CHAPTER ONE

INTRODUCTION

1.1 Background

Climate change is considered the most critical global challenge of the century. Over the last century, the earth's surface temperature has been increased by about 0.74°C on a global average (IPCC, 1998). The mean global temperature is projected to increase by 1.8–4°C by the end of this century, depending upon the scenario of greenhouse gas emissions (IPCC, 2007). Emission of Global greenhouse gases due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 and this emissions at or above current rates would cause further warming and induce many change in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century (IPCC, 2001). In Asia, climate change is affecting many sectors (IPCC, 2007). The IPCC (Intergovernmental Panel of Climate Change) reports (1998) show that South Asian region has the highest portion of highly vulnerable sectors.

Nepal is regarded as "hot spot" by climatic expert as average temperature rise is higher than other developing countries (Shrestha *et al.,* 1999). Least developed countries such as Nepal, while not contributing significantly to global warming, are more sensitive to the effects of climate change because of their weak coping capacity (Huq *et al.*, 2004). Temperature in Nepal is increasing at a high rate in recent years similar to the phenomenon observed globally. The average temperature has been increased consistently and continuously at a rate of 0.05˚C/year from 1971 to 2005 (DHM, 2008). However, warming in Nepal has been much more pronounced with higher than the global average of 0.74°C over the last 100 years in the Middle-Hills and the high Himalaya than in the Terai and Siwalik regions (Kansakar *et al.,* 2004). The mountains and hills are vulnerable to extreme climatic events because of sloppy and fragile topography (Regmi and Adhakari 2007).

Climate change most likely result in new combinations of soil, climate, atmospheric constituents, solar radiation, pests and diseases (Gonalez, 2011). Similarly, glacier melting, extreme weather events such as floods, droughts and heat waves, changes in plant morphology, physiology, phenology, reproduction, species distributions, change in crop production patterns, spread of infectious diseases and pests are some of the incidences likely to happen as a result of climate change (IPCC 2007). In fruit and vegetables, increasing in flowering and decreasing in fruiting has been noted (IPCC 2001). Agriculture is the major income source of nearly 60% of the population in Nepal and accounts for 35% of the GDP (Ministry of Population and Environment 2004). However, 64% of the cultivated land is totally dependent on monsoon rainfall (CBS, 2010) which makes country's agricultural production highly vulnerable to climate change. In agriculture, crop yields are expected to decline by 5 - 30% by the 2050s due to rising temperatures in the Himalayas, and this will lead to increase severe food insecurity at a local scale, including in Nepal (Dahal, 2008). The temperature increase is expected to reduce maize and wheat production while climatic variability will pose serious threat leading to the famine and death of the poorest at first (PAN, 2009).

Climate change has also accelerated the loss of agro-biodiversity (Upreti & Upreti, 2002). Agro-biodiversity and climate change interact in two ways. Agro-biodiversity in one hand is threatened by climate change as rapid shifts in local environmental conditions may drive species to extinction and on the other hand agro-biodiversity also represents a crucial resource for adaptation to climate change. Thus, there is the potential need of agro-biodiversity conservation for food security in the face of climate change (Pascual *et al.*, 2011).

Agro-biodiversity, the subset of biodiversity can be understood as the diversity within and among plant, animals and microorganisms at genetic, species and ecosystem level which are necessary to sustain key functions in agro-ecosystem (Cromwell *et al.*, 2001). Agro-biodiversity refers to the human-managed or modified biological diversity in agro-ecosystem which helps to recycle nutrients, reduce pests and diseases problems, maintain good soil and water conditions, and handle climatic stress (Altieri, 1987) and many studies have found greater biodiversity in human-managed ecosystems than in natural systems (Pimentel *et al.*, 1992). Climate change would also speed the loss of agro-biodiversity as some areas become unsuitable for less tolerant varieties. In recognition that farmers are likely to modify their farming practices in light of changed conditions, more attention has been given recently to adaptive responses to climate-related yield of cereal crops changes (Kaiser *et al.*, 1993; Darwin *et al.*, 1995).

Additionally, agricultural practices commonly observed in many traditional farming systems in Nepal and India are also pivotal in achieving yield stability, maintaining soil fertility and attaining a constant supply of human and animal food (Subedi, 2003; Sthapit *et al.,* 2008). Thus, farmers with traditional farming systems incorporating *in situ* conservation (diversity, integration and conservation) are contributing to agro-biodiversity conservation (Upreti *et al.,* 1999). Therefore, local level coping options should be identified and prioritized for planning of adaptation through agro-biodiversity resource management among different adaptive ways they have been practicing (UNFCCC, 2007).

People's perception and interpretation about climate change may vary in a small geographic area in relation to local climatic differences and subsistence activities. This directly influence the way they respond and choose appropriate options (Byg and Salick, 2009). The farmers' perception needs to be acknowledged to deal with the practical problems by the direct stakeholders and find the best possible solution. Changing climatic conditions has thus enforced the farmers to adapt the modern conventional farming system which is suspected as asset to cope the climatic stresses with synthetic fertilizers, chemical pesticides, and irrigation equipment required to produce high yields (Preety, 2002). And the recent agricultural development strategy (ADS), has envisioned commercialization of agriculture as the mean to uplift the national economy under changing climatic conditions (ADB, 2013). Furthermore, as a direct result of growing commercialization and industrialization of farming systems (e.g., via the 'Green Revolution'), agro-ecosystems are increasingly characterized by high levels of intensification with low levels of agro-biodiversity (Thrupp, 1998; Jackson *et al.*, 2007).

