299	23.645	0.00000
Int A X B X C	**120**	1,376.755	11.473	8.399	0.00000
Error	**466**	636.568	1.366		
Total	**701**	32,023.162			

ANOVA Table for TB

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**2**	1,075.485			
Factor A	**12**	17,252.959	1,437.747	45.597	0.00000
Factor B	**2**	24,439.442	12,219.721	387.536	0.00000
Int A X B	**24**	2,820.451	117.519	3.727	0.00000
Factor C	**5**	547,835.293	109,567.059	3,474.805	0.00000
Int A X C	**60**	51,341.089	855.685	27.137	0.00000
Int B X C	**10**	6,219.142	621.914	19.723	0.00000
Int A X B X C	**120**	13,544.540	112.871	3.580	0.00000
Error	**466**	14,693.847	31.532		
Total	**701**	679,222.248			

Variation in aboveground biomass carbon (t ha^{-1}) of vegetation relative to elevations and systems in sub-watersheds of Giri catchment

ANOVA Table for AGC

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**2**	169.653			
Factor A	**12**	2,815.708	234.642	43.938	0.00000
Factor B	**2**	3,748.872	1,874.436	351.001	0.00000
Int A X B	**24**	381.629	15.901	2.978	0.00000
Factor C	**5**	85,379.693	17,075.939	3,197.588	0.00000
Int A X C	**60**	7,819.726	130.329	24.405	0.00000
Int B X C	**10**	994.455	99.446	18.622	0.00000
Int A X B X C	**120**	2,046.923	17.058	3.194	0.00000
Error	**466**	2,488.559	5.340		
Total	**701**	105,845.219			

ANOVA Table for Below

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**2**	12.344			
Factor A	**12**	173.173	14.431	42.257	0.00000
Factor B	**2**	301.432	150.716	441.327	0.00000
Int A X B	**24**	87.622	3.651	10.691	0.00000
Factor C	**5**	6,139.464	1,227.893	3,595.517	0.00000
Int A X C	**60**	707.677	11.795	34.537	0.00000
Int B X C	**10**	80.748	8.075	23.645	0.00000
Int A X B X C	**120**	344.189	2.868	8.399	0.00000
Error	**466**	159.142	0.342		
Total	**701**	8,005.791			

ANOVA Table for TBC

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**2**	268.871			
Factor A	**12**	4,313.240	359.437	45.597	0.00000
Factor B	**2**	6,109.861	3,054.930	387.536	0.00000
Int A X B	**24**	705.113	29.380	3.727	0.00000
Factor C	**5**	136,958.823	27,391.765	3,474.804	0.00000
Int A X C	**60**	12,835.272	213.921	27.137	0.00000
Int B X C	**10**	1,554.785	155.479	19.723	0.00000
Int A X B X C	**120**	3,386.134	28.218	3.580	0.00000
Error	**466**	3,673.462	7.883		
Total	**701**	169,805.562			

Variation in soil organic carbon (%) relative to elevations and systems in sub-watersheds of Giri catchment

ANOVA Table for OC

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**2**	0.488			
Factor A	**12**	9.450	0.788	8.490	0.00000
Factor B	**2**	0.122	0.061	0.656	0.51918
Int A X B	**24**	18.117	0.755	8.138	0.00000
Factor C	**5**	1.492	0.298	3.217	0.00724
Int A X C	**60**	14.004	0.233	2.516	0.00000
Int B X C	**10**	2.807	0.281	3.026	0.00101
Int A X B X C	**120**	25.145	0.210	2.259	0.00000
Error	**466**	43.226	0.093		
Total	**701**	114.851			

ANOVA Table for BD

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**2**	2.777			
Factor A	**12**	1.310	0.109	73.773	0.00000
Factor B	**2**	2.834	1.417	957.711	0.00000
Int A X B	**24**	0.136	0.006	3.824	0.00000
Factor C	**5**	0.391	0.078	52.813	0.00000
Int A X C	**60**	3.756	0.063	42.315	0.00000
Int B X C	**10**	0.019	0.002	1.287	0.23505
Int A X B X C	**120**	0.322	0.003	1.812	0.00001
Error	**466**	0.689	0.001		
Total	**701**	12.233			

ANOVA Table for CD

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**2**	3,127.387			
Factor A	**12**	7,084.201	590.350	9.599	0.00000
Factor B	**2**	4,168.425	2,084.213	33.889	0.00000
Int A X B	**24**	12,090.547	503.773	8.191	0.00000
Factor C	**5**	1,217.061	243.412	3.958	0.00159
Int A X C	**60**	12,049.270	200.821	3.265	0.00000
Int B X C	**10**	1,540.250	154.025	2.504	0.00615
Int A X B X C	**120**	16,705.587	139.213	2.264	0.00000
Error	**466**	28,659.872	61.502		
Total	**701**	86,642.601			

