

EFFECT OF CHEMICALIZED FARMING ON ENVIRONMENTAL QUALITY IN MID-HILLS OF HIMACHAL PRADESH

Thesis

by

**POOJA J
(F-2015-21-M)**

submitted to



**Dr. YASHWANT SINGH PARMAR UNIVERSITY OF
HORTICULTURE AND FORESTRY
SOLAN (NAUNI) HP - 173 230 INDIA**

in

Partial fulfillment of the requirements for the degree

of

**MASTER OF SCIENCE
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CERTIFICATE-I

This is to certify that the thesis entitled, **“Effect of chemicalized farming on environmental quality in mid-hills of Himachal Pradesh”** submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE in 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 **Ms. Pooja J (F-2015-21-M)** daughter of Late Shri Jayanna HE 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:

(Prof. S K Bhardwaj)
Chairman
Advisory Committee

CERTIFICATE-II

This is to certify that the thesis entitled, “**Effect of chemicalized farming on environmental quality in mid-hills of Himachal Pradesh**” submitted by **Ms. Pooja J (F-2015-21-M)** daughter of Late Shri Jayanna HE to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE in Environmental Science** has been approved by the Student’s Advisory Committee after an oral examination of the same in collaboration with the external examiner.

Dr. S. K. Bhardwaj
Chairman
Advisory Committee

External Examiner

Members of the Advisory Committee

Dr D Tripathi Principle
Scientist cum Joint Director
of Research

Dr Rajesh Kaushal
Principle Scientist
Department of Soil Science
and Water Management

Dean’s Nominee

Professor and Head
Department of Environmental
Sciences

Dean
College of Forestry

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Place: Nauni, Solan

Date :

(Pooja J)

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ABBREVIATIONS USED

%	Per cent
APHA	American Public Health Association
BSI	Bureau of Indian Standards
ICP	Inductively Coupled Plasma Analyser
CD	Critical difference
km ²	Square Kilometre
HP	Himachal Pradesh
m ha	Million hectares
Kg	Kilogram
NTU	Nephelometric turbidity unit
SOC	Soil organic carbon
PCA	Principal component analysis
FYM	Farm yard manure
EC	Electrical conductivity
COD	Chemical oxygen demand
BOD	Biological oxygen demand
Mg m ⁻³	Mega gram per cubic meter
SSP	Single super phosphate
SQI	Soil quality index
µg g ⁻¹	Microgram per gram
Gg C	Giga tons of carbon
dS m ⁻¹	Deci Siemen per metre
g cm ⁻³	Gram per cubic centimetre
mg l ⁻¹	Milli gram per litre
mg kg ⁻¹	Milli gram per kilogram

Kg ha^{-1}	Kilogram per hectare
Ppm	Parts per million
Cmol (p+) kg^{-1}	Centimole proton per kilogram
cfu g^{-1}	Colony forming units per gram
$\mu\text{g g}^{-1} \text{ h}^{-1}$	Microgram per gram per hour
$\mu\text{g TPF g}^{-1} \text{ h}^{-1}$	Microgram triphenyl formazen per gram per hour
WHO	World Health Organisation

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Chapter-1

INTRODUCTION

Agriculture has been the backbone of the Indian economy and 70% of population in India depends on this profession. Green Revolution in India started in the late 1960s and with its success India attained food self-sufficiency within a decade. Introduction of high yielding crop varieties, increase in area under irrigation, increased use of chemical fertilizers, pesticides and increase in cropping intensity led to green revolution. The adoption of this system drove India towards self sufficiency in food production, improved rural welfare and overall economy mainly during the last decade of twentieth century. Since then use of chemicals in the form of fertilizers and pesticides has become way of agriculture which is now referred as chemical farming.

To keep pace with alarming increase in human population and their food demand, farmers in our country are being forced to produce higher yields by adopting multiple and intensive cropping systems which necessitated more and more use of chemicals. Fertilization is the most important soil amendment being used in modern agricultural production. Interestingly, research in this area is mostly focused on increasing crop yields, through application of chemicals, however, their impacts on soil health has been neglected till recent period (Mandic *et al.*, 2011).

In order to reduce crop losses which have been reported to be 40% worldwide, farmers are using pesticides to check pests. Although pesticides are credited with success in increasing food production, however, there are also concerns that they have the potential to harm human and environmental health and even compromise with the sustainability of agricultural systems. The use of pesticides has been reported to contribute to water and soil pollution and has ultimately deteriorated the whole ecological system. Today, man is living in a “Chemical Sphere”. These chemicals whether natural or manmade have the capacity to degrade the delicately balanced ecological system by poisoning air, water and soil. Hence, while realizing the need of chemicals in agriculture the quality of the environment should be considered on priority (Hariprasad and Dayananda, 2013). Regular application of chemicals in the

agricultural fields also have been reported to increase of heavy metals particularly Hg, Cr, Cd, Pb, Fe, Zn and As in the farming systems (Atafar *et al.*, 2010).

Overall decline in the productivity capacity of soil under intensive chemical use, and enhancement of input cost in agriculture and presence of chemicals in the food chain, loss of biodiversity and environmental degradation is now indicating towards an alternative solution to problematic chemical farming. Consequently, the world is now thinking to adopt natural farming system which was prevalent earlier on the planet earth.

Soils, whether in urban or agricultural areas represent a major sink for pollutants like metals released into the environment from a wide variety of anthropogenic sources (Sherene, 2010). Application of fertilizer and pesticides, sludge and municipal waste dumping has been identified as the principal source of soil contamination by heavy metals. Failure to mitigate toxic metal build up in soils may result in mobilization of heavy metal contaminants in flora and fauna and subsequently into the food chain with consequent deleterious health effects. Once heavy metals get into the environment whether in small or large quantities, they cannot be completely eliminated. However, their effects on the ecosystem can be mitigated through immobilization (Ogundiran and Osibanjo, 2008). Heavy metal accumulation in agricultural soils leads to disorder of various beneficial soil functions, which in turn affects crop growth. The toxic metals get translocated to crops thus, posing a risk to human health and ecosystem services (Guo *et al.*, 2013).

To keep pace with the other parts of the country the farmers of Himachal Pradesh have also adopted chemicalized farming. The state is known for commercial farming of off season vegetables, flowers and fruit crops wherein indiscriminate use of chemicals has become common. Moreover, the lack of proper knowledge on the use of chemicals in crops and the greediness to get higher yields has led to their indiscriminate use thereby resulting into various environmental problems. Like other parts of the state the mid hills of Solan district of Himachal Pradesh are known for commercial farming of vegetables like tomato, capsicum, beans, peas and cauliflower and protected cultivation of flower as well fruit crop production wherein lot of chemicals are being applied each year for enhancing the production. Such farming practices are expected to pollute soil and water source. Therefore, present study

entitled “Effect of chemicalized farming on environmental quality in mid hills of Himachal Pradesh” has been conducted with the following objectives:

1. To study the effect of fertilizer and pesticide applications in agriculture on water quality parameters and physico-chemical and biological properties of soil.
2. To study the effect of chemical inputs on heavy metal build up in soil and water.

Chapter-2

REVIEW OF LITERATURE

Land and water are the most precious natural resources important to human civilization. The intensive use of fertilizers and pesticides in crop production has caused nutrient accumulation, in soil surface and water bodies (McDowell and Sharpley, 2001). The pertinent literature has been scanned to gather information and idea to assess the various cropping systems in mid hills of Himachal Pradesh and their impact on environment. Available literatures pertaining to aspects taken in the present study have been reviewed under the following headings.

2.1 Soil physico-chemical and microbiological characteristics

2.2 Physical and chemical properties of water

2.3 Toxic metal buildup in soil and water

2.1 SOIL PHYSICO-CHEMICAL AND MICROBIOLOGICAL CHARACTERISTICS

2.1.1 Soil physico- chemical properties

2.1.1.1 Soil pH and Electrical conductivity

Soil pH reflects the hydrogen ion activity in the soil solution and defines most chemical and biological activity thresholds whereas, electric conductivity is a measure of soil salinity and can also be used to estimate soluble nutrients present (Rhoades, 1996). These parameters are influenced by the farming systems and use of chemicals such as fertilizers, sludge liquid manures as well as pesticides (Smith and Doran, 1996).

The cultivated soils of Palampur and Ahju were found to have soil pH ranged from 5.3 to 6.5 which was slightly acidic due to use of nitrogenous fertilizers (Minhas *et al.*, 1997). Sharma *et al.* (2001) reported that application of lime in combination with N, P and K brought the soil to neutrality by increasing the pH to 6.8 from the initial values of 5.8. A decline in soil pH in NPK treated plots as compared to FYM once over a long period of time was also reported by Ghosh *et al.* (2001).

The major crop production areas in China have been noticed to be affected by the problem of soil acidification due to high input of nitrogenous fertilizers (Guo *et al.*, 2010). 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. Loria (2012) studied physical and chemical properties of cultivated soils at catchment area of pong dam in Himachal Pradesh and reported pH (6.71) EC (0.12 ds/m).

The cultivated lands of north western Ethiopia region were found to have soil pH (5.06 to 5.61) which was moderately acidic under all farming systems (Selassie and Ayanna, 2013). A study conducted in the cultivated soils of Nagchoon Pond Khandwa, MP, India by Mahajan and Billore (2014) reported that a high concentration of salts resulted in alkaline nature of the soil and its conductivity becomes high.

2.1.1.2 Soil porosity

Higher bulk densities have been reported under zero-tillage cultivation compared with other tillage practices (Gantzer and Blake, 1978). Various studies (Patel and Singh, 1981; Ankeny *et al.*, 1990) had reported that compaction increases bulk density in turn decreases porosity by disrupting soil aggregates or by compression of soil aggregates forming restrictive layer and thus decreases soil volume by compressing soil particles (Chowdhry *et al.*, 1991). Benito and Diaz-Fierros (1992) studied the effects of various cropping systems on the structural stability of soils containing various soil organic matter contents and found that a decrease of soil organic matter content led to a decrease in soil structure stability.

Deterioration in the aggregated structure of the soil was influenced by the soil organic carbon content Cambardell and Elliot (1994). Organic matter is an important soil component influencing the physical, chemical and microbiological properties of soil to a great extent. All physical properties of soil are affected by changes in organic matter level in soil. Decrease in bulk density in turn increase in porosity with the addition of organic matter has been reported by Ray and Gupta (2001).

Variations in land cover, management practices and long-term cultivation has caused significant modifications in soil characteristics such as bulk density, particle density and porosity (Shepherd *et al.*, 2001). While studying the natural forest land soils in the high land mountain ecosystem on the eastern Black sea region of Turkey Gol and Denigiz (2008) reported that land was seriously degraded and destructed due to intensive agricultural practices. Land use change and subsequent tillage practices resulted in significant decrease in organic matter, total porosity, total nitrogen and reduced soil aggregates stability. There was also a significant change in bulk density among cultivated, pasture and natural forest soils and further observed long term continuous cultivation of the natural forest soils and changes in physical and chemical characteristics of soils.

The continuous application of chemical fertilizers on surface and subsurface soils has been reported to have more effect on surface soil physical properties compared to subsurface soil (Qiang 2013). Selassic and Ayanna (2013) studied the impact of cultivated and uncultivated land on soil physic-chemical properties of soils in north western Ethiopia and reported the lowest bulk (1.18 mg/m^3) and particle densities (2.41 mg/m^3) and the highest total porosity (63.47 %) under natural forest land use system. In contrast, the highest bulk (1.41 mg/m^3) and particle densities (2.59 mg/m^3) and the lowest total porosity (45.63 %) were obtained under the cultivated land use system.

Long-term effects of pesticides and chemical fertilizers usage on soil properties and heavy metals accumulation in Ardabil- Iran was observed by (Yargholi B *et al.*, 2014). The results showed that soil physical characteristics such as bulk density were changed in long-term and it was increased compared to control soil.

2.1.1.3 Soil organic carbon

Soil organic carbon content is recognized as a key indicator of soil fertility and sustainability of agricultural systems. It has long been recognized as a source of plant nutrients, principally N and substantially P, S and micronutrients, besides being a promoter of a range of soil physical characteristics.

In Himachal Pradesh, significantly higher soil organic content is found in agro-forestry systems as compared to pure agricultural fields. Kaistha *et al.*(1990)

reported that organic carbon content varied from 0.3 to 8.3 per cent in the soils of different regions of Himachal Pradesh. Singh *et al.* (1991) reported moderately high content of organic carbon (1.40 to 2.58 per cent) in the mid altitude soils of Himachal Pradesh. Minhas *et al.* (1997) reported lower amounts of organic carbon in cultivated soils of Palampur (Kangra) and Ahju (Mandi) regions of Himachal Pradesh.

Saha *et al.* (1999) studied physico-chemical properties of soil under different land uses (different silvi-pastoral systems) and found that organic carbon content was higher in silvi-pastoral system than in cropped land. Direct and residual effects of organic manures applied in combination with chemicals fertilizers on crop productivity and soil fertility in a rice- wheat cropping pattern for three years was studied and found that the application of only inorganic fertilizers reduced carbon content from 13 to 19 per cent and addition of organic manure increased carbon (Bodruzzaman *et al.*, 2002). Ishaq *et al.* (2002) studied the layer wise distribution of available nutrients and soil organic carbon and noticed that fertilizer application in the agriculture system improved the status of organic carbon.

Anwer *et al.* (2005) observed that the application of organic manure and inorganic fertilizer increased soil organic carbon, available nitrogen and available phosphorus in soils. The soil received organic manure alone or in combination with inorganic fertilizers had higher available nutrients and soil organic carbon than control (no fertilizer or manure) and inorganic fertilizer treated soil. This study indicated that combined application of manure and fertilizer helps to increase crop productivity and maintaining soil fertility. Chen *et al.* (2011) reported that farm management practices significantly affect the content of soil organic carbon in the soil surface layer of 0-25 cm in the Yanqing Basin, North western Beijing. Loria (2012) studied physical and chemical properties of soil at catchment area of pong dam in Himachal Pradesh and reported organic carbon (0.61 %) under agriculture land use. Selassic and Ayanna (2013) studied the impact of cultivated and uncultivated land on soil physic-chemical properties of soils in north western Ethiopia and reported the lowest organic carbon under cultivated land, whereas the highest values were found under forest.

2.1.1.4 Soil nutrients

In intensive cropping systems being followed in various agro-climatic conditions of India, the imbalanced application of chemical fertilizers have been reported to influence the soil fertility adversely (Nambiar and Ghosh, 1987). Effect of continuous cropping and fertilization on the nutrient status of mollisols in India was studied by (Tyagi and Bhardwaj, 1994) and found that the graded application of NPK fertilizers, significantly increased nitrogen, phosphorus and potassium availability relative to control. Whereas, Bharwaj and Omanwar (1994) reported depletion of available nitrogen and phosphorus under continuous cropping without fertilization to a considerable extent while the fertilized plot showed an increase in the concentration of the nutrients in soil .

The enrichment of soil with nutrients has been reported to be stronger in the orchard and vegetable field than in the cropland due to intensive tillage, fertilization and irrigation in the surface layer (Ellert and Gregorich, 1996). The balanced supply of each nutrient in relation to plant growth is essential for obtaining normal yield and quality of produce. Protection of soil quality under intensive land use and fast economic development is a major challenge for sustainable resource use in the developing world (Doran *et al.*, 1996). Prasad *et al.* (1997) studied the changes in different forms of P in an acid alfisol due to long-term manuring and fertilization and found that total P status of soil increased from 605 to 1020 mg/kg soil with the increase in NPK level from 50-150 per cent of the recommended dose.

Wells *et al.* (2000) reported that the intensive vegetable farming has the potential to deteriorate soil health, leading to poor productivity and large environmental impacts. They observed that after three and half years of vegetable farming the total nitrogen and phosphorus had increased. Agricultural activities have an important contribution to nonpoint pollutants as more intensive uses of pesticides and fertilizers have led to rise in both phosphates and nitrates in both soils and water (Horan and Shortle, 2001).

Appropriate fertilizer application is an important management practice to improve soil fertility and quality. Bodruzzaman *et al.* (2002) studied the direct and residual effects of organic manures on yields in a wheat- rice cropping pattern and found the available N and P level increased by organic manure application than in

inorganic fertilizer and control. Sharma *et al.* (2002) also reported that shiwalik soils were low to high in available N and P and low to medium in available K, sufficient in exchangeable Ca and Mg and deficient to sufficient in available micronutrients cations depending upon the cropping systems. Bulluck *et al.* (2002) examined the effects of organic and synthetic soil fertility amendments on soil physical and chemical properties at three organic and three conventional vegetable farms in Virginia and Maryland during 1996 and 1997. They reported higher Ca, Mg, K, Mn, thermophilic microorganisms and enteric bacteria in greater numbers in soils amended with alternative than synthetic amendments. Sharma (2003) reported that soils of agricultural lands of mid-hill zone of Himachal Pradesh were medium to high in available Nitrogen and low to high in available phosphorus and potassium.