Though traditional farming applying only organic manures in the field was an age old farming practice (MOAC, 2008); green revolution during 1960s promoted farmers to follow conventional farming (Shrestha, 2010). This modern conventional farming has often been accompanied by the introduction of inputs i.e. chemical fertilizers and pesticides (Chapagain, 2006), may have led acidification of soil. Though, numerous studies have examined agricultural modernization and soil management in Nepal, the constraints and complexities of modern agricultural systems are not thoroughly understood (Tiwari *et al.,* 2008; Paudel and Thapa, 2004). The consequences of this dramatic shift to modern agriculture included a loss of crop genetic diversity, heighted vulnerability to pests and disease, loss of soil fertility, pollution of water supplies by pesticides and fertilizers from agricultural runoff, loss of traditional food crops, loss of ecosystem biodiversity, and increased pesticide-related illness (Drinkwater *et al.,* 1995). New plant and animal varieties and high-input agricultural systems have dramatically increased food output but have replaced many traditional agricultural products. In Nepal, modern varieties replaced landraces on three quarters of cultivated rice land between 1960 and 2000 (FAOSTAT, 2006). Although modern agriculture has increased crop yields but also posed severe environmental problems as the fertilizer inputs may acidify soil limiting microbial growth and activity (O'Donnell *et al.,* 2002).

However, production of adequate and nutritive hygienic food products, using all the available modern inputs and technology of farming, is the demand of rapidly growing population, but have severe impacts on biological diversity (Paudel and Thapa, 2004). Thus, the chemical products applied in the conventional systems can not only contaminate natural resources but also suppress the soil microbial activity, which make the system less sustainable and more dependent on agricultural inputs (Whipps, 1997; Garbeva *et al.,* 2004). Organic farming combines the knowledge and skill of farmers with the latest scientific innovations to promote farmer self-reliance and to minimize dependence on costly external inputs resulting in the enhancement and conservation of agro-biodiversity, including plant genetic resources, livestock, insects and soil organisms (Pretty, 2002).

The key characteristics of organic farming involve protecting the long-term fertility and quality of the soil. The input of organic fertilizers controls weed, disease, and pest through crop rotations, natural predators, diversity, organic manuring, and limited biological and chemical intervention, extensive management of livestock and minimizing the impact on the wider environment (Mader *et al.,* 2002). Organic farming practices reduce the vulnerability of crops to floods and drought by increasing the organic matter in soils, thereby enhancing the soils' water retention capacity. Increased soil carbon enhances soil fertility, reduce erosion and nutrient runoff and improve water quality and thus promoting the sustainability of agricultural system (Lal, 2004). The organic farms had greater microbial colony which results the greater organic carbon that in turn enhance the species richness above the ground than the modern conventional farms (Bengtsson *et al.*, 2005; Hole *et al*., 2005).

The alternation in the soil processes affects the net productivity through plant pathogens. If pest damage or disease incidence increases when synthetic insecticides, fungicides etc. are no longer management options, then yield on organic farm is lower as compared to the conventional farms despite soil related factors (Liu *et al.,* 2007). However, non- target effects of pesticides on beneficial organisms can be minimized under reduced application of more selective materials and biological pests and pathogens control can be optimized (Drinkwater *et al.,* 1998).

The Phalabang VDC of Salyan district produces several agricultural crops like corn (*Zea mays L*.), tomatoes (*Lycopersicon esculentum L*.), beans (*Phaseolus vulgaris L*.), wheat (*Triticum aestivum L*.) and rice (*Oryza sativa L*.). The high production capacity of this region is attributed to modern intensive agricultural practices. This reveals that majority farmers are practicing the modern farming pattern while still there are few farmers following the traditional farming pattern. Therefore, present study aims to explore the scenario behind adapting the modern farming leaving the traditional farming practices and among them which one is more sustainable and environmental friendly. In this background, the hypothesis presented here is that traditional farming system is more sustainable than conventional farming system.

1.2 Objectives

The general objective of the study is to observe the farmer's perception towards climatic changes and influences of these changes in agro-biodiversity. The specific objectives of the study are;

- To analyze the climatic trends in relation to farmer's perception
- To document the possible adaptation measures followed by farmers.
- To determine the impact of climate change on agro-ecosystem services in traditional-organic and modern-conventional tomato farms.

1.3 Justification

In the context of Nepal, climate change is increasingly pronounced and affecting agricultural systems and livelihoods. Thus, documentation of local people's perception, knowledge, valuation and responses on the climate change and its impacts on agro-biodiversity is one of the issues of this study as the local people are the eyewitness of climate change and its impacts on agro-biodiversity which they have been monitoring and observing in their lifetime. Increasing temperature and change in precipitation patterns leading to increase incidence of extreme weather events and increase greenhouse gases in the atmosphere are principal factor that could lead to diminishing of agro-biodiversity.

Agro-biodiversity loss include a loss of crop genetic diversity, highlighted vulnerability to pests and disease, loss of soil fertility and soil microbes and as a whole loss of ecosystem biodiversity. Adequate understandings of the climate change impacts are still less. Thus, it is crucial to explore strategies that the local people are adapting to cope the various climatic stresses which favours the agro-biodiversity conservation. As the maximum farmers are following the modern pattern of farming and very less number of farmers are still following the traditional farming in the study area, the studies at different scale from landscape to laboratory will be helpful in directing agro- biodiversity conservation efforts, determining the path to on farm value added biodiversity and gaining ecosystem services for farmers from both natural and managed ecosystem.

