IMPACT OF LAND USE CHANGES ON ECOSYSTEM SERVICES IN KULLU DISTRICT OF HIMACHAL PRADESH

Thesis

by

PRAKRITI SINGH

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ENVIRONMENTAL SCIENCE

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of Horticulture and Forestry, Nauni
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CERTIFICATE-I

This is to certify that the thesis entitled, **"Impact of land use changes on ecosystem services in Kullu District of Himachal Pradesh"** submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (FORESTRY) Environmental Science** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) is a record of bonafide research work carried out by **Miss Prakriti Singh (F-2013-13-M)** 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 has been fully acknowledged.

Place: Nauni-Solan
Dated:

(Dr S K Bhardwaj)
Chairman
Advisory Committee

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This is to certify that the thesis entitled, **"Impact of land use changes on ecosystem services in Kullu district of Himachal Pradesh"** submitted by **Ms. Prakriti Singh (F-2013-13-M),** College of Forestry, Dr. Yashwant Singh Parmar University of Horticulture & Forestry, Nauni-Solan in partial fulfillment of the requirements for the award of degree of **M.Sc (Environmental Science)** has been approved by the Advisory Committee after the thesis viva-voce examination in collaboration with the external examiner.

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Dean's Nominee

Professor & Head

Dean
College of Forestry
Dr YS Parmar University of Horticulture & Forestry
Nauni-173 230, Distt. Solan (HP)

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This is to certify that all the mistakes and errors pointed out by the external examiner have been incorporated in the thesis entitled, **“Impact of land use changes on ecosystem services in Kullu District of Himachal Pradesh”** submitted to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) by **Miss Prakriti Singh (F-2013-13-M)** in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (FORESTRY) Environmental Science.**

(Dr S K Bhardwaj)
Chairman, Advisory Committee

Dr S K Bhardwaj
Professor and Head
Department of Environmental Science
Dr Y S Parmar, UHF, Nauni-173 230, Solan (HP)

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Date:
Place: Nauni, Solan **(Prakriti Singh)**

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ABBREVIATIONS USED

%	Per cent
km^2	Square Kilometre
et al.	Co-workers
LULCC	Land-use land-cover change
HP	Himachal Pradesh
m ha	Million hactares
kg	Kilogram
C	Carbon
N	Nitrogen
P	Phosphorus
K	Potassium
SOC	Soil organic carbon
EC	Electrical conductivity
COD	Chemical oxygen demand
BOD	Biological oxygen demand
$Mg\ m^{-3}$	Mega gram per cubic meter
Cd	Cadmium
Hg	Mercury
Pb	Lead
As	Arsenic
Zn	Zinc
Cu	Copper
Fe	Iron
$\mu g\ C\ g^{-1}$	Microgram carbon per gram of soil
Gg C	Giga tons of carbon
$dS\ m^{-1}$	Deca Siemen per metre
$g\ cm^{-3}$	Gram per cubic centimetre
$Cfu\ g^{-1}$	Colony forming units per gram of weight

Chapter-1

INTRODUCTION

Humankind benefits in a multitude of ways from ecosystems. Collectively, these benefits are known as ecosystem services. Ecosystem services are regularly involved in the provisioning of clean drinking water and the decomposition of wastes. While, scientists and environmentalists have discussed ecosystem services implicitly for decades; however, the concept of these services was popularized by the Millennium Ecosystem Assessment (MA) in the early 2000s. This grouped ecosystem services into four broad categories as *provisioning* (the production of food and water), *regulating* (control of climate and disease), *supporting* (nutrient cycles and crop pollination) and *cultural* (spiritual and recreational benefits).

Over the past 50 years, human has changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fibre and fuel. This has resulted in a considerable and largely irreversible loss in the diversity of life on earth. The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development. These gains however, resulted in the degradation of many ecosystem services and the exacerbation of poverty for some groups of people. These problems, unless addressed, will substantially diminish the benefits that future generations obtain from ecosystems.

The evidence is now overwhelming that human activity has significantly altered basic element cycles, the water cycle and the land surface at regional, continental, and planetary scales. These alterations are influencing the regional and global environment including the earth's climate system. During the last 300 years more than 50% of the land surface has been affected by land-use activities. More than 25% of forests have been permanently cleared. Agriculture occupies more than 30% of the land surface, and globally there are 10,44,106 km^2 of land that are recovering from previous human land-use activities (Turner *et al.* 1990; Vitousek *et al.* 1997). Land-use changes have altered the surface albedo, surface aerodynamic roughness, rooting depth and terrestrial carbon balance, with resulting effects on regional-global weather, hydrology and climate (Pielke *et al.* 2002; Pongratz *et al.* 2010).

Land-use change has a significant impact on the world's ecosystems. Changes in the extent and composition of forests, grasslands, wetlands and other ecosystems have large impacts on the provision of ecosystem services, biodiversity conservation and returns to landowners. Identifying the causes of land-use change requires understanding both how people make land-use decisions and how specific environmental and social factors interact to influence these decisions. It is also critical to understand that land use decisions are made and influenced by environmental and social factors across a wide range of spatial scales. Household level decisions that influence local land use practices to policies and economic forces can alter land use regionally and even globally (Lambin and Helmut, 2006). Traditional land use pattern in the Himalayas has been changing rapidly mainly in response to population growth and the resultant increased demand on natural resources as well as due to increasing socio-economic marginalization. Large changes in climate and land use typically resulted in large changes in ecosystem service supply. Some of these trends may be positive and offer opportunities for employment. However, many changes increase vulnerability as a result of a decreasing supply of ecosystem services.

Anthropogenic land-use and land-cover change (LULCC) affects climate through two different pathways. The biogeophysical pathway considers alteration of the physical characteristics of the land surface such as albedo, soil moisture, and roughness. The second, the biogeochemical pathway, takes into account alterations of the atmospheric concentrations of greenhouse gases (GHGs) such as CO_2, CH_4, and N_2O in response to changes in the land–atmosphere fluxes of these trace gases (Arora and Boer, 2010; Canadell *et al.,* 2007; Houghton, 2003; House *et al.*, 2002; Pongratz *et al.*, 2009 and Shevliakova *et al.,* 2009). LULCC was previously shown to result in seasonal changes in temperature, precipitation patterns, snow cover in high-latitude regions, and atmospheric dynamics (Bala *et al.*, 2006; Chase *et al.,* 2000; Claussen *et al.,* 2004 and Feddema *et al.,* 2005).

In most countries agriculture is the main user of land resources, and changes in agricultural land use is one of the major driving forces for most of environmental changes at global and local level. Conversion of agricultural land to artificial surfaces can have several environmental impacts on soil, water and biodiversity resources.

A general decrease in agricultural areas has been observed in the last decades in industrialized countries because of growing demand for urban, industrial and infrastructural areas. Increased land development often results in higher prices for land and has an important impact on the environment and on agricultural landscapes. The impact is obviously very diversified in the case of a change to urban land compared to the case of land abandonment.

Kullu district of Himachal Pradesh is undergoing fast development especially in the sector of horticulture, tourism and hydro-power generation. These activities are heavily dependent on land resource utilization. The changing land use in the district like other parts of the world may impact ecosystem services in the region. Since in order to improve land use planning, management and decision-making the information on the influence of land use changes on the total bundle of ecosystem service is essentially required, therefore, the present study entitled **"Impact of land use changes on ecosystem services in Kullu District of Himachal Pradesh"** has been conducted with following objectives:

1. Identification of land use changes in mid-hills of Kullu district of Himachal Pradesh.
2. To study the impact of land use changes on ecosystem services like soil-water quality and carbon sequestration.

Chapter-2

REVIEW OF LITERATURE

Ecosystem services are the conditions and processes through which natural ecosystems and the species that make them up sustain and fulfil human life. These services maintain biodiversity and are responsible for the production of ecosystem goods such as seafood, forage, timber, biomass fuels, natural fibre, many pharmaceuticals, industrial products and their precursors. Therefore, economic valuation of ecosystem services is becoming increasingly important to understand the multiple benefits provided by ecosystems as per the concept of Zhao *et al.* (2004). Nowadays, imbalanced provision of economic and ecological services has become an issue of increasing concern. It is widely known that land-use/land-cover changes play a pivotal role in environmental and ecological changes and furthermore contribute to global climate change. Changes in land use and land cover impact natural resources and significantly influence the key aspects of earth system functioning and are being considered primary source of soil degradation (Tolba and El-Kholy, 1992). The cohesiveness in the representation of the research related to present investigation entitled **"Impact of land use changes on ecosystem services in Kullu District of Himachal Pradesh"** has been reviewed under following headings:

2.1 Global status of land use change

2.2 People's perception on land use change

2.3 Impact of land use changes on ecosystem services

- 2.3.1 Soil quality
- 2.3.2 Water quality
- 2.3.3 Carbon sequestration

2.1 GLOBAL STATUS OF LAND USE CHANGE

The distribution of historical land use and land cover change over time is highly regionalized. By 15th century, large areas of Western Europe had been partially cleared for agriculture and for timber harvesting. Land-use land-cover change (LULCC) intensified, particularly in Western Europe, through 1800 while significant LULCC also occurred over much of Asia including India and China. Future loss of the Amazon forest, logging of boreal forests, and other land-use changes could exacerbate the extinction crisis and lead to additional regional–global climate changes (Bonan *et al.* 1992; Cox *et al.* 2000; Wise *et al.* 2009).

Indeed, by the year 1750, 7.9–9.2 million km^2 (which corresponded to 6–7%) of the global land surface was under cultivation. Western Europe and the parts of Northern China had more than 60% agricultural cover. During 1990, 35-39% of the global land surface was cultivated consequently reducing about 11 million km^2 forest area (Ramankutty and Foley, 1999). Intensive LULCC had impacted parts of the United States, much of Western Europe, India, Northern China and elsewhere. Large areas of the Southern Hemisphere underwent LULCC throughout the 19th century. By 2000, only a few desert regions, the central Amazon and Congo Basins and the Arctic and Antarctic had not been affected by LULCC (Klein Goldewijk, 2001; Defries *et al.*, 1995; Hurtt *et al.*, 2006). Klein Goldewijk *et al.* (2010) provides details of the methods used to reconstruct historical LULCC.

The global area of cropland has increased dramatically and is now almost 11% of the total land area (Williams, 1990; Klein, 2001;Richards, 1990).Agricultural expansion and intensification were the major drivers of global LULCC. The global area of cropland reported to increase from 300 m ha in 1700 to 1530 m ha during the year 2000 (Klein Goldewijk *et al.*, 2011). In the past changes in cropland had been reported by various workers (Ramankutty and Foley, 1999, Williams, 1990, Richards, 1990, Matthews, 1983.

The global area used for grazing livestock has increased at an alarming rate, from 324 million ha in 1700 to 3429 million ha during the year 2000 (Richards, 1990). During mid 20th century the urban area was only 1% of the total land geographical area of the world and has now increased upto 5% of the total global land area (Klein *et al.* 2010; Potere, 2007).

China has cultivated wheat and rice for thousands of years, especially in the north-eastern provinces however, during late 17th century, its area under cropland had increased alarmingly due to opening up of its borders to the emerging world economy Richards (1990). In the 18th century, intensification and commercial cropping was replaced by shifting cultivation in the hills the land clearance on slopes because of this practice resulted in land degradation and flash floods which drastically influenced the ecosystem services.

Recently, the forest area in China has increased due to large-scale reforestation programs. Richards and Flint (1994) assessed land use changes in 13 countries in tropical Asia during 1880–1980and reported that since 1900 the forests, woodlands and wetlands decreased by almost 50% while the cultivated area increased by 106 million ha in the region. They further reported that 81% of the lost forest and wetland have now been converted into agricultural land. In recent decades, rapid deforestation has occurred in Southeast Asia due to logging pressures and the expansion of palm oil plantations.

2.2 PEOPLE'S PERCEPTION ON LAND USE CHANGE

Farmers in many tropical rain forest areas have traditionally relied on the forest for regeneration of fallows and more importantly as a source of plant materials and to supplement their agricultural produce. However, in the recent past shift to global economy and increased population has put tremendous pressure on rainforests consequently decreased area under rainforests and influenced the ecosystem services (Wiersum, 1997).

Understanding peoples' perceptions of the services provided by natural systems can provide insights into the interplay of the innate linkages between humans and their environment. This in turn can contribute towards identifying ways to reduce future impacts on society from environmental change.

Recognition of environmental change should, arguably, be facilitated by an individual's connection to a specific place or landscape. How people assess the conditions of the places they know and have meaning for them has historically been studied by researchers within the construct of place attachment, with contradictory results. Higher levels of place attachment have been correlated with both heightened perceptions of environmental change and degradation (Kyle *et al.,* 2004) and with lower levels of perceived risks (Billing, 2006; Bonaiuto *et al.*, 1996; Rollero and De Piccoli, 2010).

The early work on risk perceptions concentrated to develop linkages between perception and response in the belief that this would assist the development of risk communication tools that would make possible to "educate" the public or change their perception of risk to make them closer in consonance with Slovic (1986), Fischhoff *et al*. (1982), cited by Gough (2000). Many studies have addressed, observed and projected changes in land cover and land use as a result of climate change (Backlund *et al.* 2008, Iverson *et al.,* 2008, Shafer *et al.* 2001, White *et al*. 2010).

Spatially explicit information on local perceptions of ecosystem services, provides a rich basis for the development of sustainable land management strategies, and could align better biodiversity conservation and social value agendas (Maes *et al.* 2012). Yet, despite the necessity for incorporating social values into land use planning, scientific understanding of ecosystem services is still embryonic and estimating the values of such in tangible forest service's remains methodologically challenging (Plieninger *et al.* 2013). Few studies have tried to quantify and map non-material benefits such as cultural and spiritual services people derive from natural systems (Hernández-Morcillo *et al.* 2013) or people's perceptions of the services they derive.

Due to decline in wild sources of palms, the indigenous people and settler communities in southeast Ecuador to incorporate palms in their agricultural system to ensure a continuous supply of palm production. Both the communities perceived a decline in palm abundance (Byg and Henrik, 2006).

People use a variety of products from conserved and highly degraded forests. Perceptions of benefits to local people from forests were studied by Abram *et al.* (2014). They observed that people of the area have perceived that while receiving various services from forest ecosystem in imbalanced manner may degrade forests. They further reported that a large scale change of forests to agricultural activities has been by the local people as the main cause of decline in ecosystem services.

Weber (1997) was of the opinion that changes can occur more or less normative based on the length of the base time comparison period. Whereas the systematic biases in the ways that humans process frequency information from experience, as opposed to statistical description have also been experienced by number of workers (Camilleri and Newell, 2011; Hertwig *et al.,* 2004; Hertwig and Erev, 2009). The socio cultural context in which people experience weather and climate influences whether they notice and remember signals, what they believe they have experienced (Goebbert *et al.,* 2012; Strauss and Orlove, 2003) and whether they perceive it as a risk (Kahan, 2012).

2.3 IMPACT OF LAND USE CHANGE

2.3.1 Soil quality

Soil quality refers to the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. The land use change influence the nutrient supply of an ecosystem; hence the soil nutrient status is better in abandoned land and least in orchards (Yang-Min *et al.,* 2012). Similar results were reported by Rongzhong *et al.(*2009). They observed that the least-managed fields under pasture had the lowest microbial biomass and phosphorus levels, whereas, turf and forest had more microbial diversity than pasture or the most intensively managed sugarcane fields.

The soil contains approx. $30x10^{14}$ kg organic carbon but distribution of this organic matter among soil type is highly variable and generally not easily predictable from ground vegetation types (Bohn, 1976). The total and microbial C and N decline consistently with profile depth and microbial carbon and nitrogen ratios differ little among soil depths and ecosystems (Ross *et al.,* 1999). The land conversion and agriculture activities have been reported to decrease soil organic carbon because of decrease in soil organic carbon inputs, soil redistribution and changes in mineralization (Pennock, 1997and Janzen *et al.,*1997).