Application of chemical fertilizers in the land uses has been noticed to increase yields but the continuous use has created nutrient imbalance (Crew and Peoples, 2004). However, While studying continuous wheat and wheat-fallow cropping sequence, Liang *et al.* (2004) found that continuous monoculture increased soil organic N and mineralizable organic N. According to Mondal *et al.* (2005), soils of agricultural land had higher nitrogen content as compared to non agricultural land due to the use of nitrogen fertilizers. Gol and Denigiz (2008) studied the natural forest land soils in the high land mountain ecosystem on the eastern black sea region of Turkey and reported the land was seriously degraded and destructed due to intensive agricultural practices. However, contents of available P were improved by application of phosphorus fertilizers in cultivated system.

Study on impact of different intensive farming systems on soil quality showed that vegetable farming resulted in higher values of available nitrogen (Amarasekara *et al.*, 2009). The excess use of nitrogen fertilizers in the agricultural area of North China Plain, has resulted in the increased concentration of nitrogen ranging from 500-600 Kg N/ha/year, exceeding the crop requirement of 200-300 Kg N/ha/year (Cui *et al.* 2010). Chen *et al.* (2011) evaluated the effect of cropping systems on the soil parameters specifically cropland, orchard and vegetable based cropping systems were examined. Results of the study suggested that land use and farming management practices significantly affect the total NPK content and found that orchard and vegetable cropping systems were found to have higher nutrients than cropland. As a result of intensive use of nitrogen fertilizer in the double cropping system had resulted

in soil acidification (Guo *et al.*, 2010). Dong *et al.* (2009) examined the effect of different fertilization treatments in China and found that available nitrogen and phosphorus was highest in organic plot while available potassium was highest in NPK treated plot.

Effect of long term application of inorganic fertilizers in the soils of the Ebonyi state, Nigeria was studied by (Ogbodo, 2013). Results showed that total nitrogen and exchangeable phosphorus ranged from moderate to medium and potassium, calcium, magnesium and sodium ranged from very low to low across the locations. Fernandez- Sanjurjo *et al.* (2014) studied the nutrients release from two compressed nitrogen-potassium-phosphorus (NPK) fertilizers in the Lourizan forest center and reported significant increase of pH and available P in fertilized soil columns that were filled with soil from the surface layer (0-20 cm).

Wani *et al.* (2010) studied the physicochemical properties and fertility of soils in Gwalior, Madhya Pradesh and reported available potassium of cultivated soils and barren land soils was between medium to high and in the garden soils it was medium. Effect of fertilizers on physical and chemical characteristics of saline soil in Sidoarjo and Surabaya, East Java, Indonesia was evaluated by (Mindari *et al.*, 2015). The result showed that exchangeable sodium, potassium, calcium and magnesium were found to be medium to high.

2.1.2 Microbiological properties of soil

2.1.2.1 Soil microbial count and biomass

Soil contains the most diverse assemblages of living organisms. Soil health focuses more on the biotic components of a soil reflecting, i.e. the maintenance of soil organisms and their proper functioning as regulators of nutrient cycling and therewith of soil fertility. Excessive use of agro-chemicals for increasing crop productivity may impact the biological properties of the soil under different cropping systems.

Chemical factors play a crucial role in the survival of microorganisms in different ecological niches of soil (Chapman, 1965). Borisova and Altimirska (1990) studied the different microbiological processes in soil under different tillage and fertilization and found that fertilizers had greater effects than tillage on soil microflora and nutrients status.

The effect of various fertilizer regimes (NPK, N, P, K, FYM, no fertilizer) on soil organisms, CO₂ output, soil structure and carbon content in a long-term field experiment revealed that FYM with fertilizers increased the number of bacteria and fungi as compared to control (Hickisch and G, 1990). Badiyal *et al.* (1990) studied the effect of fertilizers and management practise on microflora in an Alfisol and found an increase in the rate of organic carbon, nitrogen and phosphorus, the bacterial population was significantly affected but fungi was not affected. Heinonen (1990) measured microbial activity of soil by different parameters like nitrification potential, dehydrogenase activity, cellulolytic activity and respiration. He found higher microbial activity in organic plant production plots in comparison to conventional plant production plots. Illmer and Schiner (1991) reported that the number of colony forming units (cfu/g) of different classes of micro-organisms increased in fertilized soils as compared to control in forest soils.

A reduction in organic matter and microbial activity on long term application of N-fertilizers was reported by (Fauci and Dick, 1992). Goyal *et al.* (1992) studied that effect of continues inorganic fertilization and organic amendments on the organic matter-microbial biomass relationship and found that soil microbial biomass carbon and nitrogen increased with the balanced fertilization (organic and inorganic fertilized). Bhardwaj and Omnavar (1994) found an increase in microbial population on an application of fertilizers. They also observed that application of N alone enhanced actinomycetes population.

A growing number of studies show that organic farming leads to higher soil quality and more biological activity (microbial populations and microbial respiration rate) in soil than conventional farming (Droogers and Bouma, 1996). Shen *et al.* (1997) carried out a plot experiment and found that soil microbial biomass carbon increased with the application of organic manures and decreased with the application of ammonium sulphate. Murata *et al.* (1997) also found that microbial biomass carbon and nitrogen increased with the organic material application. Zang and Zak (1998) reported that a low addition of nitrogen had a short positive effect on microbial biomass but no long-term effect whereas high addition of nitrogen decreased ectomycorrhizal colonization. The bacteria and actinomycetes have significantly positive relationship with crop yield and available nutrient status in the plot receiving

organic and inorganic fertilizers while fungal is negatively correlated to FYM addition.

Patil and Varade (1998) studied the effect of application of NPK fertilizers to a sorghum-wheat cropping sequence on a specific field experiment in Maharashtra and reported that the population of fungi, bacteria and actinomycetes were affected significantly with the increasing rates of fertilizers. Sharma *et al.*, (2000) found that microbial population enhanced significantly due to crop residue and FYM incorporation along with chemical fertilizers as compared to chemical fertilizers alone.

According to Lupwayi *et al.* (2001) conventional farming practices and use of chemicals inputs resulted reduction of soil biodiversity. Bhardwaj *et al.* (2010) reported that the application of organic including biofertilizers improved the physico-chemical and biological properties of the vegetable growing soils. The microbial population varied between 4.9×10^7 to 6.6×10^7 cfu/g soils with a predominance of bacterial count under mid hill conditions of Himachal Pradesh.

After 25 years of long-term fertilizer experiment in Jabalpur, Jain *et al.* (2003) found that FYM application along with chemical fertilizers was much superior in maintaining the soil biological health as compared to the chemical fertilizers alone. Whereas, Rabary *et al.* (2008) studied the impact of agricultural land uses on biological and biochemical properties of soils under seeded cropping systems of Madagascar and found that there was no interaction between soil management strategies and the use of fertilizer. Furthermore, the fertilizer did not affect the soil carbon and nitrogen content or the acid phosphatase and urease activities.

The pesticide application in commercial cropping systems has been reported to influence arthropods, earthworms, fungi, bacteria, protozoa, and other beneficial micro-organisms and consequently the health of the soil (Arias-Estervez *et al.*, 2008). Bio-organics application in French bean cauliflower based cropping system in mid hills of Himachal Pradesh has also been reported to reduce bulk density and increase water holding capacity, soil organic carbon, bacterial and fungal counts in the organic farming base treatment (Bhardwaj *et al.*, 2010). Lou *et al.* (2011) studied the impacts of organic inorganic nitrogen management on total organic carbon and microbial biomass carbon in a maize field in Northeast China. They reported microbial biomass

carbon varied from 178 ± 7.8 to 451 ± 25.5 mg/kg and significant increase in total organic carbon concentration was recorded (10.6 mg C/ha).

The effect of different long-term fertilization practices on soil environmental variables and microbial communities in subtropical China was studied by (Dong *et al.*, 2013) reported that organic matter treatment led to increases in soil organic carbon, total nitrogen and total phosphorus contents while the mineral fertilizer led to increase in dissolved organic carbon content.

2.1.2.2 Phosphatase and Dehydrogenase enzyme activity

Soil enzyme activities are believed to indicate the extent of specific process and also act as an indicator of soil fertility. The general name of phosphatase has been used to describe a broad group of enzymes that catalyze the hydrolysis of both esters and anhydrides of ortho-phosphoric acid (Schmidt and Laskowski 1961). Phosphatase activity has been found to be a good indicator of the organic matter (Hattori, 1988).

Soil is considered as a biological entity, i.e., a living tissue with complex biochemical reactions and these reactions are catalyzed by different types of enzymes. Singaram and Kamlakumari (1995) reported that the combined application of FYM and inorganic fertilizers recorded maximum activity of enzymes compared to inorganic fertilizers alone. They also found that increasing level of inorganic fertilizers enhanced enzyme activities in soil. Park *et al.* (1998) studied the effects of liming and fertilization on soil properties and found that soil dehydrogenase activity showed an increasing trend with liming whereas fertilization had a negative effect on dehydrogenase activity. Simek *et al.* (1999) studied the effect of organic and inorganic fertilizers on soil chemical properties, estimates of soil microbiological community size and activity of enzymes and found that dehydrogenase activity was lower in soils that have received the largest amount of inorganic fertilizers alone as compared to the combined application of organic and inorganic fertilized soils.

The long-term fertilizer experiment conducted in Tamil Nadu to assess the microbial population and enzymatic activities showed that phosphatase enzyme was higher in the treatment where 100% NPK + FYM was applied than the 150% NPK and control treatment (Manna and Ganguly, 2001). Beknazarov (2002) studied the effect of NPK fertilizers on phosphatase and pyrophosphates activity in chernozem

soils at different depths under cotton cultivation and found that the activity of enzymes increased with increase in soil depths. He also reported that enzymatic activities were also increased by increasing the rates of fertilization.

The effect of different levels of fertilizers on dehydrogenase activity under maize-cowpea crop rotation was observed by Sriramchandrsekharan (2002) and found that the application of FYM along with the recommended dose of fertilizer registered the highest dehydrogenase activity as compared to inorganic fertilizers alone and control.

2.2 PHYSICAL AND CHEMICAL PROPERTIES OF WATER

Water quantity and quality are important services that can be enhanced or degraded by agriculture. Excess use of fertilizers and pesticides in agricultural activities to enhance productivity due to increasing population and advancement in technology have threaten the ground and surface water sources at a large scale.

The agricultural land use within catchments has been linked to increasing concentrations of inorganic nitrogen in drainage water. 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). Study by Hamilton and Helsel (1995) indicated increased concentration of nitrates beyond permissible limits for drinking water in the ground water at five different regions of United States which was due to application of commercial fertilizers and manure. They also reported increased level of potash, calcium and magnesium in ground water around agricultural areas. Gallangher *et al.* (1996) studied the impact of cropping systems on regional water resources of Red river of north basin in USA and reported high levels of zinc, cadmium, lead, sulphates, nitrates and chlorides.

The concentration of nitrate-nitrogen, potassium and magnesium beyond permissible limits have been observed by Ostrowska *et al.* (1997) in farm wells of six different regions of Poland. Intensive agriculture is known to emit more nutrients, particularly N and P to the environment, which may result in serious water quality impairment (Gillingham and Thorrold, 2000). Study by Randall (2000) reported high concentration of nitrates in surface water of Mississippi river basin, due to surface

drainage from row crop agricultural production system. Cho *et al.* (2000) reported high concentrations of heavy metals in surface and ground water of Wonju, Korea due to surface drainage from row crop agricultural production system.

According to State *et al.* (2001) nutrients and pesticides can enter surface waters thereby seriously affecting the quality of water. Nitrate and Phosphate are the main nutrient pollutants of water. Their presence in surface water also can have serious consequences for aquatic life. Erosion of soils resulted in sedimentation of water courses and deterioration in the quality of water and aquatic ecosystems. Impacts on water are closely related to those on soils as nutrient pesticide pollution of water resulted from surface runoff and subsurface flow. The heavy irrigation in commercial cropping systems have been as reported as a major cause of salinisation of soil and underlying groundwater by causing soil accumulation of salts and rise in water table (Zibilske *et al.*, 2002)

The trend of increased use of fertilizers and pesticides in an effort to increase crop productivity has been reported to contribute for deterioration of water quality (Sharma, 2003). Nagumo *et al.* (2004) studied nitrogen pollution from agricultural fields in stream water in a rural area of central Hokkaido, Japan and reported 0.9 mg/l of total nitrogen concentrations in agriculture runoff during snow melt season and 0.7 mg/l in the post- rice-planting season.

As plants grow, they absorb nutrients from the soil and on their harvesting the soil become deficient unless such nutrients are supplied from outside as organic or chemical fertilizers. The chemical fertilizers because of their faulty application and low use efficiency remain in soil and enter the ground water and consequently impair its quality. On the other hand, imbalanced use of fertilizers in some developing countries has resulted in soil degradation due to mining of micronutrients (MEA, 2005). Lord and Clay (2006) studied the impact of oil palm cultivation on water quality and reported that runoff, sedimentation, leaching of nutrients from fertilizer, pesticides and other agrochemicals has affected the water quality in Indonesia. Rafiu *et al.* (2007) reported that the pH range from 6.53 to 10.88, electrical conductivity (820 to 7500 $\mu\text{S}/\text{cm}$) and temperature (18 to 25 °C) in water samples from the spruit of South Africa. Milovanovic (2007) studied the Axios Vardar River, an interboundary river located in the Balkan Peninsula and reported nitrate, nitrite,

ammonium, total phosphorous, BOD, Cd Cr, Zn, Pb in the water samples of agricultural runoff from cultivated areas.

Impact of fertilizer inputs in agricultural on water quality in Evros region of Northern Greece, was studied by Nikolaidis *et al.* (2008) and noticed that nitrate, sulphate and phosphate in the range of 2 to 212, 250 and 0.2 to 6.28 ppm were found in water samples due to agricultural runoff. Study by Wichelns and Oster (2008) indicated that run-off from irrigation can reduce ground and surface water quality by depositing substances such as salts, silt, selenium, arsenic, and boron and residues from fertilizers and pesticides.

Runoff water can transport eroded soil particles from fields to water bodies. Suspended particles contribute significantly to water turbidity, which reduces light penetration, impairs photosynthesis, alters oxygen levels and reduces the food supplies for certain aquatic organisms (Bilotta and Brazier, 2008). Study by Zhang *et al.* (2008) reported organophosphate pesticide and pyrethroid use in dormant sprays was associated with high pesticide concentrations in water and sediment in San Joaquin River. Lee *et al.* (2007) studied the nitrate concentration in northern and southern Han river and reported that nitrate concentration in the south Han river were much higher than those in the north Han river which may be due to more extensive distribution of agricultural fields, residential areas and animal forms in the south Han river drainage basin.

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). Manssour and Al- Mufti (2010) studied the physico-chemical parameters of Quttianlake in Syria and reported that water quality parameters (temperature, pH, EC, dissolved Oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), phosphate, nitrate ions and phosphorous varied from one site to another. Phosphorus concentration in surface water varied between 0.51 mg/l and 2.2 mg/l and reported that it was added from agriculture runoff. Michinori (2002) studied the effect of heavy fertilizer applications on soil and water under different cropping systems and found high nitrate concentration in ground and surface water sources adjoining the fields.

Razmkhah *et al.* (2010) studied EC, pH, TDS, NH₄, NO₃, NO₂, turbidity, total hardness Ca, Mg, Na, K, Cl, total coliform and faecal coliform in water samples and found that presence of nitrate in the Jajrood river of Iran suspected to originate from overland runoff from agricultural fields where irrigated horticultural crops are grown inorganic fertilizers are rather frequently used (usually as ammonium nitrate). The seasons of the year by influencing surface runoff and leaching process has also been noticed to influence the impact of agricultural activities on soil and water quality of a region (Juned and Arjun, 2011). In another study in Jenin area of Palestine, Ghanem *et al.* (2011) reported high concentration of pesticides and heavy metals due to increased farming activities in the catchment.

Application of chemical fertilizer has been reported to deteriorate the quality of water surface ground level. The processes of leaching and surface runoff have been noticed to increase nitrate and phosphatic levels beyond permissible limits prescribed by WHO (Divya and Belagali, 2012). Sharma (2014) studied the land use impact on water quality and reported pH (7.37), EC (245.75 μ S/cm), TDS (276.86 mg/l), temperature (19.25°C), turbidity(4.29 NTU), BOB (1.01 mg/l), COD (8.96 mg/l), calcium (48.43 mg/l), magnesium (5.96 mg/l), chloride (2.86 mg/l) and nitrate (4.69 mg/l) under agricultural land use under forest land use pH (6.14), EC (219.00 μ S/cm), TDS (209.24 mg/l), temperature (16.42°C), turbidity (1.19 NTU), BOD (0.30 mg/l), COD (3.34 mg/l), calcium (55.34 mg/l), magnesium (4.72mg/l), chloride (1.59 mg/l) and nitrate (1.36 mg/l) were lower than agriculture land use in Kunihar block of Solan district, Himachal Pradesh.

The study was conducted to see the impact of cropping systems of mid hills of Himachal Pradesh in Shimla district and observed that the surface water bodies pollution was caused by nearby cropping systems and pointed out that the commercial vegetable and fruit crop systems have started impacting the water quality of the region because of the injudicious use of chemicals (Chauhan *et al.*, 2014). Rana *et al.* (2016) during the study conducted in mid hills of Solan district of Himachal Pradesh indicated that the agriculture land use have started impacting the surface water quality of the region. While comparing different land uses it was noticed that the agricultural activities tended to increase TDS, BOD, COD, Cl and NO₃ content in surface water sources of the region.