1.4 Limitations

- The entire work was carried out in the limited time for six month.
- The study was conducted in only one VDC.
- Some of the respondents were not patient enough until the entire questionnaire, so the sufficient information from them could not be realized
- Fundamental differences between traditional and modern agro-ecosystem was determined only in the context of tomato farm due to seasonal limitation.
- Documentation of only the cereal crops was done.

CHAPTER TWO
LITERATURE REVIEW

2.1 Global scenario of climate change and people's perception

According to IPCC (2001) climate change refers to a change in the state of the climate that can identify by change in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time whether due to natural variability or as a result of human activity (IPCC, 2001).

UNFCCC (2007) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of global atmosphere and which is in addition to natural climate variability observed over comparable time period". Climate change popularly known, as global warming, but it is much broader than global warming. Temperature change is just one aspect of the broader subject of climate change. The scientific opinion on climate change as expressed by the UN Intergovernmental Panel on Climate Change (IPCC) and explicitly endorsed by the National Science Academies of the G8 Nations is that the average global temperature has risen 0.6±0.2˚C since the 19thcentury and that it is likely the most of the warming observed over the last 50 years is attributable to human activities (IPCC, 2001).

Global temperature is increasing by 0.3˚C to 0.6˚C since the last of 19th century and 0.2˚C to 0.3˚C over the last 40 years (1960-2000) indicating that the global temperature will increase further in the upcoming days (Liu *et al.*, 2000). Global Green House Gas (GHGs) emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004. Continued GHGs emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century (IPCC, 2001).

Climate change will reduce the stream flow and ground water recharge. Demand for water is generally increasing due to population growth and economic development. Higher temperatures, hence higher crop evaporative demand, mean that the general tendency would be towards an increase in irrigation demands (IPCC, 2001).

It is reported that the developing countries are more susceptible to climate change impacts as they have limited capacity to adapt. The least developed countries are among the most vulnerable to extreme weather events and the adverse effects of climate change. Also these countries have a very least capacity to cope with and adapt to adverse effects of climate change. The major risk reduction approach is adaptation to global change (UNFCCC, 2007).

Climate is always associated with particular place and region which is normally reflected through climatic and non- climatic indicators. People are always aware about the local event of their surrounding either that is due to climate or not. Perception of climate change is informed and structured by the dynamic nature of human environment relationship, farmers made sense of local climate through the use of categories that were not or determined by traditional weather cycle (Vedwan and Rhoades, 2001).

Roncoli *et al*. (2002) studied peoples' perception. They reported that the farmer's interpretation of seasonal rainfall forecasts are anchored in their remembrance desirable or dreaded situations they lived through, their observations about the condition that brought them about and their assessment of how they manage through them. They also suggest that local weather/climate forecasting draws from an assessment of phenomena and indicators that appear in the landscape and the spiritual world.

Climate change is a global challenge which has strong effect on developing countries such as Nepal where agriculture is the main source of income for majority of people and agriculture highly depend upon climatic change factors but adaptive capacity is low. Most farmers perceived that climate change acutely respond to it, based on their own indigenous knowledge and experiences through both agricultural and non-agricultural adaptations at an individual level. A wide array of agro- biodiversity management strategies offer options and opportunities for farmers to cope with the adverse impact of climate change. There is a need to go beyond the individual level and to plan and provide support for appropriate technologies and strategies in order to cope with the expected increasing impacts of climate change. However, this is possible only if adaptation is incorporated into the existing development efforts with sufficient understanding of local livelihood context and strategies instead of separately planning climate change adaptation programmes (Manadhar *et al.,* 2011; Paudel *et al.,* 2004; Regmi *et al.,* 2007).

2.1 Impact of climate change on agro-biodiversity and adaptation measures

Nepal is highly vulnerable to climate change. It is suggested that more than 1.9 million people are highly climate vulnerable and 10 million are increasingly in risk, with climate change likely to increase this number significantly in the future (MoEP, 2004). In terms of agriculture and food security, local communities have identified changes in climate as being largely responsible for declining crop and livestock production. Decline in rainfall from November to April adversely affects the winter and spring crops. Rice yields are particularly sensitive climatic conditions and these may fall in the western region where a larger population of the poor live and this could threaten overall food security. Food insecurity is also due to loss of some local land races crops (Regmi and Adhikary, 2007).

Excessive rainfall, longer drought periods, landslides and floods affect agriculture in that extent that it directly affect the agriculture based industry (Shrestha *et al*., 1999) in a study based on an analysis of temperature trend from 49 stations for the period 1977 to 1994 indicate an annual rate of growth of temperature at 0.06^{o}C in Nepal. Similarly a study conducted by practical action Nepal (2009) using data from 45 weather stations for the period of 1976-2005; indicate a consistent and continuous warming in maximum temperature at an annual rate of 0.04^{o}C.

Climate change will have a significant impact on agriculture in many parts of the world (IPCC, 1998). Particularly vulnerable are subsistence farmers in the tropics, who make up a large portion of the rural population and who are weakly coupled to markets (IPCC, 2001). Agriculture in tropical Asia is vulnerable to frequent floods, severe droughts, cyclones and storm which can damage life and property and severally reduce agricultural production and could threaten food security in many developing countries in Asia. Reduced food production may have several adverse impacts for these people such as loss of income to farmers, loss of nutritional base, increased suffering illness due to hunger, loss of life due to starvation etc. (FAO, 1999). Risk levels of climate change often increase exponentially with altitude; therefore, small changes in the mean climate can induce large changes in agricultural risks in mountain areas.

Agriculture is likely to get affected positively and negatively. Negative effects are feared to be larger than the positive effects. Some studies have been conducted for evaluating the potential effects of climate change on crop yields (Dixon *et al*. 1994). Increased temperature during the growing season can reduce yields because crops speed through their physiological development producing less grain. More rapid plant development and modification of water and nutrient budges in the field (Long, 1991) will make existing farming technology unsuitable.