In Himachal Pradesh, significantly higher soil organic content was in agro-forestry systems as compared to pure agricultural fields (Goswami, 2008). Another study conducted by Mbah and Idike (2011) inferred that total carbon stored in soil was recorded highest in natural uncultivated forests as 37, 62 and 27 per cent over alley cropping, sewage sludge dump and *Gmelina arborea* forest, respectively. The study further revealed that forests and alley cropping can store large quantities of C in soils as compared to other agricultural practices. The soil organic carbon content was found to be significantly lower in textile mill effluent affected soil as compared to normal rain fed soils. There was a sharp depletion in the contents of available nutrients in effluent affected soils (Sharma *et al.,* 2000). Enrichment of soil with organic carbon due to addition of industrial effluents was also reported by Jadhav and Savant (1975). An increase in pH, EC, organic matter and total nitrogen content of soil was observed with increase in concentration of paper mill waste water (Behera, 1986, Mishra and Sahoo, 1989).

Singh *et al.* (2011) while studying quality of soil from eight districts of Punjab under agriculture land use observed that the pH of the sample varied from 7.0 to 9.2. Electrical conductivity for the surface soil samples varied from 0.30 to 1.68 dS/m which was very high. A study conducted in the soil of Nagchoon Pond Khandwa, MP, India during summer season a high concentration of salts resulted in alkaline nature of the soil and its conductivity becomes high (Mahajan and Billore, 2014). The nitrate and phosphate concentration in soil was also noticed to be affected due to agricultural runoff and anthropogenic activity in and around Nagchoon pond.

The use of land as receptor of waste water has been practiced for hundreds of years throughout the world. Sewage farming was used in Germany as early as the 16th century and was common in England until the late 1800 (Wolman, 1977). Due to the disposal of industrial effluent on land, the physico-chemical properties of soil have been reported to be influenced which consequently changed the composition of micro-organisms in soil (Alexander, 1978). The nutrient and organic matter rich effluents use also reported to add toxic metals in agricultural soils and have influenced crop and human (Mittar *et al.,* 1992; Medhappan, 1993; Rao *et al.,* 1993). The accumulation of heavy metals has been reported to be more in surface (0-15 cm) than in subsurface soils (Adhikari *et al.,* 1993, Kuhad *et al.,* 1989).

Urban soil profiles show abrupt changes from one layer to another depending upon the constructional history of the soil. If topsoil is scraped away and later backfilled, two distinct layers result, particularly if the topsoil is from elsewhere. The abrupt change is commonly referred to as a lithologic discontinuity and an interface is created. This condition is common in home construction. Craul and Klein (1980) observed this layer to range from 6 to 35 cm in streetside soils. Each layer may drastically differ in texture, structure, organic matter content, pH and bulk density together with their related properties of aeration, drainage, water holding capacity and fertility. One layer may be hospitable to plant root growth and survival, while the other may not. Therefore, great vertical variability exists which could present multiple problems for plant root growth. Patterson (1976) found average values of bulk density due to surface compaction, ranging from 1.74 to 2.18 Mg m^{-3} in four profiles of the Washington, D.C. Mall. Root penetration is highly restricted at values exceeding 1.70 Mg m^{-3}. Craul and Klein (1980) found a range of 1.54 to 1.90 Mg m^{-3} with most centring on 1.82 Mg m^{-3}. Values from New York's Central Park (unpublished data) range from less than 1 .00 to 1.34 Mg m^{-3} for undisturbed surface soil and 1.52 to 1.96 Mg m^{-3} for subsoils.

Leafy vegetables grown in heavy metals contaminated soils, have been noticed to accumulate higher amounts of metals than those grown in uncontaminated (Al Jassir *et al.,* 2005). Vegetables can absorb toxic metals from the soil as well as from deposition on parts of vegetables exposed to the air from polluted environments (Haiyan and Stuanes, 2003). The toxic metals in soils were reported to inhibit root, shoot growth, nutrient uptake and homeostasis and were noticed to be accumulated frequently by agriculturally important crops. So, the contamination of leafy vegetables (Brassica species) with Cu, Zn, Cd, Ni, Pb and

Cr and subsequent human exposure risks, were determined at two sites in the city of Hazare, where waste water is used for irrigating vegetables (Mapanda *et al.,* 2005).

In order to study the impact of industrial land use a field experiment was conducted by Bansal *et al*. (1992) to observe the effect of use of industrial waste water for irrigation in soil at an interval of 0, 2 and 5 years and it was found that there was a decrease in wheat yield and soil pH and increase in available heavy metal content in soil, grain and straw.

The adverse influence of effluent irrigation on soil and crop growth has also been recorded by various (Anand *et al.,* 1969; Karande *et al.,* 1993; Maddhapan, 1993 ; Rao *et al.,* 1993 and Vijaykumari *et al.,* 1993). Sharma and Naik (1991) studied the effect of a steel mill effluent on agricultural soil and vegetable crop. The study showed that the concentration of Ca^{++}, Mg^{++} decreased in *Abelmoschus esculentus* (Bhindi).

Fytianos *et al.* (2001) analyzed different vegetables from industrial and rural areas of Greece and reported no significant differences in the concentration of metals in most of the vegetables analyzed except a significant uptake of Zn in spinach. Research work conducted by Itana (2002) in Addis Abada, Ethiopia revealed that cabbage was the least accumulator of chromium among different vegetable crops.

A high concentration of Pb (3.0-10.7 mg/kg) was reported by Demirezen and Ahmet (2006) in different samples of vegetables. They also found that the levels of Cu (22.19- 76.50 mg/kg) were higher in leafy than non-leafy vegetables species in Turkey and this was related to the richness in chlorophyll.

The content of Zn, Fe, Cu, Pb and Ni were found to be high in the plant samples of fodder, vegetables, cereals and oilseed crops in Bhiwani, Hansi, Karnal, Charkhi, Dadriand Dabra areas which were irrigated with sewage water for 20 to 25 years (Malik *et al.*, 2008).

Land cover change may alter soil phosphorus transformation by modifying the amount of plant P demand, litter quality and quantity, and soil physical, chemical, and biological properties (Ross *et al*., 1999; Chen *et al.,* 2003, 2008).

2.3.2 Impact on water quality

Land use change is a primary factor affecting water-quality and causing habitat degradation (UN, 2003). There have been several investigations in recent years on the effect of land use on water quality. Historical land use/land cover change has impacted the annual water balance in many Midwestern basins by decreasing annual evapotranspiration (ET) and increasing stream flow and base flow (Schilling *et al*., 2008).

Forests are good for water environment, as they increase rainfall and runoff, regulate flows, reduce erosion, floods and act as natural filter for better water quality (Calder, 2003). According to Hamilton (2005) forest is the best land cover for maximizing the water yield, regulating the seasonal flow and ensuring high water quality. Forest cover influences groundwater levels, wells and springs, as well as safeguarding water quality as noted by Foster and Chilton (1993).

Suspended sediments are found to be lowest for forest catchment as compared to the urban catchment where they are highest (Lenat and Crawford, 1993). Lenat and Crawford in their study on water quality of North Carolina piedmont streams further found that most of the nutrients were highest in the agricultural fields and maximum average concentrations of heavy metals (Cr, Pb and Cu) were at urban areas. Subramanian (2004) studied the water quality of the Himalayan and Southern peninsular rivers of India and observed large variations in water quality of different rivers because of their catchments.

A case study in the Chaohu Lake basin in China indicated that there was significant negative correlation between forest land and grassland and the water pollution and the built-up area had negative impacts on the water quality while the influence of the cultivated land on the water quality was very complex (Huang *et al.,* 2013).

The conversion of grassland into pine forests in Cathedral peak in Natal has been reported to influence the hydrologoical cycle of the region (Bosch, 1979). The plantation forestry was found to increase dry season flows on long term basis through alterations to the hydraulics of the drainage system Robinson *et al.* (1997). Forested catchments were found to have high levels of DO and low levels of NH^{4-} and NO^{3-} compared to those from farmland, industrial, residential and market places in Ruvu River Watershed (Ngoyi and Machiwa, 2004). In the catchment of the watershed higher nutrient concentration were noticed during rainy season. The anthropogenic activities like change in land use etc. were reported to impair the water quality of different sources.

Patel *et al.* (1994) while comparing the effect of industrial land use on water quality with that of rural areas observed that drinking water quality of rural areas was better/safe as compared Rourkela industrial complex. The nitrate-N concentration of surface and ground water in three rural communities in the central Red River Delta, Northern Vietnam was found to be lower than 0.4 ppm, whereas ammonium-N was relatively higher and exceeded the Vietnamese water standard for the drinking purpose. The low pH of the ground water measured at some sites in the grey degraded soil area was also observed beyond standard for drinking use in the country (Kurosawa and Ngoyen, 2004). Vijaya Shankar et al. (2014) studied the physio-chemical characteristics and Water Quality of groundwater at Angarai Panchayat of Lalgudi taluk of Tiruchirapalli District in Tamil Nadu, India and reported that pH, EC, Cl, Ca, Mg, carbonates and bicarbonates were within the maximum permissible level prescribed by ISI (1992).

The ground water quality in rural areas of Rohtak, India did not comply with WHO standard and overall water quality was unsatisfactory for drinking purpose (Bishnoi and Arora, 2007). In another study by Garg *et al.* (2008) the quality parameters like TDS, pH were noticed to be beyond permissible limits in ground water in the village of southwestern Haryana, India. Similarly the ground water quality assessment in Eshtehard District, Tehran, Iran , revealed a high salinity, SAR and Na per cent in most of the water samples which has been found to restrict the use of water for irrigation purpose (Khodapanah *et al.*, 2009).

The agricultural land use within catchments has been linked to increasing concentrations of inorganic nitrogen in drainage waters. The concentration of NO^{3-} in stream water was found strongly correlated with the proportion of agricultural land associated with grassland and common upland crops in the catchment (Tabuchi *et al.,*1995). The agricultural lands contribute and most of the nitrogen loading in the system followed by impervious urban areas, forest and finally barren land (Tong and Chen, 2002).

The precipitation and mineralization of soil organic matter greatly influence the drainage losses, nitrate concentrations and its loadings in subsurface drainage water. Randall (2000) reported high concentration of nitrates in surface water of Mississippi river basin, due to surface drainage from row crop agricultural production system. Zhulu *et al.* (2015) studied the impact of agricultural land uses on regional water resources of the Red River of the North Basin, an international river basin shared by the US and Canada from pre-EISA (US Energy Independence and Security Act of 2007) to post-EISA. The influence of the land use change on spring snowmelt flooding and downstream water quality was also assessed using watershed modelling. In the river basin it has been observed that the area under corn and soybean crop has increased by 62% and 18% from 2006 to 2013; while those for spring wheat, forest, and pasture have decreased by 30%, 18%, and 50%, respectively, in the same time period. In addition to this area under new crops sugarbeet, canola, dry beans and alfalfa has increased. Interestingly the area under traditional agriculture crop like barley and oats, have decreased drastically. Hydrological simulation also showed that the sediment and nutrient loads at the basin's outlet in the US and Canada border increased by 2.6%, under the post-EISA land use scenario.

The persistence of contaminants was reported to be increased because of slow groundwater travelling time in urban and suburban areas (Howard and Pilon, 1987). A positive correlation of water quality of urban and sub-urban areas with land use pattern was reported by Eckhardt and Stacklberg (1995). The pollution in rivers near urban stretches has been reported to be more especially in rivers of south Asian countries such as Nepal, India and Bangladesh (Karan and Harada, 2001). Trojan *et al.* (2003) carried out water quality analysis of Anoka Sand Plain Aquifer of Minnesota to study the effect of different land uses and observed that the concentration of several trace inorganic chemicals was greatest under sewered urban areas. The results further revealed that the land use was dominant factor affecting shallow ground water quality. The change in land-use practices, especially urbanization and intensive agriculture has been reported to deteriorate the water quality (Chattopadhyay *et al.*, 2005). Studies carried out by various workers showed that the unplanned urban, industrial expansions and domestic and industrial waste discharge has a direct impact on water quality of the lakes and hence change of land use to such activity has direct impact on the quality of water (Mcadams, 2006; Fachrul, 2007 and Basturk, 2007).

The impact of changed forest land use to suburban has been well illustrated in New York City water catchment. In the catchment due impervious surface under changed suburban areas has deteriorated water quality due to run-off from septic system, roads, agricultural fields and animal (Heisig 2000).

A study carried to observe the spatial variation of physio-chemical and hydrological parameters with land-use in Venkatapura catchment in Karnataka, indicated variation in dissolved oxygen and free carbon dioxide according to the flow nature of water and increased amount of phosphorus in stream closer to anthropogenic activities (Karthick and Ramachandra , 2007). The alluvial plains of Haryana have been reported to contain high concentration of arsenic along with lead, cadmium and nickel in groundwater sources (Kamra *et al.*, 2002).The urban areas shows higher mean values of TDS, TS,EC and PO_4 in groundwater especially in dry seasons as compared to peri-urban areas (Orebiyi *et al.*, 2010). Similarly, Eni *et al.* (2011) studied the impact of urbanization on sub-surface water quality in Calabar municipality, Nigeria and found high pH at some locations due to boreholes lacated very close to cementaries and defunct sewages. Nitrate and chlorine concentration increased with increasing urbanization. Yisa *et al.* (2012) determined the physio-chemical parameters of the water so as to evaluate the level of contamination of Doko community of Niger state, Nigeria. The results of this study showed that chloride and iron content were below the WHO limits while chemical oxygen demand (COD) and nitrate (NO^{3-}) values exceeded the permissible limit of WHO. Bandela *et al.* (2012) reprted high levels of nitrate, TDS, TSS and TS in water samples taken from borewells and handpumps of Jabalpur near Municipal solid waste.

The status of Nainital Lake at Uttarakhand, India was studied by Gupta *et al.* (2010) and it was noticed that pH of the water remained alkaline with an annual average value of 8.35 throughout the year. The high levels of BOD, nitrate-nitrogen, ammonium-nitrogen, phosphate-phosphorus in water were found to be very high. The concentration of micronutrients namely, Cu, Zn, Mn and Fe was low and below the permissible limit prescribed by WHO.

The disposal of sewage from surrounding areas has shown high levels of hydrological parameter and biological pollution indicator in Shanmuganadhi river, Tamil Nadu (Kathikeyani *et al.*, 2002). Similarly, Iqbal and Gupta (2009) reported deterioration of ground water quality due to improper solid waste dumping as heavy metal ions present in it are potentially toxic to human health.

The water quality index of ground water in Mahanadi and Atharabanki rivers and Talanda Canal in Paradip area in three different seasons were assessed and it was reported that there was deterioration of water quality in the rivers due to industrialization and human activities (Samantray *et al*., 2009). In Rajasthan area deterioration of the groundwater quality under quicklime units and cement industry has also been reported (Anonymous, 2009). High EC values of groundwater have been recorded in different areas around the cement industry (3.02- 7.45 dS/m).

Increasing level the effluents from paper mill has reported to decrease the soil pH, EC and organic carbon (Singh and Singh, 2005). Hazarika *et al.*(2007) reported pH (1.3 units higher), EC (more than three times), chloride concentrations (197 mg/kg) higher in soils irrigated with effluents discharged from pulp and paper mill as compared to soils irrigated with water from shallow tube well in Assam.

The effect of land uses on Water Quality in Kluang, Malasia was studied by Aweng *et al.* (2011) to determine physical and chemical water quality for three rivers which flowed through different land uses. They recorded high conductivity, temperature, salinity, turbidity, COD, BOD, ammonical nitrogen, nitrate, phosphate and total suspended solid for Mengkibol river, while high concentration was recorded for Madek (logging) and Dengar (oil palm plantation) stations including the reference (Hulu Dengar) and back-up reference stations (Gunung Berlumut). There was no significant difference in pH of these rivers. The Water Quality Index (WQI) results for all the rivers were under class I & II except Mengkibol river that was under class III according to Malaysian's WQI guideline.

The low level of industrialization has less polluting effect on surface as well as ground water sources. The groundwater sample from less industrialized areas of Kwahu, west district of Ghana was relatively free from heavy metal contamination and if any present, were below permissible limit (Nkansah *et al*., 2010).

Schultz (1996) studied most agro forestry systems and stated that a 25m wide buffer of tree, shrub, herb and grass vegetation can remove 80 to 95 per cent of the sediment and more than 90 per cent of the herbicides running of the crop fields. Trees are especially important in this mix, because their rhizoshpere usually supports and abundance of microorganisms that can degrade herbicides, insecticides and some other toxic compounds (Haselwander and Bowen, 1996).