2.3 TOXIC METAL BUILDUP IN SOIL AND WATER

The amount and distribution of trace metals in soil are dependent upon the biogeochemical cycle of the ecosystem in which it occurs. Although biological systems have been known to be adapted to low levels of trace metals in their respective environments. This delicate balance may be disrupted by land enrichment of these metals by humans. Inputs of trace metals by human include fertilizers, lime, sewage sludges or manure, coal residue, fly ash, mining and smelting. Application of phosphatic fertilizers, pesticides, compost, cattle and poultry manure on soil has been reported to result in soil heavy metal accumulation such as lead, cadmium, copper, arsenic and zinc (Alloyway, 1990; Jensen and Bro, 1992).

A research conducted in North Carolina by Lenat and Crawford (1993), concluded that agricultural fields have maximum concentrations of heavy metals (Cr, Pb and Cu). Alloway (1995) reported that the accumulation of heavy metals in agricultural soils is increasing which is worldwide concern because of food safety and human health and ecosystem risks. Mortvedt and Beaton (1995) reported that p-fertilizers are among the sources of heavy metal input into agricultural systems. On average, phosphate rock contains 11, 25, 188, 32, 10 and 239 mg/kg of As, Cd, Cr, Cu, Pb and Zn, respectively. Use of p-fertilizers such as triple superphosphate resulted in accumulation of these elements which increased the contamination potential of Cd in the soil.

Phosphatic fertilizer application is a significant contributor of trace element, especially for Cd accumulation in crop land soils (McLaughlin *et al.*, 1996). Chen *et al.* (1997) analysed agricultural soils, both orchard and vegetable soils in Hong-kong and reported the accumulation of As, Cd, Cu and Zn originating from applications of pesticides, animal manures and fertilizers.

A research conducted in Hawkesbury Nepean River by Markich and Brown (1998) concluded that the increased concentration of nutrients (nitrogen and phosphorus) and trace metals (Cu, Zn, Pb, Cd, Ni, CO and Mn) in surface water was due to agriculture runoff. While naturally occurring and ubiquitous, trace such as As and Cd may be introduced into crop land soils by anthropogenic activities. Human activity can contribute to increased Cd levels as a result of agricultural practices (Adriano, 2001). Kambole (2003) studied the impact of anthropogenic (agriculture)

activities on the Kafue River in Zambia and reported eutrophication and high concentration of heavy metals from NPK fertilizers in water body.

Long term application of chemical fertilizers and pesticides in wheat crop has been reported to increase heavy metals like Cd, Pb, As in soils (Atafar *et al.* , 2010) Hassan *et al.* (2013) studied the heavy metals content in the phosphate fertilizer and its components collected from Abu-Zaabland Abu-Tartur fertilizers and chemical industries in Egypt and reported phosphorus, sulphur, calcium, zinc, arsenic, iron and manganese in phosphate fertilizer. The results showed that heavy metal content was lower in Abu- Tartur phosphate. Phosphate rock is a source of heavy metal pollution of air, soil, water etc, therefore requires removal of heavy metals from the rock prior to its use.

Nitrate and heavy metal pollution resulting from agricultural activities was examined by Hariprasad and Dayananda (2013) who pointed out increased levels of Pb, Hg and NO_3^- in water and built up of heavy metals like Pb, Cd, Fe, and Mn in soils. A research conducted in Ikingi Nasser, Egypt by Goher *et al.* (2014) analyzed the surface sediment and reported the abundance of heavy metals in the following order $\text{Fe} > \text{Mn} > \text{Zn} > \text{Cr} > \text{Ni} > \text{Cu} > \text{Pb} > \text{Cd}$, with mean concentration of 12.41 mg/g, 279.56 mg/g, 35.38 mg/g, 30.79 mg/g, 27.56 mg/g, 11.21 mg/g and 0.183 $\mu\text{g/g}$, respectively and reported that agriculture activities represent the main anthropogenic sources of heavy metals in the lake.

Yargholi and Azarneshan (2014) evaluated the long -term effects of pesticides and chemical fertilizers usage in agriculture on soil properties and heavy metals accumulation pointed out deterioration in soil physical and chemical properties. Zhao *et al.* (2015) studied heavy metal contamination in soils of rice farm land in China and reported high concentrations of copper, nickel, lead and zinc in soils in southeast part whereas cadmium were high in northeast and further reported that the accumulation of all the studied metals is related to the long- term application of agrochemicals.

Rana *et al.* (2016) investigated heavy metals in surface and ground water sources under agriculture, forest and urban land use in mid hills of Himachal Pradesh and observed that higher As (0.05 ppb), Cd (0.14 ppb), Fe (1.68 ppb) and Pb (0.14 ppb) was observed under surface water sources of urban land use whereas higher Zn content of 0.46 ppb was observed under forest land use. However, in ground water

sources higher As (0.03 ppb), Fe (2.83 ppb), Zn (0.73 ppb) was observed under forest land use, whereas Cd (0.18 ppb) in urban land use and Pb (0.13 ppb) was recorded under agriculture land use system.

The above cited literature indicated that physico-chemical properties of soil and water are being influenced by the farming systems depending on the crop, nutrient amendments and tillage practices employed. Therefore, to enhance the farming systems performance through improvement in soil and water condition, research is needed to better understand their interactions with the environment so that recommendation on appropriate adoption strategies can be made.

Chapter-3

MATERIALS AND METHODS

The present study entitled **“Effect of chemicalized farming on environmental quality in mid-hills of Himachal Pradesh”** was conducted during 2016-17 to determine the effect of chemical inputs on physico-chemical and biological properties of soil and water quality parameters in Solan district. The study was conducted in the Department of Environmental Science, College of Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India. The materials 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 samples and laboratory analysis
4. Interpretation of data
5. Statistical Analysis

3.1 GENERAL DESCRIPTION OF THE STUDY AREA

3.1.1 Location

The study was conducted in mid hills of Solan district of Himachal Pradesh falling under North-Western Himalayan region zone in India. The area lies between 30°30' N and 31°50' N latitude and 76°42' E and 77°20' E longitude. The elevation of the district ranges from 300 to 3,000 meters above mean sea level having 1936 km² geographical area. The area falling within elevation of 650-1800 m constitutes the mid hill region of the district and, therefore, selected for study. The study was conducted in areas like Solan, Kandaghat, Chail and Nauni.

3.1.2 Physiography

In general, the physiography is marked by undulating landscape dotted by elevations and depressions. The soils have been derived from red and grey gypsiferous and calcareous shales. The soils are shallow to medium deep and are

mostly sandy loam to sandy clay loam in texture. The agricultural fields have been carved out of the hill and are, therefore, sloppy and small in size. Therefore, they require altogether different soil and crop management practices, from the ones' practiced in the plains. Because of hilly terrain the soils are subjected to severe erosion hazards and each year immense quantity of valuable soil is washed away by monsoon rains.

3.1.3 Climate and weather condition

The climate in mid hills of Solan district of Himachal Pradesh is sub-humid temperate with considerable variation in the seasonal and diurnal temperature. In general, May and June are the hottest whereas, December and January, are the coldest months of the region. The zone has moderate climate with annual average rainfall of about 1100 mm. The bulk of which is received during monsoon months (June-September) with few pre-monsoon showers. Precipitation during winter is common but in low quantum. The mean minimum and maximum temperature varies from -2 to 15°C in winter and 25 to 36°C in summer months.

3.2 EXPERIMENTAL DETAILS

In order to document the prevalent farming systems the survey of mid hill region of Solan district of Himachal Pradesh was conducted. To meet out the objectives, the study was conducted by taking six farming systems as treatments. The farming systems like: Traditional, Organic, Polyhouse, Vegetable, Flower, and Orchard were selected for the study. The treatments were arranged under randomized block design by taking four locations viz Solan, Kandaghat, Chail and Nauni of mid hills as replications.

The traditional farming is the oldest system and is being practised by the mountain people since time immemorial. Traditional farming system was composed of wheat, maize, barley and pulses, wherein, farmers apply farm yard manure and no fertilizer or chemical input and was considered as control. In the organic farming system traditional crops like maize, wheat and pulses and in some cases tomato, capsicum and cucumber crops were generally grown wherein, farmers apply only FYM and other organic based inputs. The polyhouse farming included capsicum, cucumber and tomato with fertilizer and pesticide application it also includes addition

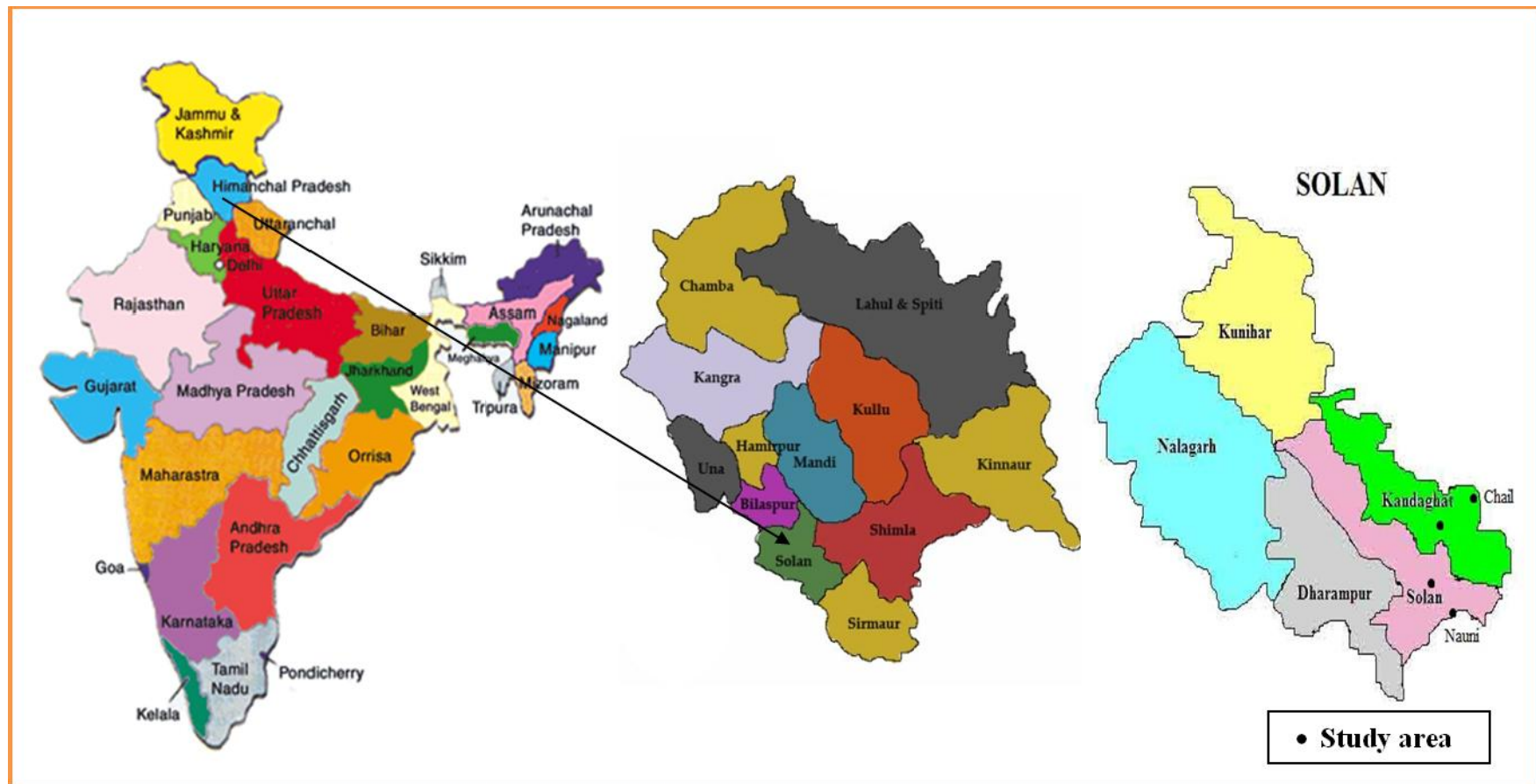


Figure 1. Map showing the study location in mid-hills of Solan district



Plate 1. Traditional farming system in mid hills of Himachal Pradesh



Plate 2. Organic farming system in mid hills of Himachal Pradesh



Plate 3. Polyhouse farming in mid hills of Himachal Pradesh



Plate 4. Vegetable farming in mid hills of Himachal Pradesh



Plate 5. Flower farming in mid hills of Himachal Pradesh



Plate 6. Orchard farming in mid hills of Himachal Pradesh

of organic inputs. The commercial vegetable farming system was composed of intensive cropping of cabbage, cauliflower, capsicum, tomato, peas etc with fertilizer and pesticide application three times a year. The flower farming includes gladiolus, carnation and gerbera and the commercial orchard was composed of apple, apricot, plum, peach and walnut crops with fertilizer application once in a year. In commercial polyhouse, vegetable, flower and orchards injudicious use of pesticides is also practised in the region. Among the selected farming systems polyhouse, vegetable and flower farming systems were noticed to be high input based farming systems.

Treatments:

- T₁: Traditional farming (control)
- T₂: Organic farming
- T₃: Poly house farming
- T₄: Vegetable farming
- T₅: Flower farming
- T₆: Orchard farming

Replications : 4 (location)

Design: Randomized Block Design

3.3 COLLECTION OF SAMPLES AND LABORATORY ANALYSIS

3.3.1 Soil Samples

The soil samples from surface layer (0 to 15 cm) were collected by using tube auger from all selected farming systems during October month. The soil samples were dried in shade and grounded using wooden pestle and mortar. The grounded soils were passed through 2 mm sieve and stored in polythene bags for subsequent analysis.

3.3.2 Soil analysis

The soil samples were analysed for the following physico-chemical and biological properties:

1. Soil organic carbon
2. Soil pH, EC and porosity
3. Available N P K S contents
4. Exchangeable soil nutrients (Ca and Mg)

5. Heavy metals (Zn, Cu, Mn, Pb, Cd, Cr, Fe)
6. Phosphatase and Dehydrogenase enzyme
7. Soil microbial count and biomass carbon
8. Soil Quality Index (SQI)

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

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} .

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 Particle Density: The particle density of the soil was determined by standard pycnometer method.

Porosity: The porosity was determined by using values of bulk density and particle density as per empirical formula given below:

$$\begin{aligned}\text{Porosity} &= (1 - \text{BD}/\text{PD}) \times 100 \\ \text{BD} &= \text{Bulk Density} \\ \text{PD} &= \text{Particle Density}\end{aligned}$$

Available Nitrogen: The available nitrogen in soil was determined by alkaline potassium permanganate method of Subbiah and Asija (1956).

Available Phosphorus: The soil available phosphorus was estimated by Olsen's method using 0.5 N NaHCO_3 as extractant (Olsen *et al.*, 1954) and determined colorimetrically by stannous chloride reduced ammonium molybdate method in HCL system (Jackson, 1973).

Available Potassium: The soil available potassium was analysed by using neutral normal ammonium acetate solution as extractant (Merwin and Peach, 1951).

Available Calcium: The soil available calcium was estimated by using neutral normal Ammonium acetate solution as extractant (Merwin and Peach, 1951).

Available Magnesium: The available Magnesium was analysed by using neutral normal ammonium acetate solution as extractant (Merwin and Peach, 1951).

Available Sulphur: Estimation of available sulphur was done by turbidimetric method by using 0.15% of CaCl_2 as extractant (Williams and Steinbergs, 1959).

Heavy metals: To analyze the heavy metals viz., Zn, Cu, Mn, Pb, Cd, Cr, Fe 0.5g of soil sample was digested in nitric acid and hydrogen peroxide mixture following US-EPA 3050 B method (APHA, 2005). The concentration of heavy metals was estimated by using ICP Spectrometer (model- ICAP 6300 duo) of Thermo Scientific make. The concentration was expressed as mg kg^{-1} .

Phosphatase Activity: The phosphatase enzyme estimation was carried out by method given by Tabatabai and Bremner (1969). One gram of soil taken in test tube was incubated with 1ml of 5 mM buffered sodium p-nitrophenyl phosphate in acetate buffer (pH 5.2) and 0.3 ml toluene at 37 °C for 1 hour. Determination of p-nitrophenol involved the colorimetric analysis of the extract obtained by treating the incubated soil sample with 4 ml water, 10 ml of 0.5 M NaOH and by filtering it through Whatman no. 42 filter paper. The suspension was obtained by shaking the mixture for 1 minute and absorbance of yellow colour of p-nitrophenol released was determined spectrophotometrically at 420 nm wavelength. The standard curve was prepared by p-nitrophenol (10-100 ppm). The result was expressed as μ mole of p-nitrophenol released per gram soil per hour ($\mu\text{mole p-nitrophenol g}^{-1}\text{soil h}^{-1}$).