The higher temperatures also increase the process of evapo-transpiration and decreases soil moisture availability. Because global warming is likely to increase rainfall, the net impact of higher temperatures on water availability is a race between higher evapo-transpiration and higher precipitation. As the precipitation is not regular, the race will be won by higher evapo-transpiration (Cline, 2008).

Initial National Communication to UNFCCC notes that there will be growing negative impacts on ecosystems and people's livelihoods with predicted increase in temperatures and change in rainfall patterns in the future (MoPE, 2004). Nepal's agricultural sector is highly dependent on the weather, particularly on rainfall. Given the low productivity increase of the last few years compared to population growth, climate change is likely to have serious consequences for the agriculture. Most of the population is directly dependent on a few crops, such as rice, maize and wheat. The predicted decrease in precipitation from November to April would adversely impact the winter and spring crops, threatening food security (Regmi and Adhikari, 2007). Higher temperatures, increased evapo-transpiration, and decreased winter precipitation may bring about more droughts in Nepal (Poudel and Thapa, 2004). Increased water evaporation and evapo-transpiration may also mean that crops will require more water through irrigation.

Agro-biodiversity has always formed the basis for human food production system and has provided cultural, spiritual, religious and aesthetic value for human societies. The potential for biodiversity to provide ecological resilience i.e., the capacity to recover from disruption of functions, and the mitigation of risks caused by disruption is compelling, but poorly documented (Holling, 1996). Agro-biodiversity can make positive contributions to productivity, sustainability and resilience of human livelihood. Community and ecosystem-level agro-biodiversity are less studied, although this has recently become an important theme in research geared to improving the sustainability of modern, intensive agriculture. On farm research and adaptive management also encourages the adoption of biodiversity-based practices with multi-functionality of biodiversity as a central theme (FAO, 1999).

Planned agro-biodiversity is the biodiversity of the crops and livestock's chosen by the farmers, while associated agro-biodiversity refers to the biota, e.g. soil microbes and fauna, weeds, herbivores, carnivores, etc., colonizing the agro-ecosystem and surviving according to the local management and environment. Included are croplands and fields, as well as habitats and species outside of farming systems that benefit agriculture and enhance ecosystem function (Vandermeer and Perfecto, 1995). Current evidence suggests that merely adding more species to most agro-ecosystems has little effect on function, given the redundancy in many groups, especially for some members of the soil biota e.g., organic matter decomposition or N-mineralization which are carried out by a large variety of bacterial and fungal species. The functions of community and ecosystem-level agro-biodiversity are less studied, although this has recently become an important theme in research geared to improving the sustainability of modern, intensive agriculture (Thrupp, 1998).

Heterogeneous composition of ecosystem in agricultural landscapes provides insurance value that is not detected by the local scale experiments that are typical of most agricultural research. There is lack of adequate knowledge of how the ecological functions that are provided by agro-biodiversity translate into tangible benefits for society. The adoption of biodiversity-based practices for agriculture however is only partially based on the provision of ecosystem goods and services, since individual farmers typically react to the private use value of biodiversity, not the 'external' benefits of conservation that accrue to the wider society (Jackson *et al.*, 2007).

Almost farmers in Pokhare Khola watershed of Dhading district in the Middle-Hills of Nepal, perceived that summers are becoming hotter and longer while 81% of interviewed farmers responded that winters are becoming warmer and shorter. Farmers perceived that duration of the rainy season has decreased from four to two months. The reduction in wheat (*Triticum aestivum L.*) production due to shorter winters and insufficient post-monsoon rain was evident. The appearance of advancing phenological development in trees and earlier ripening of some crops were often cited as impacts of change in climate (Baul *et al.*, 2013).

2.2 Comparison between organic and conventional agricultural systems

In the mid-hill and high mountain regions increasing temperature has led to the expansion of agro-ecological belts into higher altitudes and increased length of growing period for some crop species (Baul *et al.*, 2013). In the mid-hills, decreasing soil moisture availability (due to change in rainfall and temperature) resulted in early maturation of crops, crop failures and reduced agricultural productivity. In addition, decreasing run-off water to fed natural streams (used for irrigation) and re-charging natural ponds, reservoirs and lakes have been reported. Thus with the aim of promoting the growth and extension of Agricultural Perspectives Plant (APP) of 1993 emphasized yield increasing technology, intensive land use and high value crops, with four priority areas for development : irrigation, fertilizers, technology and infrastructures. Thus there is trend towards modern conventional agriculture in mid hills (Brown and Shrestha, 2000; Chapagain, 2006; Dahal *et al.*, 2009).

The continuous and strong increase in population pressure in many regions has caused agricultural land use to expand and intensify. Incited by the Green Revolution, this expansion has often been accompanied by the introduction or the multiplication of inputs i.e. chemical fertilizers and pesticides. This modern conventional agriculture may have led to soil acidification in the hill areas of Nepal. Although numerous studies have examined agricultural modernization and soil management in Nepal, the constraints and complexities of modern agricultural systems are not thoroughly understood (Paudel and Thapa, 2004; Tiwari *et al.*, 2008). The consequences of this dramatic shift to modern agriculture included a loss of crop genetic diversity, heightened vulnerability to pests and disease, loss of soil fertility, pollution of water supplies by pesticides and fertilizers from agricultural runoff, depletion of aquifers for irrigation, loss of traditional food crops, loss of ecosystem biodiversity, and increased pesticide-related illness (Drinkwater *et al.*, 1995). Although modern agriculture has increased crop yields but also posed severe environmental problems. Fertilizer inputs may acidify soil limiting microbial growth and activity (O'Donnell *et al.*, 2001). In agro-ecosystems, where farmers normally have well-established (formalized or customary) rights to use land, agro-biodiversity conservation depends on encouraging people to apply certain practices on their farms. This is known as on-farm or in-situ conservation, which may be facilitated by institutional support or economic incentives, and leads to both conservation and enhanced farm-level adaptability to climate change (Eyzaguirre and Dennis, 2007).