2.3.3 Impact on Carbon Sequestration

Total organic matter accumulated in soils constitutes a major of the world's fixed carbon reserves. Soil contains approximately 30 x 10^{14} kg organic carbon. Distribution of this organic matter among soil types is highly variable and generally not easily predictable from above ground vegetation types. The ratio between SOC and biomass carbon is 2.5 to 3 times in the terrestrial ecosystem (Post *et al.*,1990).

Tree improve soil productivity through ecological and physio-chemical changes that depend upon the quantity and quality of litter reaching soil surface and rate of its decomposition and nutrient release (Meentemeyer and Berg, 1986). According to Adger *et al.* (1991) the high forests in Britain contained 30.4 m t C in coniferous stands and 50.5 m t C in broad leaved wood lands.

Forest soil organic carbon (SOC) is influenced by the complex interactions of climate, soil type, management and tree species (Lal, 2005). A growing body of evidence has demonstrated that forest species composition will influence soil carbon turnover due to its different microclimates at the forest floor (Berger *et al.,* 2002). These effects have been attributed to the fact that tree species could potentially alter size and physiochemical properties of carbon additions in litter from the aboveground and belowground flora and fauna. Distribution of the root systems of plants in the soil profile, as well as that of carbon within the soil matrix and it's inter- action with clay surfaces (Oades, 1988; Berger *et al.,* 2002). Several studies have shown that mixed forests may influence soil carbon and nitrogen (N) concentrations and stocks (Berger *et al.,* 2002; Borken and Beese, 2005; Tang *et al.,* 2006).

Afforestation and reforestation can greatly affect soil GHGs fluxes by changing key physical and chemical properties that influence soil nutrients and carbon cycling and microbial activity (Paul *et al.,* 2002; Merino *et al.,* 2004; Kelliher *et al.,* 2006). Tree species are considered to alter soil chemical, physical (e. g. moisture and temperature) and biological processes through their root system, crown structure, foliage, leaf structure and litter quality (Borken and Beese, 2006; Jonard *et al.,* 2007; Ullah *et al.,* 2008). Thus conversion of monoculture forests to mixed forests is closely related to the GHGs reduction of afforestation.

Deforestation, changes in land use and predicted climate change has been reported to alter the amount of organic carbon held in the superficial soil layer (Batjis, 1996). Conversion of natural forests to agriculture in the humid tropics had been reported to reduce ecosystem carbon storage due to removal of above ground biomass and a gradual subsequent reduction in soil carbon. The land-use changes especially deforestation may limit the capacity of an ecosystem to provide more ecosystem services on a sustained basis and can result in long-term degradation of environmental quality. Land conversions also reduce the potentials for biomass carbon production (Lal, 2003, Portela and Rademacher, 2001). Estimation of biomass and sequestered carbon on farm forest plantations in northern New South Wales, Australia (Specht and West, 2003) revealed that organic carbon content of soil below plantations and adjacent pasture paddocks decline with time following establishment.

Global warming and its effect on soils in terms of SOC management have led to several quantitative estimates for global C content in the soils (Eswaran *et al.,* 1999; Batjes, 1996 and Kimble *et al.,* 1990). According to Lugo and Brown (1992) changes in land-use and rates of carbon accumulation by them including mature, logged and fallow tropical forests and degraded lands can be used to estimate the role that the tropical landscape provide as a sink of atmospheric carbon. Singh and Lodhiyal (2009) studied biomass and carbon allocation in Poplar agroforestry plantation in the Tarai region of central Himalaya in India and found that the Poplar agroforestry plantation in the region had a significant amount of biomass and carbon, which was considered as an additional carbon sink in the region.

Tree- based systems with short rotation species either as farm forestry or agroforestry systems have the potential to sequester carbon in a short period (Prasad *et al.,* 2012). The researchers analysed the carbon storage of two land use systems (farm forestry and agroforestry) with two short rotation species viz. Leucaena and eucalyptus and evaluated their carbon sequestration potential in degraded lands in several districts of Andhra Pradesh, India. The carbon stock of Leucaena farm forestry system was 62 mg ha^{-1}, whereas in eucalyptus farm forestry system it was 6234 mg ha^{-1} for a rotation of four years.

Pandya (2013) explored innovative ideas for nature and biodiversity conservation and enlightened the possible approaches made by scientists and researchers or various fields. The study was a small assortment of different biomass methods, which would cooperate to estimate the carbon budget in the ecosystem. The study also gave exposure on the role of Indian Forests in carbon sequestration in International arena.

During the post independence period Kullu District of Himachal Pradesh witnessed large scale socio-economic developments, commercial horticulture, road construction, tourism and other infrastructure developments in Beas river basin (Gardner, 2002). Therefore, the need to study the impacts of such changes on ecosystem was suggested. The study conducted by Chandel *et al.* (2013) has revealed that the land cover changes in the Kullu region was manifested with forest degradation.

It is evident from the reviewed literature that land use changes happening world over have significant impacts on most of the ecosystem services. Hence there is an urgent need to identify and quantify the land use land cover changes and their impacts on ecosystem services so that land use planning can be improved for better decision making.

Chapter-3

MATERIALS AND METHODS

The study entitled '**Impact of Land use change on Ecosystem services of Kullu District of Himachal Pradesh'** was conducted during 2014-15 to determine the spatial and temporal impact of land use change on major ecosystem services in Kullu district. The study was conducted under the department of Environmental Science, College of Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India. The material and methods used to conduct the study are presented under the following headings:

1. General description of study area
2. Experimental details
3. Collection of data
4. Collection of samples
5. Laboratory testing
6. Analytical tools employed

3.1 GENERAL DESCRIPTION OF THE STUDY AREA

3.1.1 Location

The study was conducted in mid hills of Kullu district of Himachal Pradesh of North-western Himalayan region in India. The area lies between 31º21' N and 32º59' N latitude and 76º49' E and 78º59' E longitude. The Kullu district of HP is comprised of five blocks namely: Naggar, Kullu, Banjar, Ani and Nirmand with an area of 54771 ha which constitute about 9.88 percent of the state. Out of the five blocks Naggar, Kullu and Banjar falling in mid hills were selected for the study (displayed in Plate1).

3.1.2 Climate and weather condition

The climate of the Kullu district is sub temperate to temperate with cold dry weather. The district receives moderate rainfall and bulk of it is received during the monsoon months. The district also receives snowfall in high hills during winter months and serves as a great source of fresh water in Beas river of the region. The maximum temperature varies from 15.8ºC in winter months to 32.8ºC in summer months, whereas the minimum temperature ranges from 21.1ºC in summer months to as low as 0.7ºC in winter months (Anon, 2009).

3.2 EXPERIMENTAL DETAILS

To meet out the objectives of the present study four land uses namely: forest, traditional agriculture, orchard and urban were selected. In order to study the season wise impact of selected land uses on major ecosystem services winter and summer seasons were selected. The following treatment combinations were replicated four times by taking selected land uses at different locations of Naggar, Kullu and Banjar blocks of mid hills of Himachal Pradesh.

Treatments:

T_1	:	Forest land use
T_2	:	Traditional area
T_3	:	Orchard
T_4	:	Urban
Seasons	:	Summer and Winter
Replications	:	4

Total treatment combinations : 4 x 2 x 4 = 32

3.3 COLLECTION OF DATA

3.3.1 Land use

In order to assess land use pattern of mid hills of Kullu district the secondary data were collected with respect to revenue villages namely Bajaura, Hat, Jia, Kharal, Khokhan, Mohal, Rote, Shamshi and Shillihar (displayed in Plate 1) falling under the three selected blocks from the respective revenue departments as well as from the Department of Land Records, Shimla, H.P. To determine change in land use the period from 1984 to 1993 was selected as base

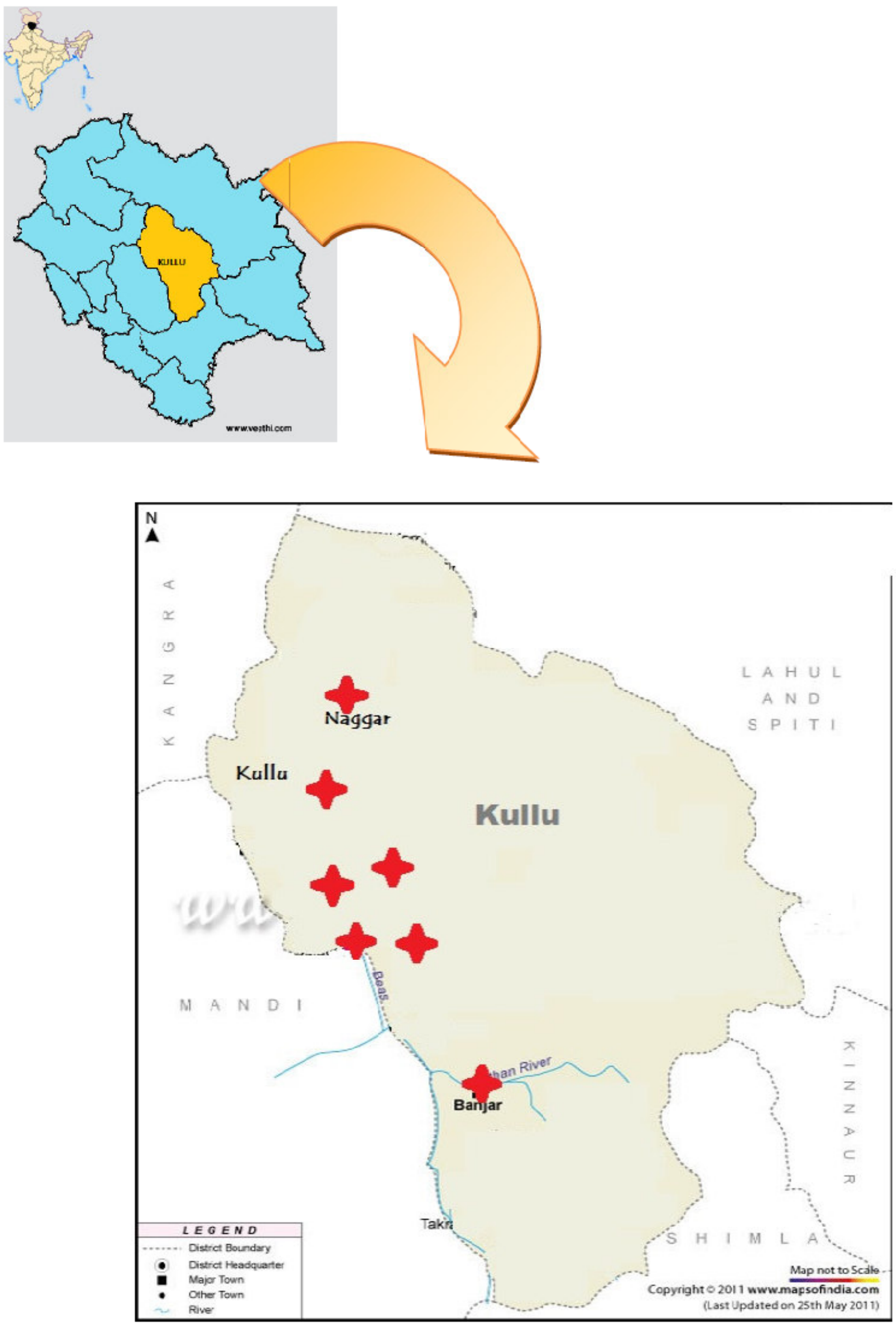

Plate-1: Layout of Kullu district map displaying selected sites

period, from 1994 to 2003 was considered as intermediate and from 2004 to 2015 was taken as assessment period.

The area under forest in the mid-hills of Kullu district of HP is 18379.05 ha, under traditional agriculture is 3552.96 ha, under orchard is 290.04 ha and under urban land use is 421.41 ha.

3.3.2 People's perception

To assess the people's perception regarding land use change and its impact on ecosystem services Kullu, Naggar and Banjar blocks were selected to carry out the survey. In the selected blocks fifteen panchayats namely Rote, Shamshi, Pinni, Jari, Jarar-Bhutti colony, Jia, Bhuin, Bara Bhuin, Bashauna, Hat, Kalehali, Tharas, Hurla, Talogi and Puid were selected on random basis. Forty percent survey of the total households of the blocks were considered to conduct survey by personally interviewing the people of the study area.

3.4 COLLECTION OF SAMPLES

3.4.1 Soil Samples

The soil samples from surface layer (0 to 15 cm) were collected by using tube auger from all selected four land uses during winter and summer seasons. The soil samples were dried in shade and then passed through 2 mm mesh sieve and stored in cloth bags for further analysis.

3.4.2 Water Samples

The water samples from surface and ground water sources under selected land uses were collected in winter and summer seasons during 2014 and 2015. The samples were preserved for quality analysis by adding 1 ml concentrated HNO_3 to the water samples to avoid microbial utilization of heavy metals.

3.5 LABORATORY TESTING

3.5.1 Soil analysis

The soil samples were analysed for the following physical and chemical properties:

1. Soil organic carbon and carbon stock
2. Soil pH, EC and bulk density
3. Available N P K contents
4. Heavy metals (Cd, Hg, Pb, Cu, Fe, Zn, As)
5. Total Microbial count and biomass

Soil organic carbon: It was determined by Walkely and Black (1934) rapid titration method.

Carbon Stock: The soil organic carbon stock Qi (Mg ha^{-1}) was computed by multiplying the soil carbon content (%) with bulk density Di (g m^{-3}), volume fraction of course elements (gravel) Gi and depth Ei (m) and expressed as Gg C as per below mentioned formula given by Batjis (1996).

$$\mathbf{Qi = Ci\ Di\ Ei\ (1\text{-}Gi)}$$

Soil Bulk Density: The bulk density was calculated by Core method (Singh, 1980). A metallic core having 8.5 cm internal diameter and 12 cm height was used for the purpose.

Soil pH: The pH of the soil was determined in 1:2 soil and water suspension (Jackson, 1973) and measured by microprocessor based pH-meter (Model 510 of EIA make).

Soil EC : The Electrical conductivity of the soil was estimated in 1:2 soil-water suspension (Jackson, 1973) by using microprocessor based conductivity meter (Model-1601 EIA make) and expressed as dS m^{-1}.

Available Nitrogen, Phosphorus and Potassium: The available nitrogen in soil was determined by alkaline potassium permanganate method of Subbjah and Asija (1956). Estimation of available phosphorus was done by Olsen's method by using 0.5 N $NaHCO_3$ as extractant (Olsen *et al.*, 1954) and determined colorimetrically by stannous chloride reduced amoonium molybdate method in HCL system (Jackson, 1973). The available potassium was analysed by using neutral normal ammonium acetate solution as extractant (Merwin and Peach 1951).

Heavy metals: To analyze the heavy metals viz., Cd, Hg, Pb, Cu, Fe, Zn and As, 0.5 g of soil sample was digested with concentrated HNO_3, H_2SO_4 and H_2O_2 in the ratio of 2:6:6 as per procedure prescribed by Saison *et al.* (2004). The concentration of heavy metals was estimated by using ICP Spectrometer (Model-ICAP 6300 duo) of Thermo Scientific Make. The heavy metal concentration has been expressed as mg kg^{-1}.

Total microbial count: The enumeration of microbial population was done by plate count technique through serial dilution using a variety of media (Wollum, 1982).

Microbial Biomass: The biomass was obtained by using soil fumigation-extraction method given by Vance *et al.* (1987).

3.5.2 Water analysis

The surface and ground water samples collected were analyzed for following parameters:

1. pH
2. COD
3. BOD
4. Heavy metals (Cd, Hg, Pb, Cu, Fe, Zn, As)

Water pH: The pH of water was determined directly by taking sample water in a 100 ml beaker using a pH meter.

Chemical oxygen demand (COD): The COD was determined with the help of TR320 Spectroquant. For the estimation, 3 ml of sample was pipette out and poured in COD Cell Test and then COD Solution A 0.3 ml and COD Solution B 2.3 ml was added into the sample and kept for digestion in spectroquant TR320 at 146ºC for 2 hrs. After that samples were kept at room temperature to cool down and readings were taken in spectroquant pharo 300 of Merk made.