Dehydrogenase activity: The dehydrogenase enzyme estimation was carried out by method given by Casida *et al.* (1964). One gram of air - dried soil taken in air-tight screw capped test tube was incubated with 0.2 ml of 3 per cent 2, 3, 5 – Triphenyl tetrazolium chloride (TTC) and 0.5 ml of 1per cent glucose solution at $28 \pm 0.5^\circ\text{C}$ for 24 h. Add 10 ml of methanol and allow to stand for 6 h. Withdraw clear pink coloured supernatant liquid and take readings with a spectrophotometer at a wavelength of 485

nm (blue filter). Extrapolate Triphenyl Formazen (TPF) formed from the standard curve drawn in the range of 10 to 90 mg TPF ml⁻¹. The result was expressed as mg TPF formed per h per g soil.

Total microbial count: The total microbial count estimation was carried out by method given by (Subba Rao, 1999). One gram of soil mixture was taken in 9 ml of sterilized water blank and the soil suspension was diluted in 10 fold series, then microbial counts was determined by standard pour plate technique on different media. The population was expressed as colony forming units per gram of soil (cfu/g soil).

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

Soil Quality Index

In order to develop soil quality index first step is the selection of critical soil quality indicators. A total of 21 physical, chemical and biological indicators were selected and were reduced to minimum data set using Principal Component Analysis (PCA). Data was reduced to a minimum data set through a series of univariate and multivariate statistical methods. One way Analysis of Variances (ANOVA) was used to identify indicators with significant treatment differences. Only variables with significant difference among treatments ($P < 0.05$) were chosen for next step in MDS formation. A standardized PCA was performed for each statistically significant variable (Bhardwaj *et al.*, 2011). Principal components receiving high Eigenvalues >1 and variables with high factor loading best represent factor loading (Brejda *et al.*, 2000). High factor loading refers to an absolute value within 10% of the highest factor loading, were selected and subjected to varimax rotation to maximize correlation between PCs and the measured attributes. Within each PC only components with high factor loading were initially retained for SQI. However, when more than one variable was retained under a particular PC, Pearson's correlation matrix was used to determine the correlation coefficients between the parameters. Significantly correlated parameters having $p < 0.05$ and highest loading factor was retained in the MDS and all others were eliminated to avoid redundancy as suggested by Mukherjee and Lal (2014). After selection of MDS, each observed value of indicator is transformed using linear scoring function into unit less values ranging between 0-1, called as indicator

scores (S) and were calculated as follows: Indicators were ranked in ascending or descending order depending upon whether a higher value is considered ‘beneficial’ or ‘detrimental’. For ‘higher is better’ indicators, each observation value was divided by highest observed value such that the highest observed value received the score 1. For ‘lower is better’ indicators, the lowest observed value was divided by each observation such that the lowest observed value received a score of 1. For those indicators where neither higher is better nor lower is better, observations were scored as ‘higher is better’ up to a threshold and then scored as ‘lower is better’ above the threshold value (Liebig *et al.*, 2001).

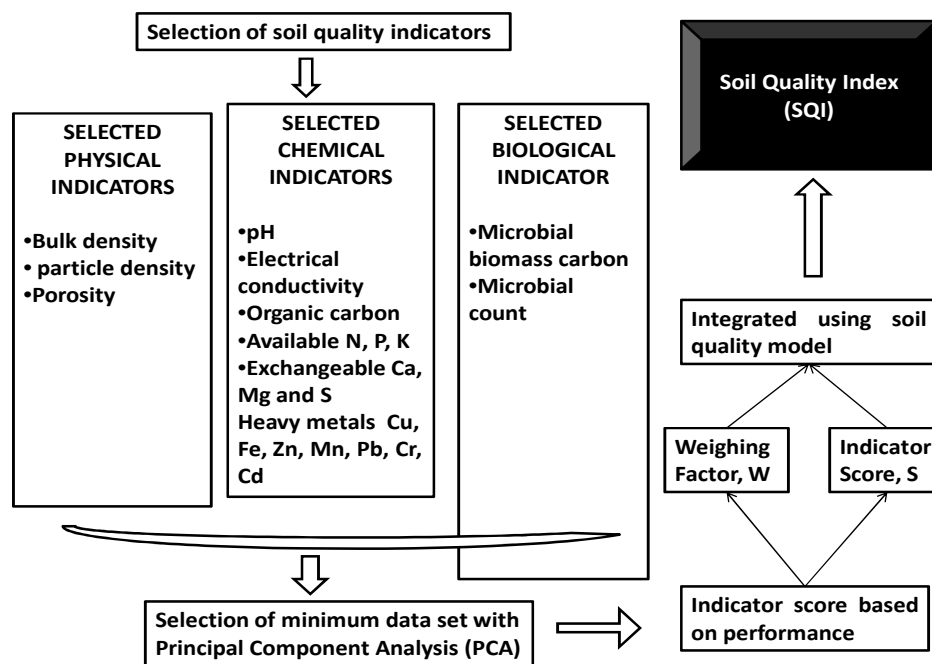


Figure 2. Conceptual framework for soil quality index

Since, some indicators have great influence than others on soil quality; therefore, the scores were multiplied by a weighing factor before taking their averages. The MDS variables for each observation were weighted using PCA results. The Per cent of variation of each PC was divided by total percentage of variation explained by all PCs with Eigenvectors >1.0 to obtain weighted factor (W) for variables chosen under a given PC. The scored indicators for each observation were summed by the following equation;

$$SQI = \sum_{i=1}^n (W_i S_i)$$

Where, S was the score of the indicator, and W the weighted factor derived through PCA. Higher scores were assumed to give the best soil quality. The calculated SQI values were tested for their significance at $p < 0.05$ by ANOVA. The selection of MDS and the PCA for SQI development were conducted using SPSS version 21.0 (SPSS 2014).

3.3.3 Water Samples

Water samples from surface and groundwater sources under adjoining farming systems were collected during the month of October. pH, EC, Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) of the samples were analyzed immediately after collection by standard methods (APHA, 2012). The water samples were preserved for quality analysis by adding 1 ml concentrated nitric acid and keeping the temperature at below 4°C but above freezing to avoid microbial utilization of heavy metals as per APHA (2005) procedure.

3.3.4 Water analysis

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

1. pH
2. EC
3. BOD
4. COD
5. Turbidity
6. Chloride
7. Heavy metals (Cd, Cr, Pb, Fe, Zn,)
8. Carbonates and Bicarbonates

Water pH: It was determined directly by taking sample water in a 100 ml beaker and using pH meter model 510 of EIA make to make the measurement.

Water EC: It was determined directly by taking water sample in a 100 ml beaker and using EC meter model 1601 of EIA make to make the measurement.

Biological Oxygen Demand (BOD): BOD was estimated by using 5 day BOD test as per 5210B method (APHA, 2005). The pH of the water samples was adjusted between 6.5- 7.5 range. Water sample (152 ml) was taken in BOD bottle and 5-6 drops of nitrification inhibitor was added and stirred properly. Gasket was kept in BOD bottle, and 3-4 drops of KOH solution were added and sensors were attached to the BOD bottle by using BOD system oxi-direct (Aqualytic make). Then BOD bottles were loaded in the system and kept in the incubator for five days at 20 ° C. BOD readings were recorded after five days and expressed as mg l⁻¹.

Chemical Oxygen Demand (COD): The COD was estimated by oxidizing water samples with hot H₂SO₄ and potassium dichromate with silver sulphate as the catalyst. The water sample was digested at 148 °C in preheated thermometer (TR 320) for 120 minutes. Subsequently, the concentration of Cr³⁺ ions was determined photometrically by using spectroquant pharo 300 (Merck make) instrument and expressed as mg l⁻¹.

Turbidity: Turbidity was determined by standard Nephelometric method (APHA, 1998).

Chloride: Chloride was estimated by using standard method (EPA 325.1). The method is also similar to APHA 4500.Cl.E (APHA, 1998).

Nitrates: The nitrate in the water samples was estimated by using standard method (APHA, 1998), where concentrated sulphuric acid (H₂SO₄) and nitrate ions were made to react with benzoic acid derivative which form red nitro compound. The intensity of coloured complex formed was determined photometrically using spectroquant pharo 300 (Merck make) and expressed in mg/l.

Carbonates and Bicarbonates: The carbonates and bicarbonates in water were determined by titrating it with standard H₂SO₄ using phenolphthalein and methyl orange as indicators given by Sing *et al.* (2005).

Heavy Metals (Zn, Pb, Cd, Cr and Fe): The water samples were first filtered using whatman filter paper (No. 1). The heavy metals were estimated using Inductively Coupled Plasma Emission Spectrometer (ICAP-6300 Duo) and expressed as mg l⁻¹.

3.4 INTERPRETATION OF DATA

The standards given by various workers were used to discuss soil organic carbon and available NPK and exchangeable Ca, Mg and available S content in Table 1 and Table 2. While the results of soil accumulation of heavy metals under different farming systems were discussed using following WHO standards prescribed for soil (Table 3). Similarly, the drinking water standards used to discuss results on impact of farming systems on water quality are given in Table 4.

Table 1: Critical limits for SOC and available NPK in soil

Nutrient elements	Soil fertility classes			References
	Low	Medium	High	
Organic carbon(%)	< 5	5-10	>10	Bhandari and Tripathi (1979)
N(kg ha ⁻¹)	< 280	280-560	>560	FAI (1977)
P(kg ha ⁻¹)	< 10	10-24.6	>24.6	FAI (1977)
K(kg ha ⁻¹)	< 98.6	98.6-280	>280	FAI (1977)

Table 2: Critical limits for exchangeable Ca, Mg and available S

Nutrient elements	Deficient	Sufficient	References
Available Ca [cmol (p ⁺)kg ⁻¹]	<1.5	>1.5	Tandon (1989)
Available Mg [cmol (p ⁺)kg ⁻¹]	<1.0	>1.0	Tandon (1989)
Available S (mg kg ⁻¹)	<10.0	>10.0	Tandon (1989)

Table 3: Permissible limits for heavy metals (mg kg⁻¹) in soil

Metal	Highest permissible level	Maximum permissible level
Pb	0.05	0.1
Cd	0.005	0.01
Zn	5.0	15
Mn	3.5	6
Cu	0.05	1.5
Fe	0.1	0.3
Cr	0.02	0.05

Source: Ekpete (2013) and Rahaman *et al.* (2013)

Table 4: permissible limits of drinking water quality parameters

Parameter	Permissible limit	Source
pH	6.5-8.5	IS 10500 : 2012
EC (dS m ⁻¹)	0.7	IS 10500 : 2012
BOD (mg l ⁻¹)	5	WHO, 1993
COD (mg l ⁻¹)	20	ICMR, 1975
Turbidity (NTU)	10	WHO, 1993
Nitrate (mg l ⁻¹)	45	IS 10500 : 2012
Chloride (mg l ⁻¹)	250	IS 10500 : 2012
Fe (mg l ⁻¹)	0.3	IS 10500 : 2012
Lead (mg l ⁻¹)	0.10	IS 10500 : 2012
Cadmium (mg l ⁻¹)	0.01	WHO, 1993
Chromium (mg l ⁻¹)	0.05	IS 10500 : 2012
Zinc (mg l ⁻¹)	5	IS 10500 : 2012

3.5 STATISTICAL ANALYSIS

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

RESULTS AND DISCUSSION

The results obtained from the present investigation entitled **“Effect of chemicalized farming on environmental quality in mid-hills of Himachal Pradesh”** are described and discussed under the following headings.

- 4.1 Physico-chemical and biological properties of soil under farming systems of mid hills
- 4.2 Soil available nutrients and heavy metal build up in soils
- 4.3 Soil quality index
- 4.4 Water quality status

4.1 PHYSICO-CHEMICAL AND BIOLOGICAL PROPERTIES OF SOIL UNDER DIFFERENT FARMING SYSTEMS OF MID HILLS

4.1.1 Soil physical properties

The soil under different farming systems exhibited bulk density in the range of 1.13 to 1.33 Mg m⁻³ (Table 5). The highest bulk density of 1.33 Mg m⁻³ was observed in soils under vegetable farming system which was statistically at par with that of flower farming (1.31 Mg m⁻³). Significantly, lowest bulk density of 1.13 Mg m⁻³ was observed in case of organic farming system. The soil bulk density distribution under different farming systems in mid hills of Himachal Pradesh was: vegetable (1.33 Mg m⁻³) > flower (1.31 Mg m⁻³) > traditional (1.26 Mg m⁻³) > orchard (1.23 Mg m⁻³) > polyhouse (1.17 Mg m⁻³) > organic (1.13 Mg m⁻³). The lowest bulk density of soil under organic farming system may be ascribed to addition of relatively higher FYM and organic materials like crop residue and through crop rotation as compared to other systems. Relatively higher bulk density under vegetable, flower, traditional, and orchard farming as compared to organic farming may be due to soil compaction caused by regular and intensive tillage operations which might have resulted in loss of organic matter through increased decomposition. In mid hills of Himachal Pradesh, Bhardwaj *et al.* (2010) has also noticed lower soil bulk density under organic based

inputs. The results are also in agreement with the findings of Coote and Ramasy (1983), Gajda *et al.* (2015) and Sharma *et al.* (1995).

The data on the status of particle density under different farming systems have been presented in Table 5. The perusal of data revealed that particle density ranged from 2.33 Mg m⁻³ to 2.37 Mg m⁻³ under different farming systems. The highest particle density of 2.37 Mg m⁻³ was observed in orchard and flower farming which was statistically at par with vegetable and polyhouse farming. Significantly, the lowest particle density of 2.33 Mg m⁻³ was observed in soils under organic farming system. The soil particle density distribution under different farming system was in the order of: orchard and flower (2.37 Mg m⁻³) > vegetable and polyhouse (2.36 Mg m⁻³) > traditional (2.35Mg m⁻³) > organic (1.13 Mg m⁻³). This variation may be ascribed to organic matter and low bulk density status of respective soils. Under different conditions, almost same values of particle density were noticed. The meagre variation in particle density under different conditions may be attributed to addition of the organic matter and tillage practices as advocated by Hillel (1980) and Fayissa *et al.* (2015).

Table 5. Physical properties of soil under different farming systems in mid hills of Himachal Pradesh.

Farming systems	Bulk density (Mg m⁻³)	Particle density (Mg m⁻³)	Porosity (%)
Traditional	1.26	2.35	46.37
Organic	1.13	2.33	51.59
Polyhouse	1.17	2.36	50.17
Vegetable	1.33	2.36	43.73
Flower	1.31	2.37	44.74
Orchard	1.23	2.37	48.53
CD_{0.05}	0.03	0.01	1.27

Soil porosity under different farming systems ranged from 43.73% to 51.59 %. Significantly, highest soil porosity of 51.59% was observed under organic farming system. Whereas, lowest of 43.73% was observed in vegetable farming system. The trend of soil porosity distribution under different farming systems as indicated by data presented in table 5 was: organic (51.59 %) > polyhouse (50.17%) > orchard (48.53%) > traditional (46.37%) > flower (44.74%) > vegetable (43.73%). The highest porosity of surface soil in different farming system was because of more addition of

FYM in the organic and polyhouse farming. These results are in conformity with the findings of Brady and Weil (2002) and Veiga *et al.* (2008) who have also noticed that tillage increased total porosity and macroporosity, and reduced bulk density during the initial period, but this effect decreased over time due to soil compaction.

4.1.2 Soil physico-chemical properties

A perusal of data presented in Table 6 indicated that farming systems of mid hills of Himachal Pradesh has exerted a significant impact on soil pH which was in the range of 6.38 to 6.98. The soils under organic farming systems registered highest pH of 6.98 which was statistically at par with traditional farming (6.83). However, soil under polyhouse registered lowest pH of 6.38. The soils under different farming system followed the trend: organic (6.98) > traditional agriculture (6.83) > flower (6.74) > orchard (6.55) > vegetable (6.55) > polyhouse (6.38). The perusal of data presented in Table 6 indicated that under all farming systems pH was in normal to slightly acidic range. Amongst the selected farming systems the lowest soil pH of 6.38 under polyhouse farming may be ascribed to regular application of acidic fertilizer like urea. The results are in line with the findings of Loria *et al.* (2016) and Gajda *et al.* (2015).

In mid hills of Himachal Pradesh the soils under all selected farming systems was found to have soil EC in the range of 0.25 to 0.38 dSm⁻¹ which is in normal range (Table 6). Significantly, highest electrical conductivity (0.38 dS m⁻¹) was noticed under polyhouse farming which was statistically at par with EC under vegetable farming (0.37 dSm⁻¹). However, significantly, lowest value of EC (0.25 dS m⁻¹) was observed under organic farming. The soil EC under different farming systems followed the trend of: polyhouse (0.38 dSm⁻¹) > vegetable (0.37 dSm⁻¹) > flower (0.34 dSm⁻¹) > orchard (0.33 dSm⁻¹) > traditional (0.29 dSm⁻¹) > organic (0.25 dSm⁻¹). The normal range of EC has also been reported by Loria *et al.* (2015) in agricultural soils of Himachal Pradesh which may be because of light textured well drained soils.