Variation in total carbon density (t ha^{-1}) of systems relative to elevations and systems in sub-watersheds of Giri catchment

ANOVA Table for TCD

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**2**	5,209.916			
Factor A	**12**	16,025.709	1,335.476	18.737	0.00000
Factor B	**2**	14,622.576	7,311.288	102.581	0.00000
Int A X B	**24**	11,732.650	488.860	6.859	0.00000
Factor C	**5**	120,757.298	24,151.460	338.856	0.00000
Int A X C	**60**	20,075.245	334.587	4.694	0.00000
Int B X C	**10**	4,793.526	479.353	6.726	0.00000
Int A X B X C	**120**	17,581.470	146.512	2.056	0.00000
Error	**466**	33,213.448	71.273		
Total	**701**	244,011.837			

Variation in density of grasslands (tillers/m^2) of herbage in grasslands of different sub-watersheds in Giri catchment

Density grassland

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**5**	698,767.790			
Factor A	**2**	131,583.578	65,791.789	1.259	0.28617
Factor B	**12**	3,460,643.204	288,386.934	5.521	0.00000
Intraction A X B	**24**	3,538,750.574	147,447.941	2.823	0.00004
Error	**190**	9,925,432.869	52,239.120		
Total	**233**	17,755,178.015			

Variation in basal area (cm^2/m^2) of herbage in grassland of different sub-watersheds in Giri catchment

Basal area grassland

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**5**	2,040.517			
Factor A	**2**	151.022	75.511	0.198	0.82069
Factor B	**12**	11,935.871	994.656	2.606	0.00310
Intraction A X B	**24**	20,999.812	874.992	2.292	0.00105
Error	**190**	72,528.585	381.729		
Total	**233**	107,655.807			

Variation in density (Plants ha^{-1}) of shrubs in grassland of different sub-watersheds of Giri catchment

Grassland Density shrubs

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	**2**	-590.426			
Factor A	**12**	24,065,329.385	2,005,444.115	254,237.509	0.00000
Factor B	**2**	1,064,746.474	532,373.237	67,490.909	0.00000
Intraction A X B	**24**	23,893,470.876	995,561.287	126,210.957	0.00000
Error	**76**	599.494	7.888		
Total	**116**	49,023,555.802			

Variation in basal area (cm^2/m^2) of shrubs in grassland of different sub-watersheds of Giri catchment

Grassland Basal area shrubs

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**2**	10.304			
Factor A	**12**	12.453	1.038	6.526	0.00000
Factor B	**2**	0.267	0.134	0.840	0.43577
Intraction A X B	**24**	16.212	0.675	4.248	0.00000
Error	**76**	12.086	0.159		
Total	**116**	51.322			

Variation in density (Plants ha^{-1}) of shrubs in silvipasture of different sub-watersheds of Giri catchment

Silvipasture Density shrubs

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**2**	10.786			
Factor A	**12**	3,288,838.530	274,069.877	1,431,862.136	0.00000
Factor B	**2**	320,181.556	160,090.778	836,384.958	0.00000
Intraction A X B	**24**	5,805,514.444	241,896.435	1,263,773.858	0.00000
Error	**76**	14.547	0.191		
Total	**116**	9,414,559.863			

Variation in basal area (cm^2/m^2) of shrubs in silvipasture of different sub-watersheds of Giri catchment

Silvipasture Basal area shrubs

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Signficance
Replication	**2**	0.224			
Factor A	**12**	2.590	0.216	92.100	0.00000
Factor B	**2**	0.045	0.022	9.579	0.00019
Intraction A X B	**24**	3.242	0.135	57.636	0.00000
Error	**76**	0.178	0.002		
Total	**116**	6.280			

CURRICULUM VITAE

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Father's name	:	Late Shri Puran Singh
Date of Birth	:	12 February, 1970
Sex	:	Male
Marital status	:	Married
Nationality	:	Indian

Educational qualifications:

Certificate/degree	Class/grade	Board/University
10+2	Second	U.P. Board, Allahabad (Uttar Pradesh)
B.Sc.	Second	GB Pant University of Agriculture and Technology, Pant Nagar (Uttarakhand)
M.Sc.	First	HNB Gharwal University Sri Nagar (Uttarakhand)

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(Matber Singh)