Organic farming is being increasingly promoted worldwide as a sustainable alternative to modern farming. Organic farming has the possibility of reducing the negative effects of conventional agriculture, as this system largely excludes applications of synthetic fertilizers and pesticides, relies on organic inputs and recycling for nutrient supply, livestock feed additives, and emphasizes cropping system design and biological processes for pest management (Rigby and Cáceres, 2001). Thus, sustainable agriculture would ideally produce good crop yields with minimal impact on ecological factors such as soil fertility.

By legal definition, traditional organic farming system eliminates the use of synthetic fertilizers and pesticides and relies on amendments such as animal manures, green manures and off -farm organic wastes to maintain soil fertility and use biological and cultural methods for the control of weeds, insects, pests and pathogens (Mader *et al.*, 2002). Organic farming claims to have the potential to provide benefits in terms of environmental protection, conservation of non-renewable resources, improved food quality, reduction in output of surplus products and the reorientation of agriculture towards areas of market demand. Sharma (2011) makes a case for organic farming as the most widely recognized alternative farming system for sustainable production without seriously harming the environment and ecology.

Clark *et al.* (1998) found that concentrations of carbon, phosphorus, potassium, calcium, and magnesium were greater in soils with incorporated manures and cover crops, and soil carbon, phosphorus, and potassium declined after manure applications ceased. Liebhardt *et al.* (1989) compared soil quality population on five paired organic and conventional farms and observed that the topsoil depth, farms in Nebraska. Organic C, total N, microbial available water holding capacity, and earthworm biomass C, and microbial biomass N were numbers were generally greater on the organic consistently higher across all organic farms, while soil bulk density was generally lower, compared with conventional farms There have been a number of reports that have indicated that organic farming practices have positive effects on soil microbial populations, processes and activities (Drinkwater *et al.,* 1995).

Soil micro-biota play an important role in the soil characteristics since many of them are involved in nutrient cycling, transformation processes and soil aggregate formation, as well as in plant pathology or plant growth promotion since they suppress plant diseases caused by soil borne pathogens, mainly by antibiosis and competition for nutrients (Bulluck *et al.,* 2002). Understanding structure and dynamics and functions of soil microbial communities represent the soil fertility and soil quality. Determining community level substrate utilization (CLSU) pattern is one approach for the characterization of microbial communities and is based on substrate utilizing functions performed by aerobic heterotrophic bacteria. CLSU analyses have been applied in many studies in order to gain information on microbial communities in various soil systems (O'Donnell *et al.,* 2002).

However, the chemical products applied in the conventional systems can not only contaminate natural resources but also suppress the soil microbial activity, which make the system less sustainable and more dependent from agricultural inputs (Whipps, 1997; Garbeva *et al.,* 2004).

Poudel *et al*. (2002) in the research carried out in California reported that potato yields in the organic systems were 58 to 66% of those in the conventional plots, mainly due to low potassium supply and the incidence of *Phytophtora infestans*. Winter wheat yields reached an average of 4.1 metric tons per hectare in the organic systems. This corresponds to 90% of the grain harvest of the conventional systems, which is similar to yields of conventional farms in the region. Cereal crop yields under organic management in Europe typically are 60 to 70% of those under conventional management. Appropriate plant breeding may further improve cereal yields in organic farming. There were minor differences between the farming systems in food quality (Drinkwater *et al.,* 1998).

Thus, Drinkwater *et al.* (1995) reported the greater number of bacterial colony in the traditional organic farms as compared to the modern conventional farms. He also found that the organic matter amended on the organic farms enhanced the microbial activity as they are responsible in the degrading and transforming the debris into organic carbon. Thus, from his research it was concluded that the organic farms had greater microbial colony which results the greater organic carbon that in turn enhance the species richness above the ground than the modern conventional farms (Hole *et al*., 2005).

Biodiversity can be measured at different levels of organization (e.g. genetic diversity within species, species diversity within taxa and trophic levels, functional diversity in communities) and at different spatial scales (e.g. plots, habitats, ecosystems, landscapes, regions). Species richness was on average, 30% higher on organic farms, with stronger effects likely in intensively managed landscapes. Bengtsson *et al.* (2005) and Hole *et al.* (2005) continue to support a positive association between organic management and on-farm biodiversity for plants. Comparisons of organic and conventional farms have primarily measured species richness of one or several taxonomic groups by sampling in crop fields or other farm habitats. Although results vary among taxonomic groups, biodiversity is clearly enhanced on organic farms compared to conventional farms in most studies.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The field study was carried out in Phalabang VDC (82°15'5.794 eastern longitudes to 28°16'6.842 northern latitudes), located in Salyan district of Rapti Zone in mid-western development region of Nepal (Figure 1). Rukum lies at the northern boundary of this district; to the south are Dang and Banke districts, to the east is Rolpa district and to the west are Surkhet and Bardia districts. The major rivers of this district are Sharada, Babai and Bheri. According to administrative division of Nepal, Salyan district is divided into 47 VDCs.