The soil organic carbon under selected farming systems of the region exhibited variation from 1.24 to 2.41% (Table 6). Significantly, highest soil organic carbon of 2.41% was observed in organic farming system. However, lowest soil organic carbon of 1.24% was observed under vegetable farming system which was however, statistically at par with flower farming (1.33%). The soil organic carbon

under different farming system followed the trend of: organic (2.41%) > polyhouse (1.83%) > orchard (1.77%) > traditional (1.46%) > flower (1.33%) > vegetable (1.24%). The highest value of soil organic carbon under organic farming may be attributed to the application of FYM and other organic inputs with optimum C: N ratio. The lowest soil organic carbon under vegetable farming system may be ascribed to rapid decomposition of organic materials due to intensive cultivation. Similar results were also reported by Bhardwaj *et al.* (2010), Bodruzzaman *et al.* (2002) and Gajda *et al.* (2015).

Table 6. Physico-chemical properties of soil under different farming systems in mid hills of Himachal Pradesh

Farming systems	pH	EC (dSm ⁻¹)	Organic carbon (%)
Traditional	6.83	0.29	1.46
Organic	6.98	0.25	2.41
Polyhouse	6.38	0.38	1.83
Vegetable	6.54	0.37	1.24
Flower	6.74	0.34	1.33
Orchard	6.55	0.33	1.77
CD _{0.05}	0.15	0.03	0.11

4.1.3 Impact of farming systems on microbiological properties of soil

A perusal of the data presented in table 7 indicated that bacterial count under different farming systems of mid hills of Himachal Pradesh ranged from 67.25×10^5 to 92.67×10^5 cfu/g soil. Significantly, the highest bacterial counts of 92.67×10^5 cfu/g soil were recorded under organic farming which were, however, statistically at par with polyhouse (91.92×10^5 cfu/g soil) and orchard farming (89.50×10^5 cfu/g soil). The lowest bacterial counts of 67.25×10^5 cfu/g soil were recorded under vegetable which were also statistically, at par with flower farming (71.17×10^5 cfu/g soil). Bacterial counts under different farming systems followed a trend of: organic (92.67×10^5 cfu/g soil) > polyhouse (91.92×10^5 cfu/g soil) > orchard (89.50×10^5 cfu/g soil) > traditional (80.08×10^5 cfu/g soil) > flower (71.17×10^5 cfu/g soil) > vegetable (67.25×10^5 cfu/g soil). The maximum bacterial counts under organic farming may be attributed to high status of organic carbon which act as food for microbes and further its oxidation as sources of energy. These findings are in line with the findings of Bhardwaj *et al.* (2010) who reported predominance of bacteria count under mid hill condition of

Himachal Pradesh in agricultural fields having high organic carbon. Low bacterial counts recorded under intensive farming systems like vegetable based may be due to addition of chemical fertilizer and pesticides. The present results corroborate the findings of Lin *et al.* (2004) who have also reported that overuse of nitrogen, phosphatic fertilizers and pesticides by influencing soil physico-chemical properties caused degradation of microbial properties under continuous vegetable cultivated soils. Similar observations were also recorded by Bhardwaj *et al.* (2010), Das and Mukherjee (1990) and Jain *et al.* (2003).

A perusal of data presented in Table 7 represented that fungal counts under different farming systems of mid hills of Himachal Pradesh ranged from 4.75×10^4 to 8.17×10^4 cfu/g soil. Significantly, the highest fungal count of 8.17×10^4 cfu/g soil were recorded under organic farming which however, were statistically, at par with polyhouse farming (7.50×10^4 cfu/g soil). The lowest fungal counts of 4.75×10^4 cfu/g soil were recorded under traditional and were statistically at par with flower farming (5.50×10^4 cfu/g soil). Fungal counts under different farming systems followed the trend of: organic (8.17×10^4 cfu/g soil) > polyhouse (7.50×10^4 cfu/g soil) > vegetable (6.83×10^4 cfu/g soil) > orchard (6.5×10^4 cfu/g soil) > flower (5.5×10^4 cfu/g soil) > traditional (4.75×10^4 cfu/g soil). The fungal counts were higher in organic farming this may be due to higher organic carbon content in soil. These findings are in line with the findings of Bhardwaj *et al.* (2010) and Varga *et al.* (2008).

It is evident from data presented in Table 7 that actinomycetes counts under different farming systems of mid hills of Himachal Pradesh ranged from 29.17×10^3 cfu/g soil to 41.17×10^3 cfu/g soil. Significantly, the highest actinomycetes counts of 41.17×10^3 cfu/g soil were recorded under organic farming. The lowest counts of 29.17×10^3 cfu/g soil were recorded under flower farming which were, however, statistically at par with vegetable farming (30.25×10^3 cfu/g soil). Actinomycetes counts under different farming systems of mid hills followed the trend of: organic (41.17×10^3 cfu/g soil) > polyhouse (38.58×10^3 cfu/g soil) > orchard (34.33×10^3 cfu/g soil) > traditional (31.58×10^3 cfu/g soil) > vegetable (30.25×10^3 cfu/g soil) > flower (29.17×10^3 cfu/g soil). The lower actinomycetes counts in flower farming may be ascribed to excess application of fertilizers. These findings are in line with the findings of Bhardwaj *et al.* (2010) and Jain *et al.* (2003) who reported higher

actinomycetes counts under organic farming because of no chemical application and high status of organic matter in soil.

Soil microbial biomass carbon under different farming systems of mid hills of Himachal Pradesh showed a wide variation from 310.69 to 459.63 $\mu\text{g kg}^{-1}$ indicating their direct impact on soils (Table 7). Significantly highest soil microbial biomass of 459.63 $\mu\text{g kg}^{-1}$ was observed in soils under organic farming which was statistically at par with polyhouse farming (436.83 $\mu\text{g kg}^{-1}$). However, flower farming registered with significantly lowest microbial biomass of 310.69 $\mu\text{g kg}^{-1}$ which was statistically at par with traditional farming (319.6 $\mu\text{g kg}^{-1}$). The trend of soil microbial biomass distribution under different farming systems was: organic (459.63 $\mu\text{g kg}^{-1}$) > polyhouse (436.83 $\mu\text{g kg}^{-1}$) > orchard (361.69 $\mu\text{g kg}^{-1}$) > vegetable (347.71 $\mu\text{g kg}^{-1}$) > traditional (319.61 $\mu\text{g kg}^{-1}$) > flower (310.69 $\mu\text{g kg}^{-1}$). The richness of soil microbial biomass carbon under organic farming may be ascribed to higher status of soil organic carbon as compared to other systems and absence of chemical inputs. Further, excessive use of fertilizers and pesticides in vegetable and flower farming systems might have contributed to lower soil microbial biomass. The results are in line with the observations of Ford *et al.* (2007), Ullah *et al.* (2013) and Quinones *et al.* (2011).

Phosphatase catalyzes the hydrolysis of both esters and anhydrides of orthophosphate anions. Major part of the phosphorus is organically bound and its fractions also vary from soil to soil. The perusal of data presented in Table 7 indicated that phosphatase activity under different farming systems ranged from 1.09 to 3.62 $\mu\text{g g}^{-1} \text{ hr}^{-1}$. Significantly, highest value of 3.62 $\mu\text{g g}^{-1} \text{ hr}^{-1}$ was observed under polyhouse farming system. The lowest value of 1.09 $\mu\text{g g}^{-1} \text{ hr}^{-1}$ was observed under flower farming which was statistically at par with traditional farming (1.36 $\mu\text{g g}^{-1} \text{ hr}^{-1}$). The phosphatase activity under different farming system followed the trend: polyhouse (3.62 $\mu\text{g g}^{-1} \text{ hr}^{-1}$) > organic (2.54 $\mu\text{g g}^{-1} \text{ hr}^{-1}$) > orchard (2.16 $\mu\text{g g}^{-1} \text{ hr}^{-1}$) > vegetable (1.46 $\mu\text{g g}^{-1} \text{ hr}^{-1}$) > traditional (1.36 $\mu\text{g g}^{-1} \text{ hr}^{-1}$) > flower (1.09 $\mu\text{g g}^{-1} \text{ hr}^{-1}$). The data further revealed that the farming systems which received the combined application of organics and in-organics gave highest phosphatase activity, followed by organic. This may be due to monoesters and diesters of phosphate, which act as a substrate for the phosphatase activity are available from the inorganic treatment and secondly the addition of organic sources maintained the continuity of addition of organic to inorganic form, so the substrate of phosphorus i.e. monoesters and diesters are

continuously available and caused the phosphatase activity. Similar results were also obtained by Gajendra (2014), Beknazarov (2002) and Liang *et al.* (2003).

The dehydrogenase activity under different farming systems varied from 2.86 to 4.30 $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$ (Table 7). Significantly highest dehydrogenase activity of 4.30 $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$ was observed in organic farming which was statistically at par with orchard farming (3.99 $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$). Whereas, lowest of 2.86 $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$ was observed in traditional farming which was statistically at par with flower farming (2.97 $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$). The trend of dehydrogenase activity under different farming system was: organic (4.30 $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$) > orchard (3.99 $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$) > polyhouse (3.77 $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$) > vegetable (3.15 $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$) > flower (2.97 $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$) > traditional (2.86 $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$). The dehydrogenase activity under different substitution of organics increased the concentration of substrate which resulted in increase in the dehydrogenase activity in soil and followed the first order reactions meaning thereby the activity of enzyme is proportional to the concentration of the substrate (Mark 1999). The results are in line with the observations of Gajendra, (2014), Park *et al.* (1998) and Manna and Ganguly (2001).

Table 7. Microbiological properties of soil under different farming systems in mid hills of Himachal Pradesh

Farming systems	Total microbial count			Microbial biomass carbon ($\mu\text{g/g}$)	Phosphatase enzyme ($\mu\text{g g}^{-1} \text{hr}^{-1}$)	Dehydrogenase enzyme ($\mu\text{g TPF g}^{-1} \text{hr}^{-1}$)
	Bacteria ($\times 10^5 \text{cfu/g soil}$)	Fungi ($\times 10^4 \text{cfu/g soil}$)	Actinomycetes ($\times 10^3 \text{cfu/g soil}$)			
Traditional	80.08	4.75	31.58	319.61	1.36	2.86
Organic	92.67	8.17	41.17	459.63	2.54	4.30
Polyhouse	91.92	7.50	38.58	436.83	3.62	3.77
Vegetable	67.25	6.83	30.25	347.71	1.46	3.15
Flower	71.17	5.50	29.17	310.69	1.09	2.97
Orchard	89.50	6.50	34.33	361.69	2.16	3.99
CD_{0.05}	7.57	1.27	2.66	26.72	0.29	0.50

4.2 SOIL AVAILABLE NUTRIENTS AND HEAVY METAL BUILD UP IN SOILS

4.2.1 Status of available NPK status

Perusal of data presented in Table 8 revealed that farming systems of mid hills of Himachal Pradesh have influenced the soil available NPK nutrient status. The soil available nitrogen in the soil ranged from 291.74 to 416.25 kg ha^{-1} , which falls under medium category. Significantly, highest buildup of available nitrogen (416.25 kg ha^{-1}) was registered in soils under polyhouse farming, whereas, and lowest of 291.74 kg ha^{-1}

¹ was observed under traditional agriculture which was however, statistically at par with orchard farming (295.12 kg ha⁻¹). Among the different farming systems of mid hills, nitrogen followed the trend of: polyhouse (416.25 kg ha⁻¹) > vegetable (398.54 kg ha⁻¹) > organic (379.73 kg ha⁻¹) > flower (362.45 kg ha⁻¹) > orchard (295.12 kg ha⁻¹) > traditional (291.74 kg ha⁻¹). Significantly higher build up of available nitrogen in soils under polyhouse and vegetable farming may be attributed to regular additions of nitrogenous fertilizers and relatively higher application of organic manures. The results are in line with the findings of Bhardwaj *et al.* (2010) and Verma and Tripathi (1982) who have reported available nitrogen in the range of 295 to 503 kg ha⁻¹ in soils of Kangra, Mandi, Bilaspur, Shimla and Sirmour of Himachal Pradesh. Degryze *et al.* (2004) have also reported increase in available nitrogen build up in soils under vegetable farming system due to continuous fertilization.

Data presented in Table 8 revealed that available phosphorus in soil of different farming systems of mid hills of Himachal Pradesh ranged from 21.64 to 38.41 kg ha⁻¹ which was in medium to high range. Significantly, highest available phosphorus of 38.41 kg ha⁻¹ was observed under polyhouse farming system. The lowest value of available phosphorus of 21.64 kg ha⁻¹ was observed in traditional farming. The available phosphorus under different farming system followed the trend: polyhouse (38.41 kg ha⁻¹) > vegetable (36.25 kg ha⁻¹) > organic (32.21 kg ha⁻¹) > orchard (31.22 kg ha⁻¹) > flower (24.94 kg ha⁻¹) > traditional (21.64 kg ha⁻¹). The highest build up of soil available phosphorus content recorded under polyhouse following vegetable farming may be ascribed to regular application of high dosage of FYM and phosphate fertilizers. The results are in agreement with the findings of Bhardwaj *et al.* (2010) and Maurya and Ghosh (1972). Bhardwaj and Omanwar (1994) reported that continuous cropping without fertilization decreased the P content of soil to a considerable extent while the well fertilized plot showed an increase in soil nutrient.

Scrutiny of data presented in Table 8 further showed that the available potassium under different farming systems of mid hills of Himachal Pradesh was in the range of 309.08 to 408.23 kg ha⁻¹. The soil available potassium was observed to be highest under polyhouse farming (408.23 kg ha⁻¹). Whereas, it was found to be lowest under flower farming (309.08 kg ha⁻¹) which was statistically at par with traditional (310.17 kg ha⁻¹) and orchard farming (320.18 kg ha⁻¹). The trend of available potassium under different farming systems was: polyhouse (408.23 kg ha⁻¹) >

vegetable (364.72 kg ha⁻¹) > organic (339.59 kg ha⁻¹) > orchard (320.18 kg ha⁻¹) > traditional (310.17 kg ha⁻¹) > flower (309.08 kg ha⁻¹). Comparatively higher potassium contents in the soils under polyhouse and vegetable farming systems may be attributed to regular addition of heavy dose of K containing inorganic fertilizers. These findings are in confirmation with the findings of Bhardwaj *et al.* (2010), Loria *et al.* (2016) and Verma *et al.* (1985) who reported that the available potassium content of different soils of Himachal Pradesh varied from 40.26 to 1507 kg ha⁻¹.

Table 8. Distribution of available NPK (kg ha⁻¹) in soils under different farming systems in mid hills of Himachal Pradesh.

Farming systems	N	P	K
Traditional	291.74	21.64	310.17
Organic	379.73	32.21	339.59
Polyhouse	416.25	38.41	408.23
Vegetable	398.54	36.25	364.72
Flower	362.45	24.94	309.08
Orchard	295.12	31.22	320.18
CD _{0.05}	19.51	2.745	25.91

4.2.2 Status of exchangeable Ca and Mg and available sulphur

Data presented in Table 9 depicted that exchangeable calcium in soils of different farming systems ranged from 3.71 to 7.40 cmol (p+)/kg. Amongst different farming systems significantly highest calcium content of 7.40 cmol (p+)/kg was noticed under Polyhouse farming. The lowest value of calcium was observed inorganic farming [3.71 cmol (p+)/kg] which was statistically at par with flower farming [4.31 cmol (p+)/kg]. The values of calcium under different farming system followed the trend of: polyhouse [7.40 cmol (p+)/kg] > vegetable [6.17 cmol (p+)/kg] > orchard [5.30 cmol (p+)/kg] > traditional [5.13 cmol (p+)/kg] > flower [4.31 cmol (p+)/kg] > organic [3.71 cmol (p+)/kg]. The higher concentration of calcium under polyhouse conditions may be attributed to regular addition of complex fertilizers. Singh *et al.* (1991) also reported higher exchangeable Ca content due to addition of more fertilizer in cultivated soils of North-West Himalayas.

The exchangeable magnesium in soils under selected farming systems of the region exhibited variations from 1.35 to 2.24 cmol (p+)/kg (Table 9). Significantly, highest magnesium content of 2.24 cmol (p+)/kg was observed under polyhouse

farming. However, the lowest value was observed under vegetable farming [1.35 cmol (p+)/kg]. Interestingly all the farming systems were statistically at par with each other. The trend of magnesium under different farming system was: polyhouse [2.24cmol (p+)/kg] > flower [2.23 cmol (p+)/kg] > orchard [2.13 cmol (p+)/kg] > traditional [1.93 cmol (p+)/kg] > organic [1.90 cmol (p+)/kg] > vegetable [1.35cmol (p+)/kg]. Higher values may be attributed to the nutrient management practices followed by the farmers of the area and also to the calcareous parent material. Similar results were also reported by Gupta and Tripathi (1989). Kaistha and Gupta (1993) also reported the comparable values for exchangeable magnesium in the soils of Himachal Pradesh [0.1 to 4.2 cmol (p⁺) kg⁻¹].

Data presented in Table 9 reveled that available sulphur in soil ranged from 42.07 to 56.60 kg h⁻¹ amongst different farming systems of mid hills of Himachal Pradesh. Significantly highest available sulphur of 56.06 kg ha⁻¹ was exhibited under Polyhouse farming. The lowest value of available sulphur was observed in traditional farming (42.07 kg ha⁻¹) which was statistically at par with flower farming (43.28kg ha⁻¹). Under different farming systems available sulphur followed the trend of: polyhouse (56.60kg ha⁻¹) > vegetable (51.26kg ha⁻¹) > organic (51.07kg ha⁻¹) > orchard (49.63kg ha⁻¹) > flower (43.28 kg ha⁻¹) > traditional (42.07 kg ha⁻¹). Comparatively higher value is attributed to the use of insecticides, pesticides (dithane and microsol) and subsequent addition of organic matter. These findings are in line with the findings of Sharma *et al.* (2001).