Biological oxygen demand (BOD): BOD was calculated by using BOD- System Oxidirect. Samples were taken into the beaker and pH of samples was adjusted between 6.5 to 7.5. Then 152 ml of sample was poured into the BOD bottles, and 5-6 drops of nitrification inhibitor (ATH) was added with one magnetic stirrer. Then in the bottles gasket was kept and 3-4 drops of KOH solution was added. After that sensor was attached to BOD bottle and bottles were loaded in the system. Finally BOD bottles loaded on BOD system was kept in incubator for 5 days at 20ºC. The readings were recorded after 5 days.

Heavy metals: The water samples were filtered with Whatman filter paper (No. 1) and heavy metals viz., Cd, Hg, Pb, Cu, Fe, Zn and As were estimated by using Inductively Coupled Plasma Emission Spectrometer (ICAP- 6300 Duo) and expressed as mg l^{-1}.

3.6 ANALYTICAL TOOLS EMPLOYED

The people's perception data was analyzed by using SPSSv16.0. The observations recorded on various parameters of soil and water were subjected to statistical analysis under Randomized Block Design. Analysis of variance (ANOVA) was worked out and critical difference at 5 per cent level of significance was calculated as suggested by Cochran and Cox (1967).

Chapter-4

EXPERIMENTAL RESULTS

The results obtained from the present investigation entitled **"Impact of land use changes on ecosystem services of Kullu District of Himachal Pradesh"** are described in this chapter under the following headings.

4.1 People's perception on land use change

4.2 Land use change impacts on physical and chemical properties of soil

4.3 Land use change impacts on surface and ground water quality

4.1 PEOPLE'S PERCEPTION ON LAND USE CHANGE

In mid-hills of Kullu district of Himachal Pradesh 92.5% people perceived that urbanization has increased in the region (Table 1). Also, 67.5% respondents perceived that over the last 30 years the area under traditional agriculture has decreased. In the region 62.5% people were of the view that area under orchard has increased, whereas, that of the vegetable based land use has decreased in the region according to 60% respondents.

Table 1: People's response (%) on land use trend in mid-hills of Kullu District of HP

Land uses	Trend	
	Decreased	Increased
Traditional agriculture	67.5 (27)	32.5 (13)
Orchard	37.5 (15)	62.5 (25)
Vegetable based	60.0 (24)	40.0 (16)
Urban	7.5 (3)	92.5 (37)

Values in parenthesis represent number of respondents

The data presented in table 2 revealed that 82.5% respondents of the mid-hills of Kullu district were of the opinion that during the last 30 years the natural springs have decreased in the region. Similarly, the streams were perceived to be decreased by 52.5%. Contrary to this the status of wells and tubewells was perceived to be decreased by 72.5% of respondents in the region.

Table 2: People's perception (%) on the status of surface and groundwater resource availability in mid-hills of Kullu district of HP

Water resource	Status	
	Decreasing	Increasing
Natural stream	52.5 (21)	47.5 (19)
Natural springs	82.5 (33)	17.5 (7)
Well/Tubewell	27.5 (11)	72.5 (29)

Values in parenthesis represents number of respondents

The data regarding people's perception on quality of ecosystem services in table 3 indicated that among the selected services the pollinators population has registered the highest decrease in the region as perceived by 67.5% respondents which was followed by soil quality (47.5% perception) and water quality (35% perception). Whereas, the region has experienced increase in crop yield as perceived by 47.5% people. Regarding the water quality service of the ecosystem the 32.5% respondents were of the opinion that it has decreased, whereas same number of people perceived that it has remained the same.

Table 3: People's perception (%) on the quality of ecosystem services

Ecosystem services	Decreased	Increased	Remained same
Water quality	35.0 (14)	32.5 (13)	32.5 (13)
Soil quality	47.5 (19)	20.0 (8)	32.5 (13)
Pollinator population	67.5 (27)	15.0 (6)	17.5 (7)
Crop yield	32.5 (13)	47.5 (19)	20.0 (8)

Values in parenthesis represent number of respondents

4.2 LAND USE CHANGE IMPACTS ON PHYSICAL AND CHEMICAL PROPERTIES OF SOIL

4.2.1 Soil Organic Carbon (SOC)

In Kullu district of Himachal Pradesh, soil organic carbon content was found to vary under different land uses. The perusal of data presented in table 4 revealed that among the selected land uses forest registered the highest SOC of 1.53% which was followed by orchard (1.11%), traditional agriculture (1.05%)

Table 4: Land use and season wise distribution of soil organic carbon (%), carbon stock (Mg m^{-2}) and microbial biomass (µg C g^{-1})

Land use / Season	Soil organic carbon			Carbon stock			Soil Microbial Biomass		
	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean
T_1 (Forest)	1.58	1.47	**1.53**	34.65	33.44	**34.05**	639.49	2510.62	**1575.06**
T_2 (Traditional agriculture)	1.11	0.98	**1.05**	30.22	27.40	**28.80**	229.57	922.41	**575.99**
T_3 (Orchard)	1.19	1.02	**1.11**	29.82	28.88	**29.35**	715.19	1436.26	**1075.72**
T_4 (Urban)	0.49	0.44	**0.46**	20.41	16.88	**18.65**	130.28	256.95	**193.62**
Mean	**1.09**	**0.98**		**28.78**	**26.65**		**428.63**	**1281.56**	
$CD_{0.05}$									
Land use	0.12			1.20			540.54		
Season	0.09			0.85			382.22		
Land use x Season	NS			NS			764.44		

and urban land use (0.46%)The seasons of the year were found to influence the SOC distribution under the selected land uses in the district. Significantly highest SOC content (1.09%) was noticed during winter whereas minimum (0.98%) was observed during summer season. It is further evident from the data that under each land uses the SOC content decreased from winter to summer season (Table 4).

The Influence of land use and seasons was found non significant with respect to soil organic carbon content (Table 4) The forest soils depicted the highest range of organic carbon (1.58 – 1.47%) variation from winter to summer season and the minimum (0.49 – 0.44%) was shown by the urban land use system. The data further indicated that in the district the seasons also represented significant influence on soil organic carbon content but no significant influence was observed between land use systems and seasons.

4.2.2 Soil Carbon Stock

The data presented in table 4 evinced that SOC stock significantly varied under different land uses. The highest SOC stock (34.05 Mg m^{-2}) was recorded under forest followed by orchards (29.35 Mg m^{-2}) and traditional agriculture (28.58 Mg m^{-2}). The lowest SOC stock (18.05 Mg m^{-2}) was noticed under urban land use. The seasons of the year also influenced land use wise distribution of carbon stock significantly. Under each land use significantly highest stock was noticed during winter season and lowest was during summer season.

In mid-hills of Kullu district dominant land uses selected were found to register the highest carbon stock of 28.78 Mg m^{-2} during winter season whereas, the lowest (26.65 Mg m^{-2}) was during summer season. The interaction between land use systems and seasons was found to exert non significant influence on carbon stock.

4.2.3 Soil Microbial Biomass

It is evident from the data presented in the table 4 that land use systems and seasons significantly influenced the soil biomass in Kullu district of

Himachal Pradesh. Significantly highest soil microbial biomass (1575.06 µg C g^{-1}) was recorded under forest land use followed by orchard (1075.72 µg C g^{-1}) and traditional agriculture (575.99 µg C g^{-1}). Whereas, minimum soil microbial biomass was recorded under urban land use (193.62 µg C g^{-1}). Contrary to SOC status, significantly highest soil microbial biomass was recorded during summer (1281.56 µg C g^{-1}) and lowest in winter season (428.63 µg C g^{-1}). However, land use wise trend remained the same.

The data presented in table 4 further revealed that land use and season interaction also resulted a significant influence on soil microbial biomass distribution. Forest land use registered highest soil microbial biomass of 2510.62 µg C g^{-1} during summer followed by 1436.26 µg C g^{-1} under orchard land use in same season. Whereas, minimum soil microbial biomass of 130.28 µg C g^{-1} was observed in winter season under urban land use.

4.2.4 Total soil organic carbon stock of mid hills of Kullu

The total soil organic carbon stock of mid hills of Kullu district of HP under dominant land uses estimated to 1314.93 Gg C yr^{-1} against a total area of 19623.48 ha (Table 5).

Table 5: Total soil organic carbon stock (Gg C) of mid hills of Kullu district of HP

Land use	Carbon stock for whole year (Mg m^{-2})	Total area (ha)	Total carbon stock (Gg C)
T1 (Forest)	68.093	18379.05	**1251.20**
T2 (Traditional agriculture)	57.618	533.14	**30.72**
T3 (Orchard)	58.695	289.88	**17.02**
T4 (Urban)	37.293	421.41	**15.72**
Total	**-**	19623.48	**1314.93**

4.3 SOIL PHYSICAL PROPERTIES

4.3.1 Soil pH

The perusal of data presented in Table 6 evinced that the soil under different land uses varied significantly from 6.35 to 7.06. The highest mean pH value of 7.06 was noticed under urban land uses followed by traditional agriculture (6.91), orchard (6.81) and forest (6.35). Irrespective of the land uses seasons of the year also found to exert significant influence on the pH which varied from 6.85 in winter to 6.72 in summer season. Land use and season interactions were found to exert non-significant influence on the soil pH.

It is further evident from the data presented in the table 6 that in mid-hills of Kullu district of Himachal Pradesh, the soil pH under all the land uses was in normal ranges and has been noticed as excellent for various ecosystem services.

4.3.2 Soil EC

The selected land uses of mid-hills of Kullu district of Himachal Pradesh exerted non-significant influence on EC of soil. The seasons of the year and their interactions with land uses was also found non-significant with respect to electrical conductivity of the soil (Table 6).

4.3.3 Soil Bulk Density

Data presented in the table 6 revealed that different land use systems were found to influence the soil bulk density. Significantly highest soil bulk density of 1.56 g cm^{-3} was noticed under urban land use followed by orchard (1.34 g cm^{-3}) and traditional agriculture (1.21 g cm^{-3}).The lowest bulk density of soil was recorded under forest land use (1.09 g cm^{-3}). The perusal of data presented in the table 6 also evinced that seasons of the year resulted non significant influence on soil bulk density. Similarly, the land use and season interaction was also found non significant with respect to soil bulk density parameters.

4.4 AVAILABLE NPK CONTENT IN SOILS

A perusal of the data presented in table 7 revealed that the dominant land uses of mid hills of Kullu district also varied significantly in their available NPK content in soil.

4.4.1 Available Nitrogen

The soils of orchard land use were found to contain the highest soil N (460.35 kg ha^{-1}) which was statistically at par with traditional agriculture (459.52

kg ha^{-1}) and forest land use (453.42 kg ha^{-1}). The minimum content of 239.71 kg ha^{-1} was noticed under urban land use. The seasons and their interaction with land use was however, found non significant with respect to available N content of soil.

4.4.2 Available Phosphorus

Similarly soil available P content laso varied significantly among land uses of Kullu district. Orchard land use was found to contain highest soil available P (26.54 kg ha^{-1}) which was statistically at par with traditional agriculture followed by forest land use (21.81 kg ha^{-1}). Whereas, the minimum available P content of 15.54 kg ha^{-1} was noticed under urban land use. The seasons of the year also resulted significant influence on the available P content of soil. Significantly highest available soil P of 25.23 kg ha^{-1} was found during summer season and minimum was noticed during winter season (18.87 kg ha^{-1}).

The season x land use interaction also found to exert significant influence on soil available P. Traditional agriculture land use was found to contain the highest soil available P (30.45 kg ha^{-1}) during summer season which was however statictically at par with orchard in same season. This was followed by forest in summer and orchard in winter seasons. Whereas, the lowest soil available P was recorded under urban land use in winter season.

4.4.3 Available Potassium

The soil available potassium content also varied significantly among land uses of Kullu district. The highest soil available K (315.07 kg ha^{-1}) was found under orchard land use which was statistically at par with traditional agriculture (300.24 kg ha^{-1}). Whereas, the minimum available K content of 114.02 kg ha^{-1} was noticed under urban land use. The seasons of the year also resulted significant influence on the available K content of soil. Significantly highest available soil K of 268.17 kg ha^{-1} was found during summer season and minimum was noticed during winter season (224.60 kg ha^{-1}).

Table 6: Land use and season wise distribution of soil pH, EC (dS m^{-1}) and bulk density (g cm^{-3}) in soils of Kullu district

Land use / Season	Soil pH			EC			Bulk density		
	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean
T_1 (Forest)	6.43	6.28	**6.35**	0.23	0.24	**0.24**	1.06	1.11	**1.09**
T_2 (Traditional agriculture)	6.93	6.91	**6.91**	0.24	0.31	**0.28**	1.23	1.19	**1.21**
T_3 (Orchard)	6.91	6.71	**6.81**	0.20	0.17	**0.19**	1.32	1.37	**1.34**
T_4 (Urban)	7.13	7.13	**7.06**	0.26	0.18	**0.22**	1.50	1.62	**1.56**
Mean	**6.85**	**6.72**		**0.23**	**0.23**		**1.27**	**1.32**	
$CD_{0.05}$									
Land use	0.15			NS			0.09		
Season	0.10			NS			NS		
Land use x Season	NS			NS			NS		

Table 7: Land use and season wise distribution of available nitrogen, phosphorus and potassium contents (kg ha^{-1}) in Kullu district

Land use / Season	N			P			K		
	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean
T_1 (Forest)	457.37	449.47	**453.42**	19.72	23.90	**21.81**	258.82	253.61	**256.21**
T_2 (Traditional agriculture)	461.68	457.37	**459.52**	18.18	30.45	**24.31**	251.14	349.34	**300.24**
T_3 (Orchard)	462.11	458.58	**460.35**	22.97	30.11	**26.54**	278.47	351.67	**315.07**
T_4 (Urban)	237.25	242.16	**239.71**	14.61	16.47	**15.54**	109.99	118.05	**114.02**
Mean	**404.60**	**401.89**		**18.87**	**25.23**		**224.60**	**268.17**	
$CD_{0.05}$									
Land use	24.22			2.28			34.06		
Season	NS			1.61			24.09		
Land use x Season	NS			3.22			48.17		

The season x land use interaction was found to exert significant influence on soil available K. The orchard land use was found to contain the highest soil available K (351.67 kg ha^{-1}) during summer season which was however statistically at par with traditional agriculture in same season. This was followed by forest in winter seasons. Whereas, the lowest soil available K was recorded under urban land use in winter season. kg ha^{-1} and mean for summer was 268.17 kg ha^{-1}. The variation in values of available K among land uses is because of addition of fertilizers in the cropping systems.

4.5 HEAVY METAL STATUS OF SOIL

4.5.1 Cadmium

The data presented in table 8 revealed seasonal and land use variations of cadmium in the soils of mid-hills of Kullu district. The soil Cd content was found to vary between 0.343-0.728 mg kg^{-1}. The highest soil Cd content of 0.701 mg kg^{-1} was recorded under urban land use system followed by orchard (0.656 mg kg^{-1}), traditional agriculture (0.581 mg kg^{-1}) and the lowest (0.364 mg kg^{-1}) was recorded under forest. Irrespective of land use highest Cd content of 0.596 mg kg^{-1} was noticed during summer season, whereas, the minimum of 0.556 mg kg^{-1} was in winter months. The interaction between seasons and land uses was found to exert non-significant influence on Cd content.

4.5.2 Mercury

A perusal of the data presented in table 8 evinced that land use systems were found to influence mercury content in the mid-hills of the Kullu district. The Hg content of soil was found to vary from 0.37-1.34 µg kg^{-1}. The soil of urban land use was noticed to have significantly highest (1.27 µg kg^{-1}) Hg content followed by orchard land use(0.70 µg kg^{-1}) and traditional land use (0.65 µg kg^{-1}) The lowest Hg content was observed under forest land use (0.37 µg kg^{-1}). There was no significant influence of seasons on mercury content; also, the interaction between the seasons and land use was observed to be non significant.

4.5.3 Lead

The lead content in soil had significantly been influenced by the land use systems and seasons. The highest (39.93 mg kg^{-1}) Pb content was found under urban land use system followed by orchard (15.45 mg kg^{-1}) and traditional land use (11.69 mg kg^{-1}). The lowest (10.98 mg kg^{-1}) Pb content was found under forest land use. The summer season showed the highest Pb content of 24.27 mg kg^{-1} however, winter season showed the lowest of 14.75 mg kg^{-1}.