Situated on the lap of Mahabharat Range Salyan district is rich in natural resources. Located on the western part of Nepal, Salyan district covers an area of 1462 sq. Km. It lies between 27˚53'N to 28˚31'N and 82˚0'E to 82˚49'E and 500 km far from Kathmandu. Altitudinal variation is from 326 masl (Babai river valley, Kaprechaur VDC) to 2827 masl (Kharsubas Hill, Jathak). Due to variation in landscape and altitude, the climate and natural vegetation of the district varies with a great influence of monsoon. Annual rainfall of this district is 1100 mm. Similarly, range of temperature during summer varies from 28°C to 35°C and during winter varies from 14°C to 27°C. According to the National Census 2011 A.D, the total population of the district is 2,42,444 with composition of 1,15,969 male and 1,26,465 female clustered in 46,556 households.

The forest covers the highest portion of land with an area of 12,8205 hectares, followed by agricultural land with an area of 45,577 hectares. This district has 38,896 hectares of cultivated land and 7,039 hectares area is irrigated land. The major crops are wheat, maize and paddy. Ginger, citrus fruits, vegetable seeds and unseasonal vegetables are cultivated in this district. The vegetation types are tropical, sub-tropical and temperate.

3.1.1 Socioeconomic information of study area

Phalabang is one of the VDC of Salyan district with total area of 43.11 sq. Km. The altitude range is 850m to 2350m above sea level. As Nepal comprises wide variety of caste and ethnic groups belonging to Tibeto-Burman and Indo- Aryan linguistic family. According to CBS (2001), Phalabang VDC also consists of different castes and ethinic groups with highest composition of Chhetri (67.13%) and other majorities are Magar, Dalit, Brahmin etc. Phalabang is divided into 9 wards. The total population of this VDC is 5,450 (2551 male and 2899 female) clustered in 1128 households CBS (2001). According to VDC profile, majority of people are involved in agriculture, livestock and poultry farming. They cultivate wheat, maize and paddy along with some cash crops like ginger, tomato, orange, lemon etc. In Phalabang, 2243 hectares land is occupied by forests and there are 16 community forests which occupies 13.19% of total land area (DFO, 2070/2071 BS).

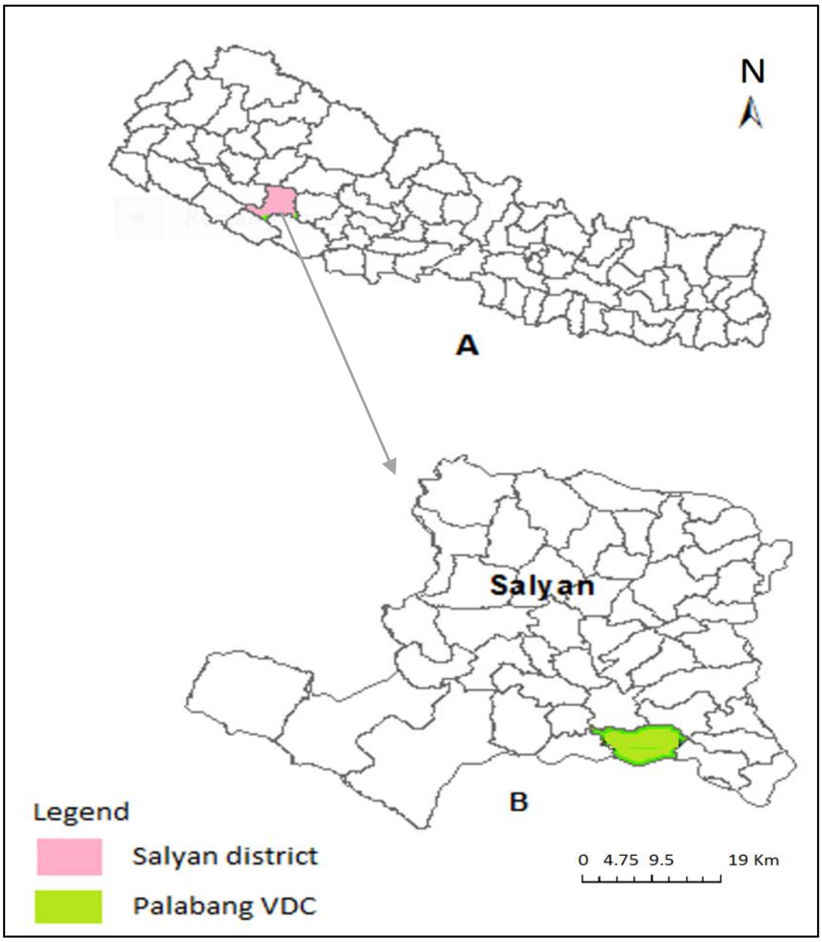


Figure 1: Map of Salyan District showing Study Area (VDCs)

3.2 Methodology

The study is based on the descriptive and explanatory research method. So, research method include household surveys, field survey, key informant interviews, focus discussion, direct observation, literature review and laboratory works. The research data were collected during May-June 2016. Both primary and secondary sources of data were used during the study.

3.2.1 Primary data collection

3.2.1.1 Questionnaire survey

Both qualitative and quantitative methods and tools were employed for the study. Primary data were collected by using different methods such as survey, interview and discussion. Altogether 60 households were randomly selected for questionnaire survey from 7 accessible wards. The household level survey questions (both close and open types/ semi-structured questionnaires) covered a variety of thematic areas such as information on socioeconomic profile, agro-biodiversity richness and their status, loss of genetic resources, agriculture management practices and production, crop calendar, food security and climate change as well as perception of local people on ecosystem based coping strategies and their resilience capacity. Focus group discussion were conducted (2-3 focus group discussions in the study site with involvement of 8-12 participants) with involvement and representing of all respective stakeholders. Key informant interviews were taken from lead farmers, social workers, schools teachers, VDC secretary and representatives of Agriculture Service Center and District Agriculture Development Office etc.