Table 9. Distribution of exchangeable Ca, Mg and available S in soils under different farming systems in mid hills of Himachal Pradesh.

Farming systems	Ca (cmol (p+)/kg)	Mg (cmol (p+)/kg)	S (kg ha ⁻¹)
Traditional	5.13	1.93	42.07
Organic	3.71	1.90	51.06
Polyhouse	7.40	2.24	56.60
Vegetable	6.17	1.35	51.26
Flower	4.31	2.23	43.28
Orchard	5.30	2.13	49.63
CD _{0.05}	0.83	0.64	4.85

4.2.3 Heavy metal build up in soil

A perusal of the data presented in Table 10 indicated that iron in soils under different farming systems ranged from 13.64 to 23.08 mg kg⁻¹. Significantly, highest

iron content of 23.08 mg kg⁻¹ was noticed in soils under vegetable system which was statistically at par with polyhouse farming (21.04 mg kg⁻¹). The lowest value of iron was observed in soils under organic farming (13.64 mg kg⁻¹) which was statistically at par with orchard and traditional with their respective value of 14.91 mg kg⁻¹ and 15.02 mg kg⁻¹. The iron content under different farming systems followed the trend of: vegetable (23.08 mg kg⁻¹) > polyhouse (21.04 mg kg⁻¹) > flower (15.71 mg kg⁻¹) > traditional (15.02 mg kg⁻¹) > orchard (14.91 mg kg⁻¹) > organic (13.64 mg kg⁻¹). Long-term application of inorganic fertilizers might also have contributed towards building up of Fe in soils under different farming systems. Further, the contaminants of commercial fertilizers, particularly phosphate ones might have also contributed towards their higher concentration as reported by Raven and Loeppert (1997) and Hazarika *et al.* (2014). Similar trends of iron were also reported by Tripathi *et al.* (1994) and Sharma and Chaudhary (2007) in soils of Himachal Pradesh.

A perusal of data presented in Table 10 indicated that different farming systems of mid hills of Himachal Pradesh have exerted a significant impact on accumulation of zinc which ranged from 2.05 to 3.68 mg kg⁻¹. Significantly, highest zinc of 3.68 mg kg⁻¹ was observed in polyhouse farming. While lowest available zinc was exhibited by traditional farming (2.05 mg kg⁻¹). The zinc in different farming systems followed the trend of: polyhouse (3.68 mg kg⁻¹) > organic (3.07 mg kg⁻¹) > vegetable (2.93 mg kg⁻¹) > flower (2.39 mg kg⁻¹) > orchard (2.18 mg kg⁻¹) > traditional (2.05 mg kg⁻¹). The highest zinc content may be due to application of fertilizers such as SSP. These findings are in agreement with the findings Mortvedt and Beaton (1995) who reported that P- fertilizers were among the sources of zinc input into agricultural systems. The results are in agreement with the findings of Tripathi *et al.* (1994).

Data presented in table 10 depicted that manganese in soils amongst different farming systems ranged from 4.13 to 9.99 mg kg⁻¹. Significantly, highest Mn of 9.99 mg kg⁻¹ was observed under vegetable farming. The lowest value of Mn was recorded in soils under organic farming (4.13 mg kg⁻¹). The Mn content under different farming systems followed the trend: vegetable (9.99 mg kg⁻¹) > polyhouse (9.20 mg kg⁻¹) > orchard (8.34 mg kg⁻¹) > flower (6.25 mg kg⁻¹) > traditional (6.01 mg kg⁻¹) > organic (3.07 mg kg⁻¹). The highest accumulation of Mn under vegetable farming may be

ascribed to Long-term application of inorganic fertilizers to the soils. These findings are in line with findings of Thakur (1986).

A Perusal of data presented in Table 10 revealed that copper under different farming systems of mid hills of Himachal Pradesh ranged from 1.74 to 6.11 mg kg⁻¹. Significantly, highest copper of 6.11 mg kg⁻¹ was observed under vegetable farming. While the lowest copper was noticed under organic farming (1.74 mg kg⁻¹). Copper under different farming systems followed the trend of: vegetable (6.11 mg kg⁻¹) > polyhouse (4.86 mg kg⁻¹) > orchard (4.35 mg kg⁻¹) > flower (3.84mg kg⁻¹) > traditional (3.33mg kg⁻¹) > organic (1.74 mg kg⁻¹). Application of inorganic fertilizers and copper sulphate might have contributed towards building up of Cu in the vegetable fields. The observations are in line with those of Bhandari (1973), Thakur and Bhandari (1986) and Sharma and Chaudhary (2007) who have also noticed enhanced level of copper under intensive farming systems of the state.

Scrutiny of data presented in Table 10 revealed that lead under soils of different farming systems of mid hills of Himachal Pradesh ranged from 0.81 to 2.48 mg kg⁻¹. Significantly, highest lead content of 2.48 mg kg⁻¹ was noticed under vegetable farming system. The lowest value of lead was observed in organic farming (0.81 mg kg⁻¹). The lead content in soils of different farming system followed the trend: vegetable (2.48 mg kg⁻¹) > polyhouse (2.05mg kg⁻¹) > flower (1.77mg kg⁻¹) > orchard (1.54mg kg⁻¹) > traditional (1.14 mg kg⁻¹) > organic (0.81 mg kg⁻¹). The highest accumulation of heavy metals in soil under the vegetable farming may be ascribed to regular application of chemical fertilizers and pesticides. The results are in conformity with findings of Muhammad *et al.* (2011), Krami *et al.* (2013), Chao *et al.* (2014) and Nazir *et al.* (2015).

A perusal of data presented in Table 10 revealed that chromium content in different farming systems of mid hills of Himachal Pradesh ranged from 0.05 to 0.54 mg kg⁻¹. Significantly, highest chromium of 0.54 mg kg⁻¹ was registered under vegetable farming system. However, lowest chromium was observed in organic farming (0.05 mg kg⁻¹). The trend of chromium content under different farming systems was: vegetable (0.54 mg kg⁻¹) > polyhouse (0.32 mg kg⁻¹) > flower (0.25 mg kg⁻¹) > orchard (0.21 mg kg⁻¹) > traditional (0.10 mg kg⁻¹) > organic (0.05 mg kg⁻¹). High chromium concentration in vegetable and polyhouse farming system might be

due to herbicide, pesticide and fertilizer application. The results are in line with the findings of O'Neill (1995), Atafar *et al.* (2010) and Yargholi and Azarneshan (2014).

Cadmium in soils under different farming systems in mid hills of Himachal Pradesh exhibited variation from 0.08 to 0.35 mg kg⁻¹ (Table 10). The soils under vegetable farming registered the highest Cd content of 0.35 mg kg⁻¹. However, the significantly lowest value was observed under organic farming (0.08 mg kg⁻¹). The trend of cadmium under different farming system was: vegetable (0.35 mg kg⁻¹) > orchard (0.25 mg kg⁻¹) > polyhouse (0.21 mg kg⁻¹) > flower (0.19 mg kg⁻¹) > traditional (0.15 mg kg⁻¹) > organic (0.08 mg kg⁻¹). Manure, fertilizer and atmospheric deposition are major cadmium sources that lead to Cd accumulation in agricultural soils McLaughlin *et al.* 2007. Excessive use of phosphate fertilizers such as single super phosphate might have contributed to excessive concentration of cadmium in soils under vegetable and orchard land uses. The results are in agreement with the outcomes of the study conducted by Ju *et al.* (2006).

Table 10. Heavy metal build up in soils under different farming systems of mid hills of Himachal Pradesh

Farming systems	Heavy metals (mg kg ⁻¹)						
	Fe	Zn	Mn	Cu	Pb	Cr	Cd
Traditional	15.02	2.05	6.01	3.33	1.14	0.10	0.15
Organic	13.64	3.07	4.13	1.74	0.81	0.05	0.08
Polyhouse	21.04	3.68	9.20	4.86	2.05	0.32	0.21
Vegetable	23.08	2.93	9.99	6.11	2.48	0.54	0.35
Flower	15.71	2.39	6.25	3.84	1.77	0.25	0.19
Orchard	14.91	2.18	8.34	4.35	1.54	0.21	0.25
CD_{0.05}	2.04	0.45	0.67	0.48	0.12	0.03	0.04

4.3 SOIL QUALITY INDEX

In order to develop soil quality index, a total of 21 physical, chemical and biological indicators were selected (Fig 3.1) and were reduced to minimum data set using Principal Component Analysis (PCA). Comparison of treatment means through ANOVA revealed that out of 21 soil indicators, all the parameters showed significant differences among treatments. All the indicators with significant differences were selected for PCA from Table 11. In the PCA using these indicators, three PCs had

Table 11: Soil properties used for the minimum data set (MDS) selection process

	BD	PD	Porosity	pH	EC	OC	N	P	K	Ca	Mg	S	Zn	Cu	Mn	Pb	Fe	MB	B	F	AM
V	1.33	2.37	43.73	6.54	0.36	1.24	398.54	36.25	364.72	6.12	3.09	22.90	2.93	6.10	10.01	2.47	23.08	347.71	67.25	6.83	30.25
F	1.31	2.38	44.75	6.74	0.33	1.33	362.45	24.94	309.07	4.30	2.23	19.56	2.39	3.83	6.25	1.76	15.71	310.69	71.17	5.50	29.17
O	1.22	2.38	48.53	6.55	0.33	1.77	295.11	31.22	320.18	5.30	2.13	22.59	2.18	4.35	8.34	1.53	14.91	361.69	89.50	6.50	34.33
P	1.15	2.36	50.17	6.38	0.38	1.83	416.25	38.41	408.23	7.4	2.93	25.38	3.68	4.86	9.20	2.05	21.03	436.83	91.92	7.50	38.58
T	1.26	2.35	46.37	6.83	0.29	1.46	291.74	21.64	310.17	5.12	1.92	18.92	2.05	3.33	6.01	1.13	15.01	319.61	80.08	4.75	31.58
O	1.18	2.33	51.59	6.98	0.24	2.41	379.73	32.21	339.59	3.70	1.90	23.89	3.07	1.74	4.13	.81	13.64	459.63	92.67	8.17	41.17
P<α^b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00

Eigenvalues > 1 and explained 85 percent of the variance in data (Table 12). The highly weighted variables under PC1, falling within 10 percent of highest weight of factor loading, were copper, manganese and lead. The rotated factor loadings of copper, manganese, and lead were 0.955, 0.901, and 0.969, respectively. Interestingly, all these indicators were highly correlated with each other (Table 13), therefore in order to avoid redundancy in indicator selection only lead was selected on the basis of its higher factor loading of 0.969. In PC2, microbial biomass, zinc and sulphur showed highest weighted value and they were highly correlated with each other therefore only microbial biomass was selected for MDS. Particle density, available nitrogen and bacterial counts showed highest weighted values respectively in PC3. However in these three indicators only nitrogen was positively and other two were negatively correlated therefore, nitrogen and particle density was selected for MDS (Table 13). Accordingly, the final MDS was composed of lead, microbial biomass, nitrogen and particle density.

Table 12: Factor loading/ eigenvectors of significant soil quality indicators

Parameter	Component		
	1	2	3
pH	-0.783	-0.343	0.423
Ec	0.872	0.153	-0.187
organic carbon	-0.739	0.622	-0.056
Bulk density	0.466	-0.720	0.383
partical density	0.536	-0.467	-0.535
Porosity	-0.611	0.690	-0.317
Nitrogen	0.365	0.669	0.562
Phosphorus	0.410	0.832	0.038
Potassium	0.394	0.772	0.093
Calcium	0.700	0.435	-0.294
Magnesium	0.702	0.359	0.163
Sulphur	0.106	0.849	-0.038
Zinc	0.205	0.856	0.262
Cu	0.955	0.033	-0.122
Mn	0.901	0.214	-0.238
Pb	0.969	0.104	0.061
Fe	0.840	0.345	0.184
MB	-0.368	0.881	0.049
Bacteria	-0.555	0.594	-0.513
Fungi	-0.116	0.732	0.241
Actinomycetes	-0.517	0.771	-0.109
Statistical parameters			
Eigenvalues	9.30	7.70	1.70
% of Variance	42.29	35.02	7.75
Cumulative (%)	42.29	77.30	85.05
Extraction Method: Principal Component Analysis			
a. Factor loadings are considered highly weighted when within 10% of Variation of the absolute values of the highest factor loading in each PC			

Table 13: Pearson's correlation matrix among soil properties under different farming systems of mid hills

	pH	Ec	OC	BD	PD	Por	N	P	K	Ca	Mg	S	Zn	Cu	Mn	Pb	Fe	MB	B	F	A
pH	1																				
Ec	-.88**	1																			
OC	.34	-.52**	1																		
BD	.02	.19	-.77**	1																	
PD	-.48*	.50*	-.60**	.41*	1																
Por	.08	-.39	.89**	-.93**	-.48*	1															
N	-.28	.35	.11	-.14	-.35	.09	1														
P	-.57**	.46*	.28	-.35	-.16	.32	.72**	1													
K	-.51**	.48*	.17	-.35	-.23	.23	.69**	.72**	1												
Ca	-.82**	.70**	-.27	-.097	.18	-.04	.35	.57**	.61**	1											
Mg	-.62**	.51**	-.34	.12	.12	-.20	.57**	.56**	.43*	.60**	1										
S	-.39	.23	.45*	-.54**	-.27	.51*	.51**	.75**	.62**	.35	.43*	1									
Zn	-.38	.28	.33	-.46*	-.40	.40	.82**	.73**	.74**	.41*	.55**	.76**	1								
Cu	-.77**	.80**	-.69**	.37	.54**	-.52**	.26	.44*	.38	.70**	.66**	.14	.14	1							
Mn	-.84**	.84**	-.49*	.19	.47*	-.35	.29	.60**	.49*	.78**	.63**	.27	.21	.92**	1						
Pb	-.73**	.87**	-.64**	.382	.482*	-.52**	.48*	.49*	.45*	.65**	.68**	.22	.29	.93**	.87**	1					
Fe	-.69**	.66**	-.42*	.21	.12	-.30	.62**	.64**	.63**	.76**	.75**	.27	.47*	.81**	.79**	.84**	1				
MB	.06	-.19	.81**	-.80**	-.62**	.80**	.51*	.61**	.49*	.11	.06	.68**	.64**	-.31	-.12	-.23	.01	1			
B	.03	-.31	.80**	-.85**	-.29	.89**	-.08	.22	.20	.04	-.22	.42*	.25	-.44*	-.26	-.55**	-.33	.71**	1		
F	-.06	.03	.59**	-.37	-.43*	.43*	.53**	.60**	.59**	.13	.06	.62**	.57**	-.09	.01	-.02	.12	.67**	.33	1	
Am	.10	-.37	.84**	-.81**	-.58**	.87**	.25	.41*	.36	.03	-.07	.58**	.52**	-.43*	-.27	-.41*	-.15	.86**	.79**	.55**	1

Soil quality index

In order to calculate SQI, first, the selected MDS variables were transformed into scores ranging from 0 to 1. Out of these significant indicators selected for MDS, soil microbial biomass was considered as ‘higher is better’, whereas other three indicators, available nitrogen, particle density and lead having optimum values with critical limits were used for scoring and were considered as ‘higher is better’ up to a threshold and then scored as ‘lower is better’ in case they exceeded the threshold value. The second component of SQI is weighted factors. Weighted factors were derived from the PCA. The percent variation in the data set explained by the PC that contributed toward the indicated variable was divided by the total percentage of variation explained by all PCs with Eigenvector >1 as per data presented in Table 12, to derive the coefficient of weighing factor.

Table 14: Soil quality index for different farming systems of mid hills of Himachal Pradesh and their classification

Farming systems	Mean	Std. Deviation	Std. Error	Soil quality classification
Traditional	0.45	0.02	0.01	Poor
Organic	0.60	0.01	0.00	Medium
Polyhouse	0.56	0.00	0.00	Medium
Vegetable	0.47	0.02	0.01	Poor
Flower	0.44	0.02	0.01	Poor
Orchard	0.48	0.01	0.00	Poor
P<α^b	0.00			

Accordingly, soil indicator values were transformed into scores and finally SQI rating for different land uses was developed on the scale of 0 to 1 using weighing factors derived from the PCA and data are presented in Table 14. The data indicated that selected farming systems of mid hills of Himachal Pradesh have exerted significant influence on the soil quality. The SQI for different farming systems ranged from 0.44 to 0.60. The organic farming registered the highest SQI of (0.60) followed by polyhouse (0.56), orchard (0.48), vegetable (0.47), traditional (0.45) and flower (0.44), the results indicated that the soil quality of organic and polyhouse farming systems was found to be medium in quality rating category ($0.50 < \text{SQI} < 0.75$) and all the remaining systems were found to fall under poor quality rating ($\text{SQI} < 0.50$) as per the classification of Xu *et al.* (2006). Injudicious application of fertilizers and pesticides in agricultural fields might have resulted in deterioration of soil quality in

the said farming systems but in traditional farming as there is no chemical application but resulted in poor quality this may be attributed to poor management practices like there is no addition of organic matter, tillage practices and nutrients.