The season x land use interaction was found to exert significant influence on soil Pb content. The urban land use was found to contain the highest soil Pb content (55.76 mg kg^{-1}) during summer season followed by same in winter seasons (24.10 mg kg^{-1}) and orchard land use in summer season (17.25 mg kg^{-1}). Whereas, the lowest soil Pb content was recorded under forest land use in winter season.

4.5.4 Arsenic

It is evident from the table 9 that different land use systems were found to have significantly varied concentrations of arsenic. The highest As content (24.01 mg kg^{-1}) was observed under urban land use system which was statistically at par with orchard land use (20.77 mg kg^{-1}) and was followed by traditional agriculture (19.06 mg kg^{-1}). The lowest As content (10.95 mg kg^{-1}) was observed under forest. The influence of seasons and the interaction between season x land use on As content was observed to be non significant.

4.5.5 Zinc

The soils of different land use systems were found to have varied zinc content in different seasons. The soil Zn content was observed highest summer season (101.88 mg kg^{-1}) and lowest in winter months (86.40 mg kg^{-1}). However there was no significant influence of land use and interaction of seasons and land uses on soil Zn content.

Table 8: Land use and season wise distribution of heavy metal content in soils under different land uses of mid-hills of Kullu district

Land use / Season	Cd ($mg\ kg^{-1}$)			Hg ($\mu g\ kg^{-1}$)			Pb ($mg\ kg^{-1}$)		
	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean
T_1 (Forest)	0.34	0.39	**0.36**	0.36	0.37	**0.37**	10.13	11.83	**10.98**
T_2 (Traditional agriculture)	0.57	0.60	**0.58**	0.62	0.68	**0.65**	11.13	12.25	**11.69**
T_3 (Orchard)	0.64	0.67	**0.66**	0.65	0.76	**0.70**	13.65	17.25	**15.45**
T_4 (Urban)	0.66	0.73	**0.70**	1.20	1.34	**1.27**	24.10	55.76	**39.93**
Mean	**0.56**	**0.60**		**0.71**	**0.78**		**14.75**	**24.27**	
$CD_{0.05}$									
Land use	0.04			0.23			5.88		
Season	0.03			NS			4.16		
Land use x Season	NS			NS			8.31		

Table 9: Land use and season wise distribution of heavy metal content in soils under different land uses of mid-hills of Kullu district

Land use / Season	As ($mg\ kg^{-1}$)			Zn ($mg\ kg^{-1}$)			Fe ($mg\ kg^{-1}$)			Cu ($mg\ kg^{-1}$)		
	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean
T_1 (Forest)	10.63	11.26	**10.95**	79.40	86.57	**82.99**	6,243.63	6,281.62	**6,262.62**	49.00	51.50	**50.25**
T_2 (Traditional agriculture)	18.59	19.54	**19.06**	81.86	97.15	**89.50**	5,507.10	5,513.50	**5,510.25**	65.66	69.00	**67.33**
T_3 (Orchard)	19.91	21.69	**20.77**	87.36	109.26	**98.31**	6,044.11	6,054.50	**6,049.31**	69.25	72.50	**70.88**
T_4 (Urban)	22.83	25.19	**24.01**	96.99	114.56	**105.78**	6,344.94	6,385.75	**6,365.35**	82.75	88.75	**85.75**
Mean	**17.99**	**19.41**		**86.40**	**101.88**		**6,034.92**	**6,058.84**		**66.67**	**70.44**	
$CD_{0.05}$												
Land use	3.73			NS			352.06			7.06		
Season	NS			14.41			NS			NS		
Land use x Season	NS			NS			NS			NS		

4.5.6 Iron

The iron content in the soils has significantly varied under different land use systems. The highest soil Fe content (6365.35 mg kg^{-1}) was recorded in urban land use which was statistically at par with forest land use (6262.62 mg kg^{-1}) and orchard land use system (6049.31 mg kg^{-1}). The lowest soil Fe content (5510.25 mg kg^{-1}) was recorded in traditional agriculture land use system. However there was no significant influence of season and interaction between seasons and land use systems on soil Fe content of the mid hills of Kullu district.

4.5.7 Copper

The data presented in table 9 indicated that land use systems had a significant influence on soil Cu content in mid hills of Kullu district of HP. The highest soil Cu content (85.75 mg kg^{-1}) was recorded for urban land use followed by orchard land use (70.88 mg kg^{-1}) and traditional agriculture (67.33 mg kg^{-1}). The lowest soil Cu content (50.25 mg kg^{-1}) was observed for forest land use. There was no significant influence of the seasons and interaction between seasons x land use systems on soil Cu content of the mid hills of Kullu district.

4.6 TOTAL MICROBIAL COUNT

The perusal of the data presented in table 10 revealed a significant difference in the microbial count of different land uses and seasons. A common trend was seen for bacterial, actinomycetes and fungal counts. The highest bacterial count was observed in forest land use (59.0 cfu g^{-1}) followed by orchard (56.5 cfu g^{-1}) and traditional agriculture (50.3 cfu g^{-1}). The lowest bacterial count was observed under urban land use (44.9 cfu g^{-1}). The maximum bacterial count of 55.9 cfu g^{-1} was observed in summer season and minimum (49.4 cfu g^{-1}) in winter season. There was no significant influence of interaction of season x land use systems on soil bacteria count of mid hills of Kullu district of HP.

The actinomycetes population was found to be highest in the forest soil (47.05 cfu g^{-1}) followed by traditional agriculture (39.09 cfu g^{-1}) and orchard land use (38.29 cfu g^{-1}). The lowest soil actinomycetes count (34.58 cfu g^{-1}) was observed under urban land use. The actinomycetes population in summer was found to be highest (43.71 cfu g^{-1}) and in winter to be lowest (35.79 cfu g^{-1}). However, there was no significant influence of interaction of season x land use systems on actinomycetes count in soils of mid hills of Kullu district of HP.

The fungal population was observed to be the highest in forest land use (4.55 cells g^{-1}) which was statistically at par with orchard land use (4.30 cells g^{-1}) followed by traditional agriculture (4,10 cells g^{-1}). The lowest soil fungal population was observed under urban land use (3.69 cells g^{-1}). The summer season showed the highest soil fungal population of 4.36 cells g^{-1} and winter season showed the lowest of 3.95 cells g^{-1}. However, the interaction of season x land use systems on soil fungal count of mid hills of Kullu district of HP was non significant.

4.7 SURFACE AND GROUND WATER QUALITY

4.7.1 Water pH

Data presented in table 11 revealed that seasons, surface and underground water and land use systems have significant effect on water pH. The surface water samples had pH values from 7.00-7.28. The highest pH of surface was observed under urban land use (7.28) followed by traditional agriculture and orchard land use and the lowest was observed under forest land use. The summer season showed highest pH of 7.10 whereas winter season showed lowest of 6.89. However, the interaction of season x land use systems on water pH of mid hills of Kullu district of HP was non significant.

The groundwater pH was highest under urban land use (7.49) which was statistically at par with forest land use (7.38) followed by traditional agriculture (7.08) and the lowest pH were observed under orchard land use (6.98). The summer season showed the highest pH of 7.32 whereas winter season showed the lowest of 7.14. The interaction between the seasons and the land use systems was found to exert non-significant influence on the pH of underground water sources.

Table 10: Land use and season wise variation in total microbial counts (cfu g^{-1}) of soils in mid hills of Kullu district of HP

Land use / Season	Microbes								
	Bacteria (10^5)			Actinomycetes (10^4)			Fungi (10^3)		
	Winter	**Summer**	**Mean**	**Winter**	**Summer**	**Mean**	**Winter**	**Summer**	**Mean**
T_1 (Forest)	55.5	62.5	**59.0**	41.83	52.28	**47.05**	4.37	4.72	**4.55**
T_2 (Traditional agriculture)	46.0	54.5	**50.3**	35.20	42.97	**39.09**	3.92	4.27	**4.10**
T_3 (Orchard)	53.2	59.8	**56.5**	32.57	44.00	**38.29**	4.10	4.50	**4.30**
T_4 (Urban)	43.0	46.8	**44.9**	33.58	35.58	**34.58**	3.42	3.95	**3.69**
Mean	**49.4**	**55.9**		**35.79**	**43.71**		**3.95**	**4.36**	
$CD_{0.05}$									
Land use	0.41			4.10			0.25		
Season	0.29			2.90			0.17		
Land use x Season	NS			NS			NS		

Table 11: Land use and season wise variation in pH of surface and ground water sources of mid hills of Kullu district of HP

Land use / Season	Surface water			Ground water		
	Winter	**Summer**	**Mean**	**Winter**	**Summer**	**Mean**
T_1 (Forest)	6.92	7.07	**7.00**	7.27	7.47	**7.38**
T_2 (Traditional agriculture)	6.77	7.02	**7.03**	6.97	7.17	**7.08**
T_3 (Orchard)	6.82	7.02	**7.03**	6.90	7.05	**6.98**
T_4 (Urban)	7.05	7.27	**7.28**	7.40	7.57	**7.49**
Mean	**6.89**	**7.10**		7.14	7.32	
$CD_{0.05}$						
Land use	0.14			0.11		
Season	0.10			0.08		
Land use x Season	NS			NS		

4.7.2 C.O.D.

A perusal of data presented in table 12 evinced that seasons and land use systems have significant effect on chemical oxygen demand of surface and ground water sources in mid hills of Kullu district of HP. For the surface water, the highest mean chemical oxygen demand (38.88 mg l^{-1}) was recorded for urban land use system followed by orchard and traditional agriculture land use system.The forest surface water exhibited significantly lowest C.O.D. (23.75 mg l^{-1}). The highest C.O.D. (23.81 mg l^{-1}) was noticed in summer season and lowest (21.25 mg l^{-1}) in winter season. However, there was no significant interaction between seasons and land use systems.

For the ground water, the highest mean C.O.D. (26.63 mg l^{-1}) was observed in urban land use system followed by orchard and traditional agriculture and the lowest mean C.O.D. (19.50 mg l^{-1}) was recorded in forest. The summer season showed the highest C.O.D. values for groundwater (23.81 mg l^{-1}) and the winter season showed the lowest of 21.25 mg l^{-1}. There was no significant interaction between seasons and land use systems.

4.7.3 B.O.D.

It is evident from the data presented in table 13 that land use systems and seasons have significant effect on biological oxygen demand in surface and groundwater sources. In surface water the highest B.O.D. (9.02 mg l^{-1}) was recorded in urban land use system followed by orchard and traditional agriculture land use system. The forest surface water exhibited significantly lowest B.O.D. (7.34 mg l^{-1}). The highest B.O.D. (8.61 mg l^{-1}) was noticed in summer season and lowest (8.03 mg l^{-1}) in winter season. However, there was no significant interaction between seasons and land use systems.

For the ground water, the highest B.O.D. (5.05 mg l^{-1}) was observed in urban land use system followed by orchard and traditional agriculture and the lowest B.O.D. (3.60 mg l^{-1}) was recorded in forest. The summer season showed the highest B.O.D. values for groundwater (4.62 mg l^{-1}) and the winter season showed the lowest of 4.01 mg l^{-1}. There was no significant interaction between seasons and land use systems.

Table 12: Land use and season wise variation in C.O.D. and B.O.D. (mg l^{-1}) of surface and ground water sources of mid hills of Kullu district of HP

Land use / Season	C.O.D.						B.O.D.					
	Surface water			Ground water			Surface water			Ground water		
	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean
T_1 (Forest)	22.50	25.00	**23.75**	18.50	20.50	**19.50**	7.00	7.67	**7.34**	3.25	3.95	**3.60**
T_2 (Traditional agriculture)	25.00	26.50	**25.75**	20.25	22.25	**21.25**	8.10	8.57	**8.34**	4.05	4.30	**4.17**
T_3 (Orchard)	28.25	31.50	**29.88**	21.75	23.75	**22.75**	8.27	8.90	**8.59**	4.20	4.70	**4.45**
T_4 (Urban)	35.75	42.00	**38.88**	24.50	28.75	**26.62**	8.75	9.30	**9.02**	4.55	5.55	**5.05**
Mean	**27.86**	**31.25**		**21.25**	**23.81**		**8.03**	**8.61**		**4.01**	**4.62**	
$CD_{0.05}$												
Land use	1.36			0.65			0.36			0.22		
Season	1.93			0.93			0.50			0.30		
Land use x Season	NS			1.31			NS			NS		

4.7.4 Status of Heavy metals in surface and ground water sources

The data on heavy metals as influenced by the land use systems and seasons are presented in Table 13.The heavy metal levels did not differed significantly with land use systems and seasons. The mean Cd level for surface water varied as 0.006-0.067 mg l^{-1}. Cd content was highest (0.125 mg l^{-1}) in urban land use system in summer season and lowest (0.005 mg l^{-1}) in forest in winter season. For underground water, the mean highest (0.009 mg l^{-1}) Cd content was observed in urban land use and mean lowest (0.006 mg l^{-1}) in forest. The lowest (0.006 mg l^{-1}) content of Cd was found in forest water in both the seasons and the highest (0.010 mg l^{-1}) simultaneously in orchard and urban land use in summer season.

The similar trend was observed for mercury content in both surface and groundwater sources which were significantly influenced by land use systems as well as season. In the surface water the highest mean Hg (1.28 µg l^{-1}) content was found in urban land use followed by orchard and Traditional agriculture land use system; the lowest mean (0.79 µg l^{-1}) was observed in forest. The highest (1.29 µg l^{-1}) Hg content was found in urban land use in summer season and the lowest (0.78 µg l^{-1}) in forest in both the seasons. The perusal of data presented in table 4.34 indicated that surface and groundwater sources were found to exhibit variation in lead content in land use systems and seasons. The Pb content of surface water was found to vary from 0.031-0.150 mg l^{-1}. The highest mean Pb content (0.145 mg l^{-1}) was observed in urban land use system and the lowest mean (0.033 mg l^{-1}) was observed in forest. The highest Pb content (0.090 mg l^{-1}) was noticed during summer season as compared to winter season. The Pb content for groundwater sources varied from 0.055-0.123 mg l^{-1}.The groundwater in urban land use system recorded the highest mean Pb content (0.116 mg l^{-1}) and the lowest mean (0.055 mg l^{-1}) was recorded in forest. In winter season the mean Pb content was recorded as 0.080 mg l^{-1} and in summer the mean increased to 0.084 mg l^{-1}.

Table 13: Land use and season wise variations in Cd (mg l^{-1}) and Hg (µg l^{-1}) content of surface and ground water of mid hills of Kullu district of HP

Land use / Season	Cd						Hg					
	Surface			Underground			Surface			Underground		
	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean
T_1 (Forest)	0.005	0.007	**0.006**	0.006	0.006	**0.006**	0.78	0.78	**0.78**	0.66	0.67	**0.66**
T_2 (Traditional agriculture)	0.007	0.010	**0.009**	0.006	0.009	**0.007**	1.04	1.05	**1.05**	0.97	1.00	**0.99**
T_3 (Orchard)	0.009	0.065	**0.037**	0.007	0.010	**0.008**	1.06	1.07	**1.07**	1.02	1.04	**1.03**
T_4 (Urban)	0.010	0.125	**0.067**	0.009	0.010	**0.009**	1.27	1.29	**1.28**	1.16	1.19	**1.17**
Mean	**0.008**	**0.052**		**0.007**	**0.008**		**1.04**	**1.05**		**0.954**	**0.98**	
$CD_{0.05}$												
Land use	0.017			0.001			NS			NS		
Season	0.025			0.001			0.11			0.10		
Land use x Season	0.035			0.001			NS			NS		

The mean Cu level for surface water varied as 0.588-0.603 μg l^{-1}. Cu content was highest (1.380 μg l^{-1}) in urban land use system in summer season and lowest (0.588 μg l^{-1}) in forest in winter season. For underground water, the mean highest (1.098 μg l^{-1}) Cu content was observed in urban land use and mean lowest (0.574 μg l^{-1}) in forest. The lowest (0.568 μg l^{-1}) content of Cu was found in forest water in the winter seasons and the highest (1.118 μg l^{-1}) in urban land use in summer season.