3.2.1.2 Experimental design

A systematic random sampling was used to compare of agro- ecosystem services between traditional organic and modern conventional farms. Sampling was done during the month of August when tomato plants were on both the field. The four conventionally-managed sites had a history of using synthetic fertilizers, and pesticide use. Only two farming sites were chosen where there was practice of using organic manure in tomato crop. A total five quadrates of size $1m^2$ in each farming field were laid. Altogether 10 quadrats in organic farm and 20 quadrats in conventional farm were laid for collection of weed species, soil collection and for the measurement of tomato yield.

(a) Soil collection

Soil samples were collected from each quadrat as mentioned above by making random 5 points within the quadrat. The soils collected from the five points within the quadrat were mixed to form a composite sample for each quadrat. Collection of samples were made from 0 to10 cm below the ground level by removing the litter and organic matter on the surface. These soil samples were then put in plastic bags separately and brought to laboratory of Central Department of Botany, TU and stored in refrigerator until use. The collected soil was used within three days of collection to carry out the bioassay for counting bacterial colony and fungal species.

i) Soil analysis

Soil samples were analyzed at the Pathology laboratory in the Central Department of Botany, Tribhuvan University. Soil pH and soil organic carbon (SOC) were estimated in the soil samples using methods described by Gupta (2000) and Zobel *et al.,* (1987).

Soil pH: Soil pH was determined using Digital pH meter in 1:2 ratio of soil-water mixture. Before measurement, the pH meter was calibrated using buffer solutions of known pH (pH 4 and pH 7). During the measurements, 10 ml of distilled water was poured into 5 g of soil sample. The mixture was stirred at least 30 minute using a magnetic stirrer and then allowed to settle down for five minutes. The electrode was dipped into the mixture and reading of pH was noted.

Organic Carbon content: Soil organic carbon was calculated by Walkey and Black's rapid titration method. Soil sample (0.25 g) passed through fine sieve (0.5 mm) was taken in a 500 ml conical flask and added 5 ml of 1N $K_2Cr_2O_7$ and 10 ml of conc. H_2SO_4 with gentle swirling. As the reaction was exothermic, the flask was left for about 30 minutes to cool down to room temperature. To that mixture 100 ml distilled water, 5 mlorthophosphoric acid, and 1 ml diphenylamine indicator solution were added successively and shaken.

Ferrous ammoniumsulphate solution (0.5 N) was run from burette, with constant stirring until the colour changed from violet to bright green through blue. The volume of ferrous ammonium sulphate solution used for titration was noted. A blank titration (without soil) was carried out at every lot of 17 samples in a similar manner.

Volume of 0.5N ferrous ammonium sulphate solution used for blank titration: X

Volume of 0.5N ferrous ammonium sulphate consumed with soil: Y

Volume of 1N $K_2Cr_2O_7$ used for oxidation of organic carbon in soil: $\frac{X-Y}{2}$

Organic carbon in soil (%) $= \frac{X-Y}{2} \times 0.003 \times \frac{100}{2}$

Myco- flora analysis

Serial dilution of soil and pour plate techniques

Soil for each soil containing 1g soil, were randomly sampled for each sample. Soil samples were analyzed for microorganisms using 10 fold serial dilutions of soil and two different selective media (*i.e*. potato dextrose agar for fungi and nutrient agar for bacteria) were used. A serial dilution method (Benson2002) was followed for the isolation of microorganisms. One gram of soil sample was first dissolved thoroughly in 9ml of sterile distilled water and then a 10 fold dilution of the mixture was made by mixing 1 ml of the soil water suspension and 9 ml of sterile distilled water (represent 10^{-2} dilution). Further dilutions of the soil water suspension were made up to 10^{-7}simultaneously. Dilution of 10^{-5} and 10^{-7} were used for plating in Nutrient Agar poured plates for bacterial growth. Similarly, dilution of 10^{-3} and 10^{-5} were used for plating in PDA poured plates (supplemented with antibiotics *i.e* amoxicillin) for fungal growth (Aneja 2003).

Pour plate techniques was used for plating , where 1 ml of the aliquots was first poured into the sterile Petri dish and then a lukewarm media was dispensed onto the plate and stirred gently by swirling the plates. Triplicate plates for each medium were used for each sample and the plates were incubated (Gallenkamp Economy incubator size 1) in laboratory at 25 ± 1^{o} C. Bacterial colonies were counted from plates after 24 hours and fungus were identified through microscopic and macroscopic morphological criterion after 5-6 days of incubation following the Standard literature (Booth 1971 and Singh *et al.*, 1991).

(b) Yield

Yield of tomato (*Lycopersicon esculentum* L.) in each quadrates of each farms were weighed by growers on a weekly basis once fruit began to ripen. Weights from each quadrates in each week were tallied, analyzed, and presented as average total per plot in metric tons per hectare (Mt/ha).

(c) Weed diversity index

Mostly weeding is done manually; no herbicide was used. Weeds were used fed to animals or were composted depending upon the distance of the farm from the household, the type of animal raised, and the quantity and type of weeds gathered. Specimens of all weed species encountered in sampling quadrates were counted, collected, tagged and pressed using a newspaper and herbarium presser. The equations for weed diversity is:

Shannon Index (H) = $\sum_{i=1}^{n} pi\ lnpi$

In the Shannon index, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and s is the number of species.