4.4 WATER QUALITY STATUS UNDER MID HILLS FARMING SYSTEMS

Perusal of data presented in Table 15 revealed that different farming systems in mid hills of Himachal Pradesh have exerted a significant effect on water properties such as electrical conductivity, BOD and COD except for pH. The electrical conductivity of water sources under farming systems ranged from 0.24 to 0.40 dSm⁻¹ which was in permissible limit as prescribed by WHO (2011) and BIS which is 40 dS m⁻¹ for EC in drinking water. Significantly, highest electrical conductivity was observed under vegetable farming system (0.40 dSm⁻¹) which was statistically at par with flower farming (0.38 dSm⁻¹). Minimum EC was observed under organic farming system (0.24 dSm⁻¹) and the remaining was significantly different with each other. Relatively, higher EC under vegetable and flower farming system can be ascribed to accumulation of more salts in water sources which could be due to fertilizer application in these farming systems. Similar results were observed by Rana (2016) who reported high electrical conductivity under farming systems in Solan district of Himachal Pradesh.

Biochemical oxygen demand of water sources around different farming systems in mid hills of Himachal Pradesh ranged from 0.78 to 1.63 mg l⁻¹ (Table 15). It is evident from the data that the BOD of water sources is within the permissible limits (5 mg l⁻¹) as prescribed by WHO (1993) in drinking water. Significantly, highest BOD was observed under vegetable farming system (1.63 mg l⁻¹) followed by organic (1.61 mg l⁻¹), flower (1.55 mg l⁻¹), orchard (1.38 mg l⁻¹) and traditional (1.35 mg l⁻¹) which was statistically at par with each other. However significantly lowest value (0.78 mg l⁻¹) was observed under polyhouse farming system. The highest BOD recorded under vegetable farming may be ascribed to release of organic waste which generally applied in relatively higher quantity. The lowest BOD of water sources under polyhouse farming system may be ascribed to negligible release of organic waste and frequent application of less quantity of water and fertigation to nearby water bodies because of complete controlled conditions. The present findings are in

line with the findings of Gupta *et al.* (2014) who reported highest BOD under high input farming systems like vegetable.

Chemical oxygen demand of water sources around selected farming systems in the mid hill region of Himachal Pradesh ranged between 17.50 to 32.53 mg l⁻¹ (Table 15). The data indicated that the COD values have exceeded the permissible limits of 20 mg l⁻¹ as prescribed by ICMR (1975) COD under all farming systems except organic farming system. Significantly, highest COD value was observed in the water sources around vegetable farming system (32.53 mg l⁻¹). Whereas, lowest COD was observed under organic farming system (17.50 mg l⁻¹). Increased level of chemical oxygen demand can be credited to the discharge of fertilizers, pesticides and insecticides from the adjoining high input based systems surrounding into the water body. Gupta *et al.* (2014) also reported that loads of organic and inorganic pollutants in water bodies as the cause of an increase of chemical oxygen demand under agriculture land use in Parwanoo area of Solan district of HP.

Table 15. Physical and chemical properties of water sources around selected farming systems in mid hills of Himachal Pradesh.

Farming systems	pH	EC (dSm ⁻¹)	BOD (mg l ⁻¹)	COD (mg l ⁻¹)
Traditional	7.75	0.29	1.35	20.28
Organic	7.71	0.24	1.61	17.50
Polyhouse	7.60	0.31	0.78	28.00
Vegetable	7.64	0.40	1.63	32.53
Flower	7.76	0.38	1.55	28.24
Orchard	7.63	0.36	1.38	27.91
CD _{0.05}	NS	0.02	0.48	2.67

The data presented in Table 16 evinced that chloride and nitrate concentration in water sources under different farming systems of mid hills of Himachal Pradesh showed a significant variation except for turbidity and bicarbonates. Chloride concentration in water bodies under different farming systems in mid hills of Himachal Pradesh ranged from 14.78 to 27.19 mg l⁻¹ which was within the permissible limits as prescribed by ICMR and WHO (200 mg l⁻¹) drinking water. However, highest chloride content (27.19 mg l⁻¹) was observed in the water sources falling around vegetable farming followed by polyhouse, flower and orchards with the respective values of 24.91, 23.83 and 22.96 mg l⁻¹ which were also statistically at par

to each other. However, significantly minimum chloride concentration of 14.78 mg l^{-1} was observed in the water sources under organic farming which was statistically at par with traditional farming (18.21 mg l^{-1}). Relatively high values of chloride in water samples around flower farming were due to application of fertilizers and pesticides in the region. These results corroborate the findings of Khound *et al.*(2012), Gupta *et al.* (2014) and Chauhan and Verma (2016) who also reported increased chloride concentration in water due to leachate of crop nutrients and fertilizers from adjacent cropping systems.

Nitrate concentration in water sources under different farming systems in mid hills of Himachal Pradesh ranged between 4.55 to 11.13 mg l^{-1} . It is evident from the data that water sources around selected farming system contain nitrate within the permissible limit. The water sources around vegetable farming system contained highest nitrate content of 11.13 mg l^{-1} among all the selected farming systems as prescribed by ICMR (1975) (permissible limit of 45 mg l^{-1} for nitrate in drinking water). However lowest nitrate concentration of 4.55 mg l^{-1} was observed under organic farming system. High nitrate content in the water may be due to excessive application of nitrogenous fertilizers, leaching and runoff of waste water or other organic waste from surrounding vegetable farms in to the water bodies (WHO 2006). These findings are in line with the findings of Gupta *et al.* (2014) and Chauhan and verma (2016) who reported high nitrate contents under agriculture land use in Parwanoo area of Solan district of Himachal Pradesh. High Nitrate level in vegetable farming system was also observed by Zhang *et al.* (2007) and Ion *et al.* (2016) and injudicious use of nitrogenous fertilizer was reported to be the cause.

Table 16. Physical and chemical properties of water sources under different farming systems in mid hills of Himachal Pradesh.

Farming systems	Turbidity (NTU)	Chloride (mg/l)	Nitrates (mg/l)	Bicarbonates (meq/l)
Traditional	2.16	18.21	8.03	6.03
Organic	1.33	14.78	4.55	6.08
Polyhouse	1.50	24.91	6.10	7.29
Vegetable	1.58	27.19	11.13	5.77
Flower	1.33	23.83	8.59	5.66
Orchard	1.33	22.96	9.59	6.02
CD_{0.05}	NS	5.63	0.82	NS

4.4.1 Status of heavy metals in water sources around selected farming systems

The iron content of water sources under different farming systems of mid hills of Himachal Pradesh ranged from 0.01 to 0.08 mg l⁻¹ (Table 17). It is evident that the Fe status of water sources around selected farming systems of mid hills was within permissible limit as prescribed by WHO (0.1 mg l⁻¹) and BSI (0.3 mg l⁻¹). Among the selected farming systems significantly, highest Fe content of 0.08 mg l⁻¹ was observed under vegetable farming system which was however, statistically at par with flower (0.07 mg l⁻¹) and polyhouse (0.06 mg l⁻¹) farming systems. The Lowest Fe content was observed under organic (0.01 mg l⁻¹) which was statistically at par with traditional farming system (0.03 mg l⁻¹). Elevated Fe concentrations in water sources was observed by Chauhan *et al.* (2014) and Rana *et al.* (2016) around high input farming systems in mid hill region of Himachal Pradesh.

Lead content of water sources ranged from 0.03 to 0.14 mg l⁻¹ under different farming systems in mid hills of Himachal Pradesh (Table 17). It is evident that the Pb status of water sources around selected farming systems of mid hills was beyond the permissible limit as prescribed by BSI (0.01mg l⁻¹). Maximum Pb content was observed under vegetable farming system (0.14 mg l⁻¹) which is at par with orchard (0.10 mg l⁻¹). Significantly lowest Pb content of water sources was observed around organic (0.03 mg l⁻¹) which is at par with traditional (0.06 mg l⁻¹) and polyhouse farming system (0.05 mg l⁻¹). These findings are in accordance with the study of Chauhan *et al.* (2014) who reported lead content in the range of 0.05 to 0.67 mg l⁻¹ under agriculture land use in Kandaghat block of Solan district of Himachal Pradesh.

Perusal of data presented in Table 17 depicted that Cd levels recorded in water sources falling around different selected farming systems ranged from 0.00 to 0.03 mg l⁻¹ which were slightly above the prescribed standards of BIS and WHO (0.01 and 0.005 mg l⁻¹) except for organic farming. Significantly, highest Cd concentration of 0.03 mg l⁻¹ was observed under vegetable farming. Interestingly no Cd was observed under organic farming (0.00 mg l⁻¹). The present results are in accordance with the findings of Chauhan *et al.* (2014) who reported cadmium content in the range of 0.01 to 0.04 ppb under different farming systems in Kandaghat block of Solan district in Himachal Pradesh. Similar to present findings McLaughlin *et al.* (1996) observed cadmium content in water bodies due to addition of phosphate fertilizers in

farm lands find its way to water bodies through runoff. These results are in line with the findings of Boyacioglu and Boyacipglu (2011) who reported that agricultural practice such as fertilization and use of fungicides are the causes of cadmium in surface water sources in Tahtali basin in Turkey.

Chromium content in water sources falling around different selected farming systems in mid hills of Himachal Pradesh ranged from 0.05 to 0.40 mg l⁻¹ (Table 17). It is evident that the Cr status of water sources was beyond the permissible limit (0.05 mg l⁻¹) prescribed by BIS and WHO. Significantly, highest Cr content of 0.40 mg l⁻¹ was observed under vegetable farming, however, lowest Cr content was observed under organic farming (0.05 mg l⁻¹) which was statistically at par with traditional farming (0.10 mg l⁻¹). The highest chromium content in water sources around different farming systems may be due to indiscriminate use of agrochemicals under intensive farming systems like vegetable, polyhouse and orchard which due to runoff might have reached the surface water bodies. The present findings corroborate the findings of Zuazo *et al.* (2011) who observed chromium content in agro ecosystems (orchards) and pointed out that agrochemicals to be the potential cause due to agricultural runoff.

Table 17. Heavy metal status of in water sources under different farming systems in mid hill of Himachal Pradesh.

Farming systems	Heavy metal (mg l ⁻¹)				
	Fe	Pb	Cd	Cr	Zn
Traditional	0.03	0.06	0.01	0.10	0.02
Organic	0.01	0.03	ND	0.05	0.07
Polyhouse	0.06	0.05	0.02	0.32	0.07
Vegetable	0.08	0.14	0.03	0.40	0.19
Flower	0.07	0.08	0.01	0.25	0.11
Orchard	0.04	0.10	0.02	0.21	0.09
CD_{0.05}	0.04	0.05	0.01	0.07	0.06

ND-not detected

Perusal of data presented in Table 17 depicted that Zn levels recorded in water sources falling around different selected farming systems ranged from 0.02 to 0.19 mg l⁻¹ which were within the permissible limits prescribed by BIS and WHO (5-3 mg l⁻¹). Significantly, highest Zn content of 0.19 mg l⁻¹ was observed in vegetable farming. The lowest Zn content was observed under traditional farming (0.02 mg l⁻¹) which was statistically at par with the organic farming (0.07mg l⁻¹) and polyhouse farming

systems (0.07 mg l^{-1}). The high zinc content of water source around vegetable farming system in water body may be due to agricultural runoff of chemical fertilizers. The present results are in accordance with the findings of Rana *et al.* (2016) and Chauhan *et al.* (2014) who reported zinc content in the range 0.00 to 0.03 ppb in water bodies under agriculture land use in Kandaghat block of Solan district of Himachal Pradesh.

Chapter-5

SUMMARY AND CONCLUSIONS

The present investigation entitled **“Effect of chemicalized farming on environmental quality in mid-hills of Himachal Pradesh”** was conducted during the year 2016- 2017 in the Department of Environmental Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The study was conducted to determine the impact of farming systems on soil and water quality. To conduct this study six farming systems namely; traditional, organic, polyhouse, vegetable, flower and orchard were selected in mid hills of Himachal Pradesh and these were considered as treatments and replicated four times under Randomized block design. In order to determine the effect of farming systems on soil physico-chemical and biological properties, the effect was also assessed on water quality parameters like pH, EC, BOD, COD, nitrates, chlorides, turbidity, carbonates, bicarbonates and heavy metals.

SOIL QUALITY

Soil physico- chemical properties

- Soil bulk density under selected farming systems ranged from 1.13 to 1.33 Mg m⁻³ and followed the trend: vegetable (1.33 Mg m⁻³) > flower (1.31 Mg m⁻³) > traditional (1.26 Mg m⁻³) > orchard (1.23 Mg m⁻³) > polyhouse (1.17 Mg m⁻³) > organic (1.13 Mg m⁻³).
- Soil particle density ranged from 2.33 Mg m⁻³ to 2.37 Mg m⁻³ under different farming systems. The trend of soil particle density distribution was: orchard (2.37 Mg m⁻³) > flower (2.37 Mg m⁻³) > vegetable (2.36 Mg m⁻³) > polyhouse (2.36 Mg m⁻³) > traditional (2.35 Mg m⁻³) > organic (1.13 Mg m⁻³).
- Soil porosity under different farming systems ranged from 43.73 % to 51.59 %. The trend of soil porosity distribution was: organic (51.59 %) > polyhouse (50.17 %) > orchard (48.53 %) > traditional (46.37 %) > flower (44.74 %) > vegetable (43.73 %).

- The soil pH was in the range of 6.38 to 6.98. The soil pH under different farming system followed the trend: organic (6.98) > traditional agriculture (6.83) > flower (6.74) > orchard (6.55) > vegetable (6.55) > polyhouse (6.38).
- In mid hills of Himachal Pradesh, the soils under all selected farming systems were found to have soil EC in the range of 0.25 to 0.38 dSm⁻¹. The soil EC under different farming systems followed the trend of: polyhouse (0.38 dSm⁻¹) > vegetable (0.37 dSm⁻¹) > flower (0.34 dSm⁻¹) > orchard (0.33 dSm⁻¹) > traditional (0.29 dSm⁻¹) > organic (0.25 dSm⁻¹).
- Soil organic carbon ranged from 1.24 to 2.41 %. The farming system wise trend of soil organic carbon distribution in soil was: organic (2.41 %) > polyhouse (1.83 %) > orchard (1.77 %) > traditional (1.46 %) > flower (1.33 %) > vegetable (1.24 %).

Impact of farming systems on microbiological properties of soil

- In soils under different farming systems bacterial, fungal and actinomycetes counts ranged from 67.25×10⁴ to 92.67×10⁴ cfu/g soil, 4.75×10³ to 8.17×10³ cfu/g soil and 29.17×10⁴ to 41.17×10⁴ cfu/g soil.
- Soil microbial biomass carbon under different farming systems showed a contrasting variation from 310.69 to 459.63 µg kg⁻¹ and followed the trend of: organic (459.63 µg kg⁻¹) > polyhouse (436.83 µg kg⁻¹) > orchard (361.69 µg kg⁻¹) > vegetable (347.71 µg kg⁻¹) > traditional (319.61 µg kg⁻¹) > flower (310.69 µg kg⁻¹).
- The phosphatase and dehydrogenase activity under different farming systems ranged from 1.09 to 3.62 µg g⁻¹ hr⁻¹ and 2.86 to 4.30 µg TPF g⁻¹ hr⁻¹, respectively.

Impact of farming systems on soil available and exchangeable nutrients

- Available nitrogen in the soil ranged from 291.74 to 416.25 kg ha⁻¹, which falls under medium category. Among the different farming systems Available nitrogen followed the trend: polyhouse (416.25 kg ha⁻¹) > vegetable (398.54 kg ha⁻¹) > organic (379.73 kg ha⁻¹) > flower (362.45 kg ha⁻¹) > orchard (295.12 kg ha⁻¹) > traditional (291.74 kg ha⁻¹).
- Available phosphorus in soils of different farming systems ranged from 21.64 to 38.41 kg ha⁻¹ which falls under medium to high category. Farming system

wise available phosphorus followed the trend of: polyhouse (38.41 kg ha⁻¹) > vegetable (36.25 kg ha⁻¹) > organic (32.21 kg ha⁻¹) > orchard (31.22 kg ha⁻¹) > flower (24.94 kg ha⁻¹) > traditional (21.64 kg ha⁻¹).

- Available potassium under different farming systems was observed in the range of 309.08 to 408.23 kg ha⁻¹ and was in high category. The available potassium followed the trend of: polyhouse (408.23 kg ha⁻¹) > vegetable (364.72 kg ha⁻¹) > organic (339.59 kg ha⁻¹) > orchard (320.18 kg ha⁻¹) > traditional (310.17 kg ha⁻¹) > flower (309.08 kg ha⁻¹).
- Exchangeable calcium, magnesium and available sulphur in soils of different farming systems ranged from 3.71 to 7.40 cmol (p+)/kg, 1.35 to 2.24 cmol (p+)/kg and 42.07 to 56.60 kg ha⁻¹ all three were found in sufficient range.