The data presented in table 14 indicated that there was no significant influence of the seasons on iron content but land use systems had a significant influence. The highest mean (0.33 mg l^{-1}) was recorded for urban land use and lowest mean (0.11 mg l^{-1}) for forest. The iron content in the groundwater has significantly varied under different land use systems. The highest mean (0.30 mg l^{-1}) was recorded in urban land use followed by orchard land use system (0.22 mg kg^{-1}) and Traditional agriculture land use system (0.21 mg l^{-1}). The lowest mean (0.11 mg l^{-1}) was recorded in forest.

The surface and groundwater sources were found to exhibit variation in zinc content in land use systems and seasons. The Zn content of surface water was found to vary from 5.04-7.57 mg l^{-1}. The highest mean Zn content (7.41 mg l^{-1}) was observed in urban land use system and the lowest mean (5.07 mg l^{-1}) was observed in forest. The highest Zn content (6.24 mg l^{-1}) was noticed during summer season as compared to winter season. The Zn content for groundwater sources varied from 5.04-6.43 mg l^{-1}.The groundwater in urban land use recorded the highest mean Zn content (6.43 mg l^{-1}) and the lowest mean (5.04 mg l^{-1}) was recorded in forest. In winter season the mean Zn content was recorded as 5.59 mg l^{-1} and in summer the mean increased to 5.68 mg l^{-1}.The mean As level for surface water varied as 1.22-5.80 mg l^{-1}. As content was highest (5.86 mg l^{-1}) in urban land use system in summer season and lowest (1.19 mg l^{-1}) in forest in winter season. For underground water, the mean highest (5.83 mg l^{-1}) As content was observed in urban land use and mean lowest (1.17 mg l^{-1}) in forest. The lowest (1.11 mg l^{-1}) content of As was found in forest water in the winter seasons and the highest (5.86 mg l^{-1}) in urban land use in summer season.

Table 14: Land use and season wise variations in Pb (mg l^{-1}) and As (mg l^{-1}) content of surface and ground water

Land use / Season	Pb						As					
	Surface			Underground			Surface			Underground		
	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean
T_1 (Forest)	0.031	0.036	**0.033**	0.055	0.058	**0.056**	1.19	1.25	**1.22**	1.11	1.23	**1.17**
T_2 (Traditional agriculture)	0.078	0.080	**0.079**	0.073	0.074	**0.074**	4.08	4.46	**4.24**	3.60	3.74	**3.67**
T_3 (Orchard)	0.091	0.092	**0.091**	0.080	0.081	**0.081**	4.61	4.70	**4.65**	4.22	4.28	**4.25**
T_4 (Urban)	0.140	0.150	**0.145**	0.110	0.123	**0.116**	5.77	5.85	**5.85**	5.80	5.86	**5.83**
Mean	**0.085**	**0.090**		**0.080**	**0.084**		**3.89**	**4.06**		**3.68**	**3.78**	
$CD_{0.05}$												
Land use	NS			NS			NS			NS		
Season	0.01			0.008			0.311			0.267		
Land use x Season	NS			NS			NS			NS		

Table 15: Effect of different land uses on seasonal variation in heavy metals content in surface and ground water

Land use / Season	Fe (mg l^{-1})						Zn(mg l^{-1})						Cu (mg l^{-1})					
	Surface			Underground			Surface			Underground			Surface			Underground		
	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean
T_1 (Forest)	0.13	0.14	**0.14**	0.11	0.11	**0.11**	5.04	5.11	**5.07**	4.99	5.10	**5.04**	0.59	0.60	**0.59**	0.56	0.58	**0.57**
T_2 (Traditional agriculture)	0.21	0.21	**0.21**	0.20	0.21	**0.21**	5.82	6.11	**5.96**	5.07	5.15	**5.10**	0.83	0.84	**0.84**	0.84	0.86	**0.85**
T_3 (Orchard)	0.23	0.23	**0.23**	0.21	0.22	**0.22**	6.06	6.17	**6.11**	5.90	6.01	**5.95**	0.96	0.99	**0.97**	0.81	0.82	**0.82**
T_4 (Urban)	0.33	0.34	**0.33**	0.30	0.31	**0.30**	7.25	7.57	**7.41**	6.40	6.46	**6.43**	1.34	1.38	**1.36**	1.07	1.11	**1.09**
Mean	**0.23**	**0.23**		**0.21**	**0.21**		**6.04**	**6.24**		**5.59**	**5.68**		**0.93**	**0.95**		**0.82**	**0.84**	
$CD_{0.05}$																		
Land use	NS			NS			NS			NS			NS			NS		
Season	0.02			0.01			0.35			0.29			0.06			0.05		
Land use x Season	NS			NS			NS			NS			NS			NS		

Chapter-5

DISCUSSION

The present investigation entitled **"Impact of land use change on ecosystem services of Kullu district of Himachal Pradesh, India"** was carried out during 2014-2015. The results obtained have been discussed in this chapter, establishing a cause and effect relationship wherever necessary and feasible in the light of available literature under different heads.

5.1 People's perception on land use change

5.2 Impact on availability of water resources

5.3 Impact of land use changes on ecosystem services

5.1 PEOPLE'S PERCEPTION ON LAND USE CHANGE

In mid-hills of Kullu district of Himachal Pradesh during the last 30 years urbanisation has increased alarmingly (92.5%), whereas, area under traditional agriculture has decreased (Table 1). This change in the land use is in accordance with the satellite images (Plate 2, 3, 4 and 5). The present change may be ascribed to adoption of commercial activities by the local people of mid hills of Kullu district in place of traditional agriculture to meet their livelihoods. Moreover, the increased tourist inflow in the region has also enhanced urban activities in the region.

The increase in urbanisation is followed by orchard land use which has also shown increasing trend. On the other hand the vegetable farming has decreased in the region. The present trend in the orchard land use may be ascribed to higher output from this farming. Whereas decrease in vegetable farming may be ascribed to the fact that vegetables being a short duration and highly perishable crop did not match with the remunerations fetched from the fruits like pomegranate and kiwi in the region. The present trend is in line with the data available with the revenue department of government of HP (Table 16).

Table 16: Periodic variation in land use status of mid-hills of Kullu district in Himachal Pradesh

Land use / Time period	Land use areas (ha)		
	Base period 1984-1993	Intermediate period 1994-2003	Assessment period 2004-2014
Traditional agriculture	733.65	679.97	533.14
Orchard	124.59	203.96	289.88
Vegetable based	1078.01	1014.44	954.54
Urban	340.90	350.70	428.07

5.2 IMPACT ON AVAILABILITY OF WATER RESOURCES

In the mid-hills of Kullu district, people have perceived (82.5%) that during the last 30 years natural springs has decreased alarmingly followed by natural streams. This trend may be ascribed to decreasing rainfall in the region as well as increased use of water because of enhanced urban settlements (Table 16) The decreasing trend of rainfall during the last 25 years has also been reported in the region by Vidya *et al.* (2015). This trend of decreasing rainfall in the region may be the reason for declining natural streams and springs. Contrary to this wells and tubewells have increased in the region. The present trend may be ascribed to increasing demand of water vis a vis decreasing availability of surface water.

5.3 IMPACT OF LAND USE CHANGES ON ECOSYSTEM SERVICES

5.3.1 People's perception

The people of mid hills of Kullu district perceived (67.5%) that among the selected ecosystem services the population of pollinators have decreased alarmingly (Table 3). This was followed by soil quality and water quality as perceived by 47.5% and 35% of respondents respectively (Table 3). The decrease in pollinators' population, soil and water quality may be ascribed to increased use of chemicals in the commercial farming activities. Interestingly, 47.5% respondents were of the view that crop yield has increased in the region. This trend may possibly be due to use of potential crop varieties. Moreover, high

Plate 2: Satellite image of study site Bhuntar of Kullu Block in Kullu district of HP (2004)

Plate 3: Satellite image of study site Bhuntar of Kullu Block in Kullu district of HP (2013)

Plate 4 : Satellite image of study site Rote of Banjar block in Kullu district of HP (2004)

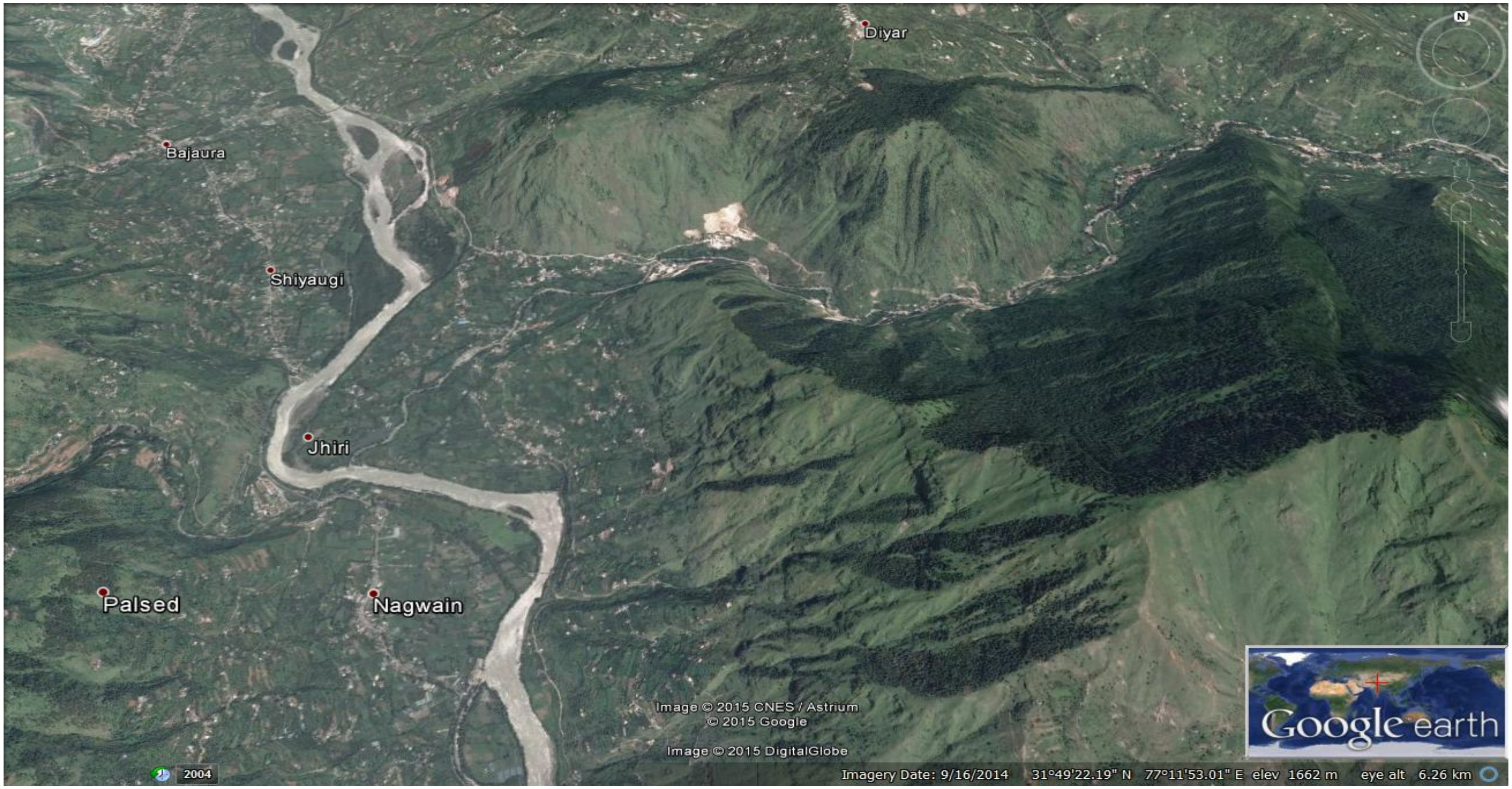

Plate 5: Satellite image of study site Rote of Banjar block of Kullu district of HP (2013)

returns of the crop due to tourist inflow and favourable climate might have encouraged the farmers to perform farming scientifically.

5.3.2 Soil Physico-Chemical Properties

5.3.2.1 Soil Organic Carbon

The soil organic carbon which is considered as a good indicator of soil health has been found to vary under different land uses in mid hills of Kullu district. The SOC status varied in order of forest (1.53%) > orchard (1.11%) > traditional agriculture (1.05%) > urban land use (0.46%). The highest SOC status under forest land use may be ascribed due to slow decomposition and relatively higher return of litter fall under such undisturbed systems. Relatively higher SOC status of orchard soils as compared to traditional agriculture and urban land use may be due to more addition of FYM and less decomposition rate because of very less tilling operations. Whereas, in traditional agriculture higher soil cultivation intensity has fastened the decomposition of organic matter and might have resulted decrease in its content.

On the other hand lowest value of SOC under urban land use may possibly be due to very less return of organic material to the soil and which is again liable to be lost as surface run-off due to compacted surfaces. The results are in conformity with the findings of Lal *et al.* (1998), Zegeye (1999), Whalen *et al.* (2003), Kundu *et al.* (2007) and Sharma *et al.* (1995). These findings are also in consonance with the findings of Zegeye (1999), Kater *et al.* (1992), Rhodes (1995), Sanneh (2007) and Minj (2008), who have also reported high SOC content in forest soils because of its undisturbed nature as compared to agricultural systems wherein higher decomposition rates due to heavy tilling operations result in less SOC build up.

Irrespective of the land uses relatively higher SOC of winter than summer season may be ascribed due to slow mineralization under very low temperature prevailing in the season. The results are in line with the findings of Bhandari and Randhawa (1985) and Sharma and Bhandari (1992) who have also reported an increase in SOC content of soil at low temperature because of slow mineralization.

5.3.2.2 Soil Carbon Stock:

The soil carbon stock of mid-hills of Kullu district was in the range of 16.88-34.65 Mg m^{-2}. The land use wise order of soil carbon stock was forest (34.05 Mg m^{-2}) > orchard (29.35 Mg m^{-2}) > traditional agriculture (28.80 Mg m^{-2}) > urban (18.65 Mg m^{-2}). The highest SOC stock of forest land use was probably due to higher status of SOC content and due to its undisturbed nature. The present trend is in agreement with the findings of Burke *et al.* (1995); Grandy and Robertson (2006); Mann (1986); Schlesinger and Andrews (2000); Schnitzer *et al.* (2006) who have also advocated tilling as the cause of depleting SOC and diminishing its stock. Minimum amount of SOC stock was observed under urban land use system may be due to less return of organic material may be due to less return of organic material to such systems and its further loss through run off as prevailing compacted surfaces.

5.3.2.3 Soil Microbial Biomass

The soil biomass carbon ranged from 130.28-2510 µg C g^{-1} under selected land uses. Among the selected uses the highest content of 1575.06 µg C g^{-1} under forest land use is in line with Vance *et al.,* 1987; Henrot and Robertson, 1994 who have reported 61-2000 mg kg^{-1} of soil biomass carbon under temperate and tropical forests. The order of soil biomass under different land uses was forest > orchard > traditional agriculture > urban. The results are in consonance with Mo *et al.,* 2006; Fang *et al.,* 2007 who have indicated that land use history can have a significant effect on the soil microbial biomass.

Relatively lowest value of soil biomass carbon (193.62 µg C g^{-1}) under urban land use system may be ascribed due to low return of organic material to such areas. The low level of organic substrate for microbes and reduced mineralization rates due to unfavourable conditions like compactions, low soil moisture and nutrient levels may be ascribed for reduced soil microbial biomass as advocated by Mo *et al.,* 1995. Further, the variations in soil biomass carbon may be ascribed on similar reasons as that of SOC distribution and are in line with the findings of Mo et al. (2008).

5.3.2.4 Soil pH:

Soil pH under different land uses and seasons of the year systems varied between 6.28 to 7.13 (Table 6) in mid hill conditions of Kullu district. The data indicated that in mid hills region the soil pH is normal under all the land uses and is considered good for better soil health and supply of essential nutrients. Slightly acidic pH of 6.28 during summer months under forest land use may be ascribed due to the higher organic matter content and more weathered soil conditions. Similar pH ranges were also reported by Raina (1998); Sharma (1994); Raina and Kumar (2000) and Verma (2005) for soils of mid hills of Himachal Pradesh. The results are also in conformity with the findings of Yadav (1963), Saralch (1994), Bhola (1995) and Nayak (1996).

5.3.2.5 Soil EC:

The electrical conductivity in general varied from 0.17-0.31 dS m^{-1} under different land use systems and seasons (Table 6). The results indicated that different land uses and seasons of the year have not influenced the electrical conductivity of the region. The EC range is normal in the region which may be because of well drained conditions of mid hills and availability of water with less salt content (Table 6).

5.3.2.6 Soil Bulk Density:

The land use wise order of soil bulk density distribution was urban (1.56 g cm^{-3}) > orchard (1.34 g cm^{-3}) > traditional agriculture (1.21 g cm^{-3}) > forest (1.09 g cm^{-3}). The highest bulk density under urban land use was probably due to compaction of soil as a result of various developmental activities (Schuler *et al*., 2000). The lowest bulk density value under forest land use as compared to other selected system (Table 6) may possibly be due to its higher SOC status and undisturbed conditions.

The reduction of bulk density due to higher soil organic carbon status has been reported in literature (Soane, 1975; Coote and Ramsay, 1983; Sharma and Aggarwal, 1984; Sharma *et al*., 1995 and Luv Bhushan, 1998).

5.3.2.7 Available NPK status of Soils:

The different land uses contained varied amount of available NPK contents in soils under mid hills conditions of Kullu district of HP. This variation of land uses with respect to availability of nutrients may be ascribed to outside application of nutrients and due to existing SOC content. The land use wise order of available N content in soils of mid hills was orchard (460.35 kg ha^{-1}) > traditional agriculture (459.52 kg ha^{-1}) > forest (453.42 kg ha^{-1}) > urban land use (239.71 kg ha^{-1}). The highest content of available N in soils under orchard land use may possibly be due to high input of nitrogenous fertilizers and organic manures. Whereas, the lowest status of available N under urban land use may be probably be due to net input and relatively less SOC.

Similarly the order of available P and K status under selected land uses was orchard (26.54 and 315.07 kg ha^{-1}) > traditional agriculture (24.31 and 200.24 kg ha^{-1}) > forest (21.81 and 256.21 kg ha^{-1}) > urban (15.54 and 114.02 kg ha^{-1}). The present trend may be explained on the similar reasons as that of available N content. The results of present study are in line with Jaipaul *et al.* (2011), Gopinath and Mina (2011) and Datt *et al.* (2003).

5.3.3 Heavy Metal Status of land uses in mid hills of Kullu district

5.3.3.1 Cadmium

The soil environment is an important sink for heavy metals. The values of cadmium in soils of different land uses ranged from 0.343-0.728 mg kg^{-1}. The distribution of Cd under different land uses was in order of urban (0.701 mg kg^{-1}) > orchard (0.656 mg kg^{-1}) > traditional agriculture (0.581 mg kg^{-1}) > forest (0.364 mg kg^{-1}). Significantly highest Cd was during summer season. The Cd content under different land uses and season was however under permissible limits as prescribed by Bowen (1966) and Singh (2007). Relatively higher Cd content under urban land use was probably due to enhanced automobile activities and urban solid waste discharge.

5.3.3.2 Mercury

The values of mercury in soils of different land uses ranged from 0.36-1.34 µg kg^{-1}. The distribution of Hg under different land uses was in order of urban (1.27 µg kg^{-1}) > orchard (0.70 µg kg^{-1}) > traditional agriculture (0.65 µg kg^{-1}) > forest (0.37 µg kg^{-1}). The Hg content under different land uses and season was however under permissible limits as prescribed by Bowen (1966) and Singh (2007).

5.3.3.3 Lead

The values of lead in soils of different land uses ranged from 10.13-55.76 mg kg^{-1}. The distribution of Pb under different land uses was in order of urban (39.93 mg kg^{-1}) > orchard (15.45 mg kg^{-1}) > traditional agriculture (11.69 mg kg^{-1}) > forest (10.98 mg kg^{-1}). The Pb content under different land uses and season was however under permissible limits as prescribed by Bowen (1966) and Singh (2007).

5.3.3.4 Arsenic

The values of arsenic in soils of different land uses ranged from 10.63-25.19 mg kg^{-1}. The distribution of As under different land uses was in order of urban (24.01 mg kg^{-1}) > orchard (20.77 mg kg^{-1}) > traditional agriculture (19.06 mg kg^{-1}) > forest (10.95 mg kg^{-1}). The As content under different land uses and season was however under permissible limits as prescribed by Bowen (1966) and Singh (2007).

5.3.3.5 Zinc

The values of zinc in soils of different land uses ranged from 79.40-114.56 mg kg^{-1}. The distribution of Zn under different land uses was in order of urban (105.78 mg kg^{-1}) > orchard (98.31 mg kg^{-1}) > traditional agriculture (89.50 mg kg^{-1}) > forest (82.99 mg kg^{-1}). The Zn content under different land uses and season was however under permissible limits as prescribed by Bowen (1966) and Singh (2007).

5.3.3.6 Iron

The values of iron in soils of different land uses ranged from 5507.10-6385.75 mg kg^{-1}. The distribution of Fe under different land uses was in order of urban (6365.35 mg kg^{-1}) > forest (6262.62 mg kg^{-1}) > orchard (6049.31 mg kg^{-1}) > traditional agriculture (5510.25 mg kg^{-1}). The Fe content under different land uses and season was however higher than permissible limits as prescribed by Bowen (1966) and Singh (2007).

5.3.3.7 Copper

The values of copper in soils of different land uses ranged from 49.00-88.75 mg kg^{-1}. The distribution of Cu under different land uses was in order of urban (85.75 mg kg^{-1}) > orchard (70.88 mg kg^{-1}) > traditional agriculture (67.33 mg kg^{-1}) > forest (50.25 mg kg^{-1}). The Cu content under different land uses and season was however under permissible limits as prescribed by Bowen (1966) and Singh (2007).

All the heavy metals were in higher concentration in soils under different land uses during summer seasons. This was probably due to less runoff under less rainfall months whereas, it was found to increase during winter precipitation. Moreover, lowest content under forest land use may be ascribed to no input application and minimum anthropogenic activities. Relatively higher contents of heavy metals under orchard and agriculture land use than forest land may be due to addition of chemicals in the form of fertilizers and pesticides. This was in agreement with the findings of Delbari and Kulkarni (2011), Shiva and Srikantaswamy (2012).

5.3.4 Total Microbial Count:

The bacterial, actinomycetes and fungal counts exhibited variations under different selected land uses (Table 10). The land use wise bacterial count distribution was in the order of forest (59.0 cfu g^{-1}) > orchard (56.5 cfu g^{-1}) > traditional agriculture (50.3 cfu g^{-1}) > urban (44.9 cfu g^{-1}). In case of actinomycetes the order was forest (47.05 cfu g^{-1}) > traditional agriculture (39.09 cfu g^{-1}) > orchard (38.29 cfu g^{-1}) > urban (34.58 cfu g^{-1}). Similar to bacterial counts the order of fungal counts was forest (4.55 cfu g^{-1}) > orchard (4.30 cfu g^{-1}) > traditional agriculture (4.10 cfu g^{-1}) > urban (3.69 cfu g^{-1}). Significantly higher bacterial, actinomycetes and fungal counts under forest land use were probably due to presence of higher organic carbon in the soil. The land use wise decrease in the counts followed the SOC trend under land use. Consequently minimum counts were observed under urban land use. The results are in line with the findings of Das and Mukherjee (1990) for alluvial soils of West Bengal, Jain *et al.* (2003) for the soil of Jabalpur and Sheeba and Chellamuthu (1999).

5.3.5 Water Analysis

5.3.5.1 Water pH

The surface and ground water sources under different land uses exhibited pH in the range of 7.00-7.28 and 6.98-7.49, respectively (Table 11). It is incident from the data that land uses did not influence water pH adversely as it was in permissible limits as prescribed by BIS (2004) for drinking and irrigation water. Relatively higher pH under the urban land use system may probably be due to continuous dumping of solid waste and other inorganic pollutants from the residences and shops. This is in confirmation with the findings of Trivedi *et al.* (2010) who also reported that dumping of waste was responsible for increase in pH in water.

The higher pH for surface and groundwater sources during summer months as compared to winter season was probably due to less availability of water, higher temperature and more evaporation during these months which might have increased the concentration of salts and ultimately pH. The present trend is in line with the findings of Sharma and Kapoor (2010) and Jinwal and Dixit (2008) and Rao *et al.* (2011) who reported a decrease in salt concentration during winter season due to dilution and leaching of salts due to rains.

5.3.5.2 COD and BOD

COD and BOD of surface water varied from 38.88-23.75 mg l^{-1} and 9.03-7.34 mg l^{-1} respectively. In groundwater sources the COD and BOD values ranged from 26.63-19.50 mg l^{-1} and 5.05-3.6 mg l^{-1} respectively. In the region, COD of both the sources of water was higher than permissible limits as prescribed by ICMR (1975). However, BOD of both the sources of water was found below the permissible limits as prescribed by ICMR (1975) for irrigation water, while the surface water was found above permissible limits of drinking water (ICMR, 1975). The higher COD and BOD of surface and groundwater sources in the urban land use system, which further decreased in orchard, traditional land use system and forest, might be due to decomposition of dumped organic waste in urban areas. Srivastava and Sinha (1996) also reported a similar trend of high COD in water sources with increased dumping of organic waste material especially under urban areas.

The higher COD and BOD of surface and groundwater sources during summer season may be ascribed to decreased oxygen concentration with higher biological activity at elevated temperature (Ghavzan *et al.,* 2006; Jinwal and Dixit, 2008; Padmanabha and Belagali, 2005 and Rajanna and Belagali, 2011). The present of seasonal variation in COD of both water sources was in line with the findings of Fokmare and Musaddiq (2002); Kaushik and Saksena (1999) and Garg *et al.* (2010).

5.3.5.3 Heavy metals

The heavy metals such as Cd, Hg, Pb, Cu, Fe, Zn and As in surface water in the mid-hills of the district varied from 0.006-0.067 mg l^{-1}, 0.79-1.28 µg l^{-1}, 0.031-0.150 mg l^{-1}, 0.588-0.603 µg l^{-1}, 0.11-0.33mg l^{-1}, 5.04-7.57 mg l^{-1} and 1.22-5.80 mg l^{-1} respectively. In groundwater sources the content of Cd, Hg, Pb, Cu, Fe, Zn and As ranged from 0.006-0.005 mg l^{-1}, 0.78-1.29 µg l^{-1}, 0.055-0.123 mg l^{-1}, 0.574-1.098 µg l^{-1}, 0.11-0.30 mg l^{-1}, 5.04-6.43 mg l^{-1} and 1.17-5.83 mg l^{-1} respectively. All the heavy metals in surface and groundwater sources in the forest, traditional and orchard land use system were in permissible range as prescribed by FAO/WHO (2001), BIS (2004) and ISI (1992). The concentration of heavy metals for both sources of water in the urban land use system was above the permissible limit as per standards. The higher concentration of heavy metals in urban areas may be due to enhanced vehicular activities and disposal of urban solid wastes in those areas. The results are in accordance with the findings of

Chiras (2001), Singh *et al.* (2004), Shah *et al.* (2005), Ananthan *et al.* (2006) and Puri (2011) who also have reported higher concentration of heavy metals in water sources near urban area.

The concentration of heavy metals in surface water was relatively higher as compared to groundwater. This trend may be ascribed to surface run-off from urban areas which might have increased the concentration of heavy metals in surface water sources. Whereas, relatively less concentration of heavy metals in ground water sources may be due to filtration effect of soil through which it is passed to the system.

In summer, the heavy metal concentration in both the sources of water was higher as compared to winter season. This difference was probably due to the dilution of ions during rains in winter in the area. This trend of decrease in content of heavy metals during winter season was also reported by Rajmohan and Elango (2005), Shankar *et al.* (2010), Rahman *et al.* (2012) and Venkatesh *et al.* (2013). The high concentration of heavy metals in summer season as compared to winters have also been reported by Kotti *et al.* (2008) and Zubair *et al.* (2010).

Chapter-6

SUMMARY AND CONCLUSION

The present investigation entitled **"Impact of land use changes on ecosystem services of Kullu District of Himachal Pradesh"** was conducted during the year 2014-15 in the Department of Environmental Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The present study was conducted to identify the land use changes in mid-hills of Kullu and to assess their impact on ecosystem services. To assess the land use change in the region survey was conducted to know the people's perception and to quantify the change secondary data was recorded from the revenue department of Government of Himachal Pradesh. In order to assess the impact of land use change on soil, water quality and soil carbon stock different land uses namely: forest, traditional agriculture, orchard and urban systems were selected in three blocks namely Naggar, Kullu and Banjar falling in mid-hills of Kullu district of HP. Land use wise variations in ecosystem services were studied in winter and summer seasons. In total there were eight treatments which were replicated four times under randomized block design.

People's perception

- ❖ In mid-hills of Kullu district of Himachal Pradesh during the last 30 years urbanization has increased followed by orchard farming, whereas traditional agricultural and vegetable farming has decreased.
- ❖ The number of natural springs and streams has decreased in the region. However, the construction of wells and tube-wells has increased.
- ❖ The pollinators responsible for crop pollination have also been decreased in a span of 30 years.

Soil properties

- ❖ The land use wise SOC status followed the order of forest> orchard> traditional agriculture> urban.

- ❖ Whereas, the SOC stock order was forest> orchard> traditional agriculture > urban.
- ❖ The soil microbial biomass was distributed as forest> orchard> traditional agriculture> urban.
- ❖ Under dominant land uses of Kullu district soil pH ranged from 6.28-7.13.
- ❖ Soil EC ranged from 0.18 to 0.31 dS m^{-1} and soil bulk density ranged from 1.62-1.06 g cm^{-3}.
- ❖ The land use wise order of available N content in soils of mid hills was orchard > traditional agriculture > forest > urban land use.
- ❖ Similarly the order of available P and K status under selected land uses was orchard > traditional agriculture > forest > urban.
- ❖ The heavy metals like Zn, Fe, Cu, Cd, Hg, Pb, and As in soils under different land uses ranged from 79.40-114.56, 5507.10-6385.75, 49.00-88.75, 0.343-0.728 mg kg^{-1}, 0.36-1.34 µg l^{-1}, 10.13-55.76, and 10.63-25.19 mg kg^{-1}, respectively.
- ❖ In case of Zn land uses followed the trend forest>traditional agriculture>orchard>urban. In case of Fe trend was traditional agriculture>orchard>forest>urban.
- ❖ The microbial count for bacteria, actinomycetes and fungi varied as 44.9-59.0, 34.58-47.05 and 3.69-4.55 cfu g^{-1}, respectively with a similar trend of highest in forest and lowest in urban land use system.

Land use wise surface and ground water quality

- ❖ In mid-hills surface water pH ranged from 7.00-7.28 which was normal and that of groundwater ranged from 6.98-7.49. In both the sources of water the pH values were found to increase from forest to urban land use system and from summer to winter season.
- ❖ In surface water, the trend of chemical oxygen demand was urban land use > traditional agriculture > orchard > forest.
- ❖ Similarly, the trend of COD in ground water was urban land use > orchard > traditional agriculture > forest.
- ❖ The order of BOD in surface and ground water was forest> traditional agriculture> orchard> urban.

- The Cd level for surface water varied as 0.006-0.067 mg l^{-1}. For underground water, the trend for Cd content was urban > orchard > traditional agriculture> forest.
- In the surface and groundwater the trend for Hg, Pb, As, Fe, Zn and Cu was urban> orchard> traditional agriculture> forest.

CONCLUSION

It can be inferred from the present study that in mid hills of Kullu district of Himachal Pradesh, the urbanization and orchard land use has increased. Whereas, the traditional agriculture and vegetable land use has decreased. The study further indicated that urbanization has started impacting ecosystem services like carbon stock, soil and water quality. Therefore, planning is urgently required to sustain ecosystem services in the region.

Chapter-7

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Dr Y S Parmar University of Horticulture and Forestry
Nauni-173 230, Solan (HP)
Department of Environmental Science

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Name of the Student	**:**	**Prakriti Singh**
Admission Number	**:**	F-2013-13-M
Major Advisor	**:**	Dr. Satish Kumar Bhardwaj
Major Field	**:**	Environmental Science
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ABSTRACT

The present investigation entitled **"Impact of land use changes on ecosystem services in Kullu District of Himachal Pradesh"** was conducted during the year 2014-15 in the Department of Environmental Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. In order to identify the land use changes a survey was conducted to get people's perception in mid-hills of Kullu district by selecting three blocks: Kullu, Banjar and Naggar. The dominant land use systems namely, forest, traditional agriculture, orchard and urban were selected to assess their impact on ecosystem services viz., soil, water quality and SOC stock in winter and summer seasons. In mid-hills of Kullu district, people perceived that over the last 30 years the area under urban and orchard land use has increased although under traditional agriculture and vegetable based system has gradually decreased. Also, the availability and quality of water was perceived to be decreased over 30 years. The results were justified with secondary data collected from the Department of Revenue, Government of Himachal Pradesh and laboratory analysis of soil and water samples collected from different land use systems. The soils of selected land use systems were normal in reaction and salt concentration. The urban land use system contained the lowest SOC of 0.46% and the highest was under forest. The microbial biomass trend was forest> orchard> traditional agriculture> urban land use; the lowest available NPK contents of 239.71, 15.54 and 114.02 kg ha^{-1}, respectively were observed under urban land use (highest under orchard as of 460.35, 26.54 and 315.07 kg ha^{-1}, respectively). The total microbial count followed the trend as forest> orchard> traditional agriculture> urban. The carbon stock for the forest was observed to be the highest (1251.20 Gg C) but the urban land use depicted the lowest (15.71 Gg C). Although the bulk density was observed to be the highest in the urban land use (1.56 g cm^{-3}) and the lowest was reported under forest (1.09 g cm^{-3}). The heavy metal content in soil was under permissible limits as prescribed by ISI (1992) and WHO (1993), except for Fe which varied from 6049.31 to 6365.35 mg kg^{-1}. The surface water under urban land use was having highest COD (38.88 mg l^{-1}) and BOD (9.03 mg l^{-1}) which was above permissible limits as prescribed by ISI and WHO. Although the ground water was observed to have relatively lower COD (26.63 mg l^{-1}) and BOD (5.05 mg l^{-1}). The heavy metal content in both surface and ground water was under permissible limits as prescribed by ISI and WHO, except for Pb which was highest (0.15 mg l^{-1}) in surface water under urban land use. Therefore, on the basis of the present study it is concluded that in mid-hills of Kullu district of HP the traditional agriculture has been replaced by orchards and urban areas which has started impacting the ecosystem services like soil, water quality and carbon sequestration.

Signature of Major Advisor **Signature of Student**

Countersigned

Professor and Head
Department of Environmental Science
Dr Y S Parmar University of Horticulture and Forestry
Nauni-173 230, Solan (HP)

APPENDIX-I

Analysis of variance table for Soil Organic Carbon (%)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.063			
Season	1	0.112	0.112	8.236	0.00917
Land use	3	4.584	1.528	112.761	0.00000
Season x Land use	3	0.017	0.006	0.409	0.74788
Error	21	0.285	0.014		
Total	31	5.060			

APPENDIX-II

Analysis of variance table for carbon stock (Mg m^{-2})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	16.769			
Season	1	36.138	36.138	27.534	0.00003
Land use	3	1,009.497	336.499	256.384	0.00000
Season x Land use	3	9.398	3.133	2.387	0.09781
Error	21	27.562	1.312		
Total	31	1,099.365			

APPENDIX-III

Analysis of variance table for Microbial Biomass (µg C g^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	365,312.482			
Season	1	5,819,877.021	5,819,877.021	21.827	0.00013
Land use	3	8,659,789.854	2,886,596.618	10.826	0.00017
Season x Land use	3	3,214,429.463	1,071,476.488	4.018	0.02090
Error	21	5,599,406.222	266,638.392		
Total	31	23,658,815.042			

APPENDIX-V

Analysis of variance table for Soil pH

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.184			
Season	1	0.120	0.120	6.267	0.02063
Land use	3	2.275	0.758	39.557	0.00000
Season x Land use	3	0.037	0.012	0.635	0.60051
Error	21	0.403	0.019		
Total	31	3.019			

APPENDIX-VI

Analysis of variance table for Soil EC (dS m^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.033			
Season	1	0.000	0.000	0.046	0.83172
Land use	3	0.033	0.011	2.185	0.11986
Season x Land use	3	0.029	0.010	1.917	0.15781
Error	21	0.105	0.005		
Total	31	0.199			

APPENDIX-VII

Analysis of variance table for Bulk density (g cm^{-3})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.062			
Season	1	0.016	0.016	2.211	0.15187
Land use	3	0.987	0.329	44.880	0.00000
Season x Land use	3	0.025	0.008	1.130	0.35961
Error	21	0.154	0.007		
Total	31	1.243			

APPENDIX-VIII

Analysis of variance table for Available Nitrogen (kg ha^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	26,005.721			
Season	1	59.120	59.120	0.110	0.74295
Land use	3	285,520.183	95,173.394	177.773	0.00000
Season x Land use	3	176.017	58.672	0.110	0.95354
Error	21	11,242.660	535.365		
Total	31	323,003.700			

APPENDIX-IX

Analysis of variance table for Available Phosphorus (kg ha^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	1.751			
Season	1	323.728	323.728	68.466	0.00000
Land use	3	541.565	180.522	38.179	0.00000
Season x Land use	3	121.145	40.382	8.540	0.00067
Error	21	99.295	4.728		
Total	31	1,087.485			

APPENDIX-X

Analysis of variance table for Available Potassium (kg ha^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	8,285.787			
Season	1	15,181.978	15,181.978	14.338	0.00108
Land use	3	201,873.323	67,291.108	63.550	0.00000
Season x Land use	3	15,007.100	5,002.367	4.724	0.01134
Error	21	22,236.310	1,058.872		
Total	31	262,584.497			

APPENDIX-XI

Analysis of variance table for Soil Cd (mg kg^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.057			
Season	1	0.013	0.013	7.124	0.01436
Land use	3	0.538	0.179	99.736	0.00000
Season x Land use	3	0.001	0.000	0.102	0.95803
Error	21	0.038	0.002		
Total	31	0.646			

APPENDIX-XII

Analysis of variance table for Hg (μg kg^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.180			
Season	1	0.046	0.046	0.936	0.34427
Land use	3	3.433	1.144	23.222	0.00000
Season x Land use	3	0.019	0.006	0.127	0.94313
Error	21	1.035	0.049		
Total	31	4.713			

APPENDIX-XIII

Analysis of variance table for Pb (mg kg^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	57.662			
Season	1	725.043	725.043	22.990	0.00010
Land use	3	4,539.163	1,513.054	47.978	0.00000
Season x Land use	3	1,313.266	437.755	13.881	0.00003
Error	21	662.272	31.537		
Total	31	7,297.406			

APPENDIX-XIV

Analysis of variance table for As (mg kg^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	7.719			
Season	1	16.145	16.145	1.274	0.27180
Land use	3	740.884	246.961	19.483	0.00000
Season x Land use	3	3.570	1.190	0.094	0.96259
Error	21	266.190	12.676		
Total	31	1,034.508			

APPENDIX-XV

Analysis of variance table for Zn (mg kg^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	1,334.686			
Season	1	1,917.197	1,917.197	5.060	0.03533
Land use	3	2,389.363	796.454	2.102	0.13047
Season x Land use	3	229.220	76.407	0.202	0.89406
Error	21	7,956.198	378.867		
Total	31	13,826.665			

APPENDIX-XVI

Analysis of variance table for Fe (mg kg^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	735,604.420			
Season	1	4,673.092	4,673.092	0.041	0.84089
Land use	3	3,487,645.231	1,162,548.410	10.278	0.00023
Season x Land use	3	1,869.646	623.215	0.006	0.99942
Error	21	2,375,289.099	113,109.005		
Total	31	6,605,081.488			

APPENDIX-XVII

Analysis of variance table for Cu (mg kg^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	97.409			
Season	1	113.833	113.833	2.501	0.12870
Land use	3	5,100.984	1,700.328	37.362	0.00000
Season x Land use	3	14.066	4.689	0.103	0.95738
Error	21	955.708	45.510		
Total	31	6,282.001			

APPENDIX-XVIII

Analysis of variance table for Microbial count -Bacteria (cfu g^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	1.208			
Season	1	3.315	3.315	22.002	0.00012
Land use	3	9.708	3.236	21.477	0.00000
Season x Land use	3	0.236	0.079	0.522	0.67159
Error	21	3.164	0.151		
Total	31	17.632			

APPENDIX-XIX

Analysis of variance table for Microbial count – Actinomycetes (cfu g^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	19.367			
Season	1	500.936	500.936	32.705	0.00001
Land use	3	661.342	220.447	14.392	0.00003
Season x Land use	3	107.629	35.876	2.342	0.10230
Error	21	321.657	15.317		
Total	31	1,610.930			

APPENDIX-XX

Analysis of variance table for Microbial count- Fungi (cfu g^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	4.018			
Season	1	1.320	1.320	23.716	0.00008
Land use	3	3.188	1.063	19.091	0.00000
Season x Land use	3	0.041	0.014	0.245	0.86369
Error	21	1.169	0.056		
Total	31	9.737			

APPENDIX-XXI

Analysis of variance table for pH of surface water

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	1.054			
Season	1	0.341	0.341	19.406	0.00025
Land use	3	0.336	0.112	6.386	0.00302
Season x Land use	3	0.011	0.004	0.203	0.89339
Error	21	0.369	0.018		
Total	31	2.110			

APPENDIX-XXII

Analysis of variance table for pH of underground water

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.414			
Season	1	0.263	0.263	21.785	0.00013
Land use	3	1.411	0.470	38.962	0.00000
Season x Land use	3	0.003	0.001	0.090	0.96497
Error	21	0.254	0.012		
Total	31	2.345			

APPENDIX-XXIII

Analysis of variance table for COD of surface water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	87.375			
Season	1	91.125	91.125	26.905	0.00004
Land use	3	1,081.125	360.375	106.402	0.00000
Season x Land use	3	25.125	8.375	2.473	0.08977
Error	21	71.125	3.387		
Total	31	1,355.875			

APPENDIX-XXIV

Analysis of variance table for COD of ground water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	72.344			
Season	1	52.531	52.531	67.240	0.00000
Land use	3	221.094	73.698	94.333	0.00000
Season x Land use	3	7.594	2.531	3.240	0.04265
Error	21	16.406	0.781		
Total	31	369.969			

APPENDIX-XXV

Analysis of variance table for BOD of surface water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	12.536			
Season	1	2.703	2.703	11.884	0.00241
Land use	3	12.273	4.091	17.987	0.00001
Season x Land use	3	0.046	0.015	0.067	0.97676
Error	21	4.777	0.227		
Total	31	32.335			

APPENDIX-XXVI

Analysis of variance table for BOD of ground water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	20.306			
Season	1	3.001	3.001	35.330	0.00001
Land use	3	8.714	2.905	34.193	0.00000
Season x Land use	3	0.604	0.201	2.370	0.09952
Error	21	1.784	0.085		
Total	31	34.409			

APPENDIX-XXVII

Analysis of variance table of Cd for surface water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.001			
Season	1	0.016	0.016	28.117	0.00003
Land use	3	0.020	0.007	11.892	0.00009
Season x Land use	3	0.017	0.006	10.446	0.00021
Error	21	0.012	0.001		
Total	31	0.066			

APPENDIX-XXVIII

Analysis of variance table of Cd for ground water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.000			
Season	1	0.000	0.000	42.880	0.00000
Land use	3	0.000	0.000	32.842	0.00000
Season x Land use	3	0.000	0.000	5.863	0.00451
Error	21	0.000	0.000		
Total	31	0.000			

APPENDIX-XXIX

Analysis of variance table of Hg for surface water (μg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.006			
Season	1	0.001	0.001	0.078	0.78328
Land use	3	1.017	0.339	32.971	0.00000
Season x Land use	3	0.000	0.000	0.008	0.99891
Error	21	0.216	0.010		
Total	31	1.240			

APPENDIX-XXX

Analysis of variance table of Hg for ground water (μg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.020			
Season	1	0.004	0.004	0.438	0.51535
Land use	3	1.112	0.371	42.656	0.00000
Season x Land use	3	0.001	0.000	0.020	0.99597
Error	21	0.182	0.009		
Total	31	1.318			

APPENDIX-XXXI

Analysis of variance table of Pb for surface water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.000			
Season	1	0.000	0.000	2.045	0.16738
Land use	3	0.051	0.017	172.630	0.00000
Season x Land use	3	0.000	0.000	0.289	0.83252
Error	21	0.002	0.000		
Total	31	0.053			

APPENDIX-XXXII

Analysis of variance table of Pb for ground water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.001			
Season	1	0.000	0.000	2.675	0.11681
Land use	3	0.015	0.005	91.363	0.00000
Season x Land use	3	0.000	0.000	1.086	0.37649
Error	21	0.001	0.000		
Total	31	0.017			

APPENDIX-XXXIII

Analysis of variance table of As for surface water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.574			
Season	1	0.226	0.226	2.558	0.12469
Land use	3	91.781	30.594	345.910	0.00000
Season x Land use	3	0.202	0.067	0.761	0.52858
Error	21	1.857	0.088		
Total	31	94.641			

APPENDIX-XXXIV

Analysis of variance table of As for ground water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.358			
Season	1	0.076	0.076	1.169	0.29181
Land use	3	89.942	29.981	460.436	0.00000
Season x Land use	3	0.009	0.003	0.048	0.98568
Error	21	1.367	0.065		
Total	31	91.753			

APPENDIX-XXXV

Analysis of variance table of Fe for surface water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.005			
Season	1	0.000	0.000	0.502	0.48655
Land use	3	0.164	0.055	147.657	0.00000
Season x Land use	3	0.000	0.000	0.070	0.97545
Error	21	0.008	0.000		
Total	31	0.177			

APPENDIX-XXXVI

Analysis of variance table of Fe for ground water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.001			
Season	1	0.000	0.000	1.544	0.22771
Land use	3	0.147	0.049	359.336	0.00000
Season x Land use	3	0.000	0.000	0.146	0.93088
Error	21	0.003	0.000		
Total	31	0.151			

APPENDIX-XXXVII

Analysis of variance table of Zn for surface water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.229			
Season	1	0.310	0.310	2.848	0.10631
Land use	3	22.184	7.395	67.828	0.00000
Season x Land use	3	0.097	0.032	0.297	0.82720
Error	21	2.289	0.109		
Total	31	25.110			

APPENDIX-XXXVIII

Analysis of variance table of Zn for ground water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.119			
Season	1	0.070	0.070	0.928	0.34638
Land use	3	10.874	3.625	47.948	0.00000
Season x Land use	3	0.003	0.001	0.014	0.99773
Error	21	1.587	0.076		
Total	31	12.654			

APPENDIX-XXXIX

Analysis of variance table of Cu for surface water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.117			
Season	1	0.005	0.005	1.445	0.24276
Land use	3	2.474	0.825	263.694	0.00000
Season x Land use	3	0.001	0.000	0.110	0.95332
Error	21	0.066	0.003		
Total	31	2.663			

APPENDIX-XXXX

Analysis of variance table of Cu for ground water (mg l^{-1})

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.020			
Season	1	0.003	0.003	1.296	0.26782
Land use	3	1.102	0.367	158.676	0.00000
Season x Land use	3	0.001	0.000	0.168	0.91703
Error	21	0.049	0.002		
Total	31	1.175			

CURRICULUM VITAE

Name	**:**	**Prakriti Singh**
Father's Name	**:**	Mr. Daljit Singh
Date of Birth	**:**	10-09-1991
Sex	**:**	Female
Marital status	**:**	Unmarried
Nationality	**:**	Indian

Educational Qualifications:

Certificate/Degree	Class/Grade	Board/University	Year
Matriculation	First	CBSE	2007
10+2	First	HPSEB, Dharamshala	2009
B.Sc. Forestry (Hons.)	First	Dr YS Parmar UHF, Nauni, Solan – 173 230 (HP)	2013

Whether sponsored by some state/ Central Govt./Univ./SAARC	**:**	No
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(Prakriti Singh)