3.2.2 Secondary data collection

Nineteen years climate (recorded temperature and rainfall) data of study site was collected from the nearest meteorological station (Kapurkot, Salyan). Published data of the Central Bureau of Statistics (CBS) and different national level reports were also used as per the need of the study. The relevant study materials were collected by consulting various published and unpublished books, thesis, reports, journals, papers, bulletins, magazine, symposium, newsletter, records, websites etc. for required qualitative and quantitative information.

3.2.3 Data processing and analysis

The data were analyzed by using Microsoft Excel 2007 and SPSS version 20. To test the hypothesis that the organic farms and conventional farms had statistically significant different mean values for each parameter (soil pH, soil organic carbon, bacterial colony, weed species diversity and tomato yield), an independent samples *t*-test was performed.

CHAPTER FOUR
RESULTS

4.1 Socio-economic status of the surveyed farmer's

The major inhabitants of Phalabang VDC were Chhetri, Magar, Dalit and Brahmins. Majority of the respondents were Chhetri (66.67%), followed by Magar (23.33%), Dalit (6.67%) and Brahmin (3.33%). Among the total respondents, 13.3% were aged below 30, 18.33% were between 31-40, 18.33% were between 41-50, 33.33% were between 51-60, 13.33% between 61-70 and 3.3% above 70. The age group of 51-60 with 20 respondents comprises the largest group of the sampled respondents. Based on the gender composition, sampled respondents consist of 65% (39) males and 35% (21) females of them 63.33% illiterates, 28.33% are literates and only 8.33% had gained the higher education. The main occupation of the respondents was agriculture (71.67%) (ANNEX II).

4.2 Climatic trends and Farmer's perception

4.2.1 Change in temperature

The majority (80%) of the respondents perceived that temperature have been increased, while around 17% of the respondents were unfamiliar and 3% perceived the constant temperature. Most of the respondents perceived that summers are hotter and the winters are warmer than the past. Peoples' perception about the temperature was confirmed by the meteorological data collected from the nearby station. The temperature data from 1997 to 2015 was used for trend analysis. The average annual mean temperature recorded was found to be 17.47˚C. Mean annual temperature shows positive correlation with years with r value 0.400.

The average mean annual maximum temperature recorded was 21.42°C which also showed the increasing trend. Mean annual maximum temperature also shows positive correlation with years with r value 0.460. But the mean annual minimum temperature showed the slow increasing trend. The average mean annual minimum temperature noted was 13.44°C. However, the mean annual minimum temperature shows very weak correlation with year (r = 0.196).

Table 1: Linear regression statistics of temperature

Temperature	F-value	P-value(0.05)
Mean Annual	3.223	0.900
Mean annual Maximum	4.558	0.048
Mean annual Minimum	0.677	0.422

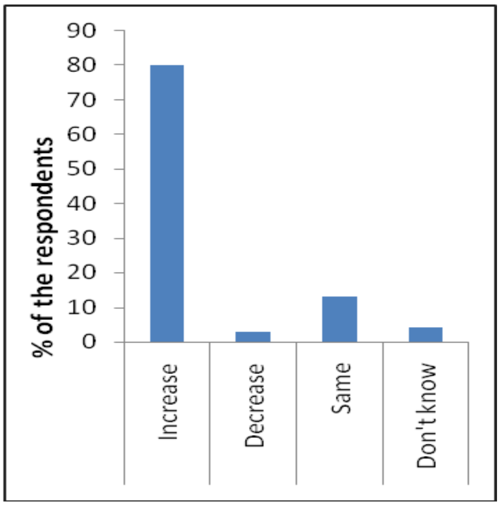


Figure 2: Perception on temperature

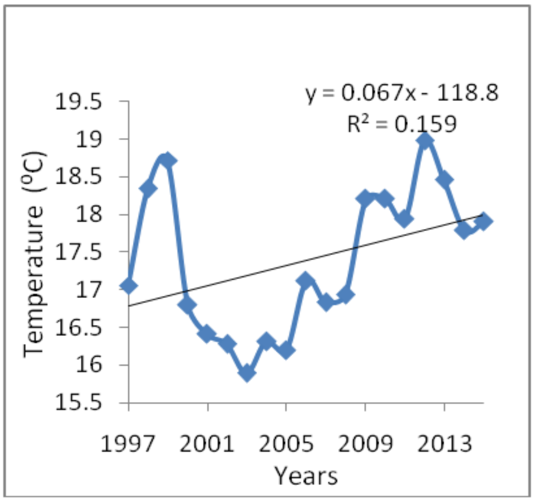


Figure 3: Mean annual temperature

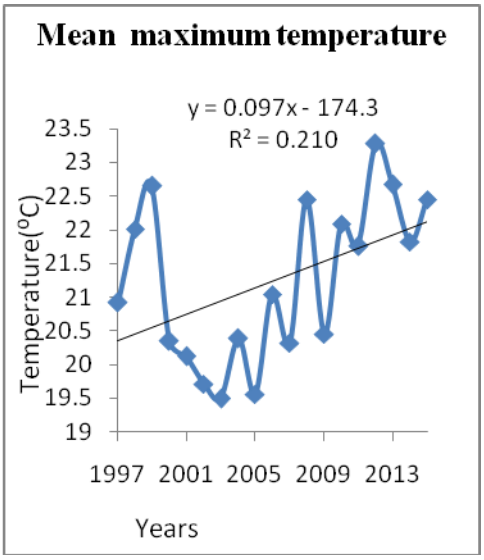


Figure 4: Mean annual maximum temperature