Heavy metal build up in soil

- The soil iron under selected farming systems of mid hills ranged from 13.64 to 23.08 mg kg⁻¹ which was above the permissible limit. The soil iron content under different farming systems followed the trend of: vegetable (23.08 mg kg⁻¹) > polyhouse (21.04 mg kg⁻¹) > flower (15.71 mg kg⁻¹) > traditional (15.02 mg kg⁻¹) > orchard (14.91 mg kg⁻¹) > organic (13.64 mg kg⁻¹).
- The soil zinc under different farming systems of mid hills of Himachal Pradesh ranged from 3.68 to 2.05 mg kg⁻¹ which was within the permissible limit. The farming system wise soil zinc followed the trend of: polyhouse (3.68 mg kg⁻¹) > organic (3.05 mg kg⁻¹) > vegetable (2.93 mg kg⁻¹) > flower (2.39 mg kg⁻¹) > orchard (2.18 mg kg⁻¹) > traditional (2.05 mg kg⁻¹).
- Manganese in soil ranged from 4.93 to 9.99 mg kg⁻¹ and its content was above the permissible limit. The manganese content under different farming systems followed the trend of: vegetable (9.99 mg kg⁻¹) > polyhouse (9.20 mg kg⁻¹) > orchard (8.34 mg kg⁻¹) > flower (6.25 mg kg⁻¹) > traditional (6.01 mg kg⁻¹) > organic (3.07 mg kg⁻¹).
- The soil Copper ranged from 6.11 to 1.74 mg kg⁻¹ which was above the permissible limit and followed the trend of: vegetable (6.11 mg kg⁻¹) > polyhouse (4.86 mg kg⁻¹) > orchard (4.35 mg kg⁻¹) > flower (3.84 mg kg⁻¹) > traditional (3.84 mg kg⁻¹) > organic (1.74 mg kg⁻¹).

- The lead concentration in soils under different farming systems of mid hills of Himachal Pradesh ranged from 0.81 to 2.48 mg kg⁻¹ and it was above the permissible limit. The trend of lead under different farming systems was: vegetable (2.48 mg kg⁻¹) > polyhouse (2.05 mg kg⁻¹) > flower (1.77 mg kg⁻¹) > orchard (1.54 mg kg⁻¹) > traditional (1.14 mg kg⁻¹) > organic (0.81 mg kg⁻¹).
- Chromium content ranged from 0.05 to 0.54 mg kg⁻¹ which was found to be above the permissible limit except the organic farming. The trend of chromium content under different farming system was: vegetable (0.54 mg kg⁻¹) > polyhouse (0.32 mg kg⁻¹) > flower (0.25 mg kg⁻¹) > orchard (0.21 mg kg⁻¹) > traditional (0.10 mg kg⁻¹) > organic (0.05 mg kg⁻¹).
- Cadmium content in soils ranged from 0.08 to 0.35 mg kg⁻¹ and was found to be above the permissible limit. The trend of cadmium under different farming system was: vegetable (0.35 mg kg⁻¹) > orchard (0.25 mg kg⁻¹) > polyhouse (0.21 mg kg⁻¹) > flower (0.19 mg kg⁻¹) > traditional (0.15 mg kg⁻¹) > organic (0.08 mg kg⁻¹).

Soil quality index

- The soil quality index under different farming systems of mid hills of Himachal Pradesh has exerted significant influence on the soil quality. The SQI for different farming systems ranged from 0.44 to 0.60. The organic farming registered the highest SQI of 0.60 followed by polyhouse (0.56), orchard (0.48), vegetable (0.47), traditional (0.45) and flower (0.44) and indicated that the soil quality of organic and polyhouse to be medium whereas, all the remaining systems were under poor in rating.

Water quality status under mid hill farming systems

- pH and EC of the water ranged from 7.63 to 7.76 and 0.24 to 0.40 dSm⁻¹, respectively and was within the normal and permissible range as prescribed by BIS for drinking water.
- The BOD and COD of the water ranged from 0.78 to 1.63 mg l⁻¹ and 17.50 to 32.53 mg l⁻¹, respectively. The values of BOD were within the permissible limit whereas, COD was beyond prescribed limit of WHO for drinking water.

- Turbidity and bicarbonates in water ranged from 1.33 to 2.16 NTU and 5.77 to 7.29 meq/l, respectively and were within the permissible limit as prescribed by WHO for drinking water.
- The water contents of chloride and nitrate ranged from 14.78 to 27.19 mg l⁻¹ and 4.55 to 11.13 mg l⁻¹, respectively, and the concentration of chloride and nitrates was within the permissible limit as prescribed by BSI for drinking water.
- The iron and lead concentration in water sources around different farming systems of mid hills of Himachal Pradesh ranged from 0.01 to 0.08 mg l⁻¹ and 0.03 to 0.14 mg l⁻¹, respectively, in water sources the iron was within the permissible limit whereas, lead was above the prescribed limit of WHO for drinking water.
- The concentration of cadmium and chromium in water was significantly influenced by farming systems. Cadmium and chromium in water ranged from 0.00 to 0.03 and 0.05 to 0.40 mg l⁻¹, respectively. The cadmium concentration was above the permissible limits as prescribed by BIS and WHO except for organic farming. While chromium was above the permissible limit in all the farming systems.
- Zn content amongst different farming systems in water ranged between 0.02 to 0.19 mg l⁻¹ and was within the permissible limit as prescribed by the BSI for drinking water.

CONCLUSIONS

In mid hills of Himachal Pradesh the commercial farming systems like vegetable, flower, orchard and even traditional farming system have started impacting physico- chemical and biological properties of the soils and ultimately resulted in poor soil quality index in comparison to organic and polyhouse farming where in soil quality was of medium category. The application of chemicals under different farming systems has also enhanced the heavy metal status beyond permissible limits. The addition of chemical inputs under such systems have also impacted quality of surrounding water sources by enhancing COD, BOD, nitrates, chlorides, and toxic element status. The study therefore, indicated that in mid hills of Himachal Pradesh there is urgent need to use of chemicals judiciously in farming or

adoption of alternative systems, like organic farming where in chemicals are not applied. This strategy may help in maintaining environmental quality on sustainable basis in this region.

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APPENDIX –I

Physical properties of soil under different farming systems in mid hills of Himachal Pradesh.

Analysis of variance table for Bulk density

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.005			
Treatment	5	0.103	0.021	54.111	0.00000
Error	15	0.006	0.000		
Total	23	0.113			

Analysis of variance table for particle density

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.000			
Treatment	5	0.006	0.001	24.342	0.00000
Error	15	0.001	0.000		
Total	23	0.007			

Analysis of variance table for Soil porosity

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	2.817			
Treatment	5	191.766	38.353	54.794	0.00000
Error	15	10.499	0.700		
Total	23	205.082			

Appendix –II

Physico- chemical properties of soil under different farming systems in mid hills of Himachal Pradesh

Analysis of variance table for Soil pH

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.017			
Treatment	5	0.971	0.194	18.225	0.00001
Error	15	0.160	0.011		
Total	23	1.148			

Analysis of variance table for EC

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.001			
Treatment	5	0.049	0.010	25.864	0.00000
Error	15	0.006	0.000		
Total	23	0.056			

Analysis of variance table for soil organic carbon

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.040			
Treatment	5	3.706	0.741	138.150	0.00000
Error	15	0.080	0.005		
Total	23	3.827			

Appendix-III

Microbiological properties of soil under different farming systems in mid hills of Himachal Pradesh

Analysis of variance table for bacterial counts

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	9.633			
Treatment	5	2,427.619	485.524	19.581	0.00000
Error	15	371.943	24.796		
Total	23	2,809.196			

Analysis of variance table for fungal counts

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	7.162			
Treatment	5	31.764	6.353	9.000	0.00041
Error	15	10.588	0.706		
Total	23	49.514			

Analysis of variance table for actinomycetes counts

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	25.160			
Treatment	5	462.188	92.438	30.012	0.00000
Error	15	46.200	3.080		
Total	23	533.548			

Analysis of variance table for microbial biomass

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	677.303			
Treatment	5	76,319.110	15,263.822	49.433	0.00000
Error	15	4,631.688	308.779		
Total	23	81,628.100			

Analysis of variance table for phosphatase enzyme

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.179			
Treatment	5	17.825	3.565	99.023	0.00000
Error	15	0.540	0.036		
Total	23	18.544			

Analysis of variance table for dehydrogenase enzyme

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.149			
Treatment	5	7.070	1.414	13.006	0.00005
Error	15	1.631	0.109		
Total	23	8.850			

Appendix-IV

Distribution of available NPK (kg ha⁻¹) in soils under different farming systems in mid hills of Himachal Pradesh.

Analysis of variance table for available Nitrogen

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	381.600			
Treatment	5	55,482.593	11,096.519	67.384	0.00000
Error	15	2,470.132	164.675		
Total	23	58,334.326			

Analysis of variance table for available Phosphorus

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	10.721			
Treatment	5	832.390	166.478	51.089	0.00000
Error	15	48.879	3.259		
Total	23	891.990			

Analysis of variance table for available Potassium

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	3,683.045			
Treatment	5	29,927.578	5,985.516	20.613	0.00000
Error	15	4,355.585	290.372		
Total	23	37,966.209			

Appendix-V

Distribution of exchangeable Ca, Mg and available S in soils under different farming systems in mid hills of Himachal Pradesh.

Analysis of variance table for exchangeable calcium

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.618			
Treatment	5	34.714	6.943	23.034	0.00000
Error	15	4.521	0.301		
Total	23	39.853			

Analysis of variance table for exchangeable magnesium

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	1.491			
Treatment	5	5.319	1.064	6.004	0.00304
Error	15	2.658	0.177		
Total	23	9.467			

Analysis of variance table for available sulphur

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	2.930			
Treatment	5	592.729	118.546	11.632	0.00010
Error	15	152.869	10.191		
Total	23	748.528			

APPENDIX-VI

Heavy metal build up in soils under different farming systems of mid hills of Himachal Pradesh

Analysis of variance table for iron

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	9.363			
Treatment	5	296.792	59.358	32.729	0.00000
Error	15	27.204	1.814		
Total	23	333.359			

Analysis of variance table for zinc

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.113			
Treatment	5	7.798	1.560	17.349	0.00001
Error	15	1.348	0.090		
Total	23	9.259			

Analysis of variance table for manganese

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.700			
Treatment	5	99.375	19.875	100.597	0.00000
Error	15	2.964	0.198		
Total	23	103.038			

Analysis of variance table for copper

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.149			
Treatment	5	43.576	8.715	84.930	0.00000
Error	15	1.539	0.103		
Total	23	45.264			

Analysis of variance table for lead

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.023			
Treatment	5	7.344	1.469	210.338	0.00000
Error	15	0.105	0.007		
Total	23	7.472			

Analysis of variance table for chromium

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.002			
Treatment	5	0.620	0.124	342.678	0.00000
Error	15	0.005	0.000		
Total	23	0.628			

Analysis of variance table for cadmium

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.005			
Treatment	5	0.168	0.034	49.359	0.00000
Error	15	0.010	0.001		
Total	23	0.183			

APPENDIX- VII

Physical and chemical properties of water sources around selected farming systems in mid hills of Himachal Pradesh.

Analysis of variance table for pH

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.076			
Treatment	5	0.092	0.018	0.692	0.63720
Error	15	0.398	0.027		
Total	23	0.566			

Analysis of variance table for EC

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.002			
Treatment	5	0.070	0.014	44.232	0.00000
Error	15	0.005	0.000		
Total	23	0.076			

Analysis of variance table for BOD

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.303			
Treatment	5	2.022	0.404	4.033	0.01611
Error	15	1.504	0.100		
Total	23	3.829			

Analysis of variance table for COD

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	6.952			
Treatment	5	640.130	128.026	41.379	0.00000
Error	15	46.410	3.094		
Total	23	693.492			

APPENDIX –VIII

Physical and chemical properties of water sources under different farming systems in mid hills of Himachal Pradesh.

Analysis of variance table for Turbidity

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.153			
Treatment	5	2.534	0.507	2.679	0.06356
Error	15	2.838	0.189		
Total	23	5.525			

Analysis of variance table for chlorides

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	21.638			
Treatment	5	424.860	84.972	6.190	0.00264
Error	15	205.900	13.727		
Total	23	652.398			

Analysis of variance table for nitrates

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.765			
Treatment	5	112.727	22.545	76.678	0.00000
Error	15	4.410	0.294		
Total	23	117.902			

Analysis of variance table for bicarbonates

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	2.816			
Treatment	5	6.933	1.387	0.248	0.93417
Error	15	83.743	5.583		
Total	23	93.492			

APPENDIX- IX

Heavy metal build up in water sources under different farming systems in mid hill of Himachal Pradesh.

Analysis of variance table for iron

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.000			
Treatment	5	0.018	0.004	4.304	0.01254
Error	15	0.013	0.001		
Total	23	0.031			

Analysis of variance table for lead

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.000			
Treatment	5	0.034	0.007	5.197	0.00577
Error	15	0.020	0.001		
Total	23	0.053			

Analysis of variance table for cadmium

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.000			
Treatment	5	0.002	0.000	7.501	0.00105
Error	15	0.001	0.000		
Total	23	0.002			

Analysis of variance table for chromium

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.003			
Treatment	5	0.342	0.068	33.169	0.00000
Error	15	0.031	0.002		
Total	23	0.377			

Analysis of variance table for zinc

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.010			
Treatment	5	0.066	0.013	7.254	0.00123
Error	15	0.027	0.002		
Total	23	0.103			

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

Title of Thesis : **“Effect of chemicalized farming on environmental quality in mid-hills of Himachal Pradesh”**
Name of the Student : **Pooja J**
Admission Number : F-2015-21-M
Major Field : Environmental Science
Minor Fields : 1. Soil Science and Water management
2. Social Science
Degree Awarded : M. Sc. Environmental Science
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Major Advisor : Prof. S K Bhardwaj

ABSTRACT

The present investigation entitled **“Effect of chemicalized farming on environmental quality in mid-hills of Himachal Pradesh”** was conducted during the year 2016-17 in the Department of Environmental Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. In order to identify the impact of different farming systems on soil and water quality in mid-hills of Solan district of HP four locations: Solan, Kandaghat, Chail and Nauni and six farming systems namely, traditional, organic, polyhouse, vegetable, flower and orchard were selected. Accordingly in total there were six treatments which were replicated four times under Randomized Block Design. In the region farming system wise variation in physico- chemical and microbiological properties indicated that practices under such systems has induced variations, however, found within the permissible range. The bacteria, fungi, and actinomycetes counts under selected systems ranged from 67.25×10^4 to 92.67×10^4 , 4.75×10^3 to 8.17×10^3 and 29.17×10^4 to 41.17×10^4 cfu/g soil and soil microbial biomass ranged from 310.69 to 459.63 $\mu\text{g kg}^{-1}$ In soil, available NPK ranged from 291.74 to 416.25, 21.64 to 38.41 and 309.08 to 408.23 kg ha^{-1} , respectively, and exchangeable Ca, Mg, and available S ranged from 3.71 to 7.40 cmol (p+)/kg , 1.35 to 2.24 cmol (p+)/kg and 42.07 to 56.60 kg ha^{-1} under different farming systems. The farming systems of mid hills has been noticed to enhance the build up of toxic metals such as Fe, Mn, Cd, Cr, Cu and Pb in the soil above the permissible limits as prescribed by BSI (1992) and WHO (1993), except for Zn. The farming systems like flower, traditional, vegetable and orchard represented poor soil quality with respective values of 0.44, 0.45, 0.47, 0.48 and organic, and polyhouse were found be in medium range with the values of 0.60 and 0.58. The pH and EC of the water ranged from 7.63 to 7.76 and 0.24 to 0.40 dSm^{-1} , respectively, and was within the normal range. The BOD and COD of water ranged from 0.78 to 1.63 and 17.50 to 32.53 mg l^{-1} , chloride and nitrate ranged from 14.78 to 27.19 and 4.55 to 11.13 mg l^{-1} , respectively, the values of BOD, chloride and nitrate was within the permissible limit whereas, COD was above the permissible limit as prescribed by BSI and WHO in all the systems except for organic farming. The heavy metals like Cd, Cr and Pb in water sources around the farming systems were within the range of 0.00 to 0.03, 0.05 to 0.40 and 0.03 to 0.14 mg l^{-1} which were above the permissible limits as prescribed by BSI and WHO, except for Zn and Fe. Therefore, on the basis of the present study it is concluded that in mid-hills of Solan district of HP the different farming systems has started impacting the soil and water quality and hence necessary measures need to be taken in time.

Signature of the major advisor
Name : Prof SK Bhardwaj
Date:

Signature of the student
Name :
Date :

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

BRIEF BIO-DATA

Name : **Pooja J**

Father's Name : Lt. Sh. Jayanna HE

Date of Birth : 25-03-1994

Sex : Female

Marital status : Married

Nationality : Indian

Educational Qualifications:

Certificate/Degree	Class/Grade	Board/University	Year
Matriculation	Distinction	Karnataka Secondary Education Examination Board	2009
10+2	First	Department of Pre-University Education	2011
B.Sc. (Agri)	First	University of Agricultural Sciences, Bengaluru	2015

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(Pooja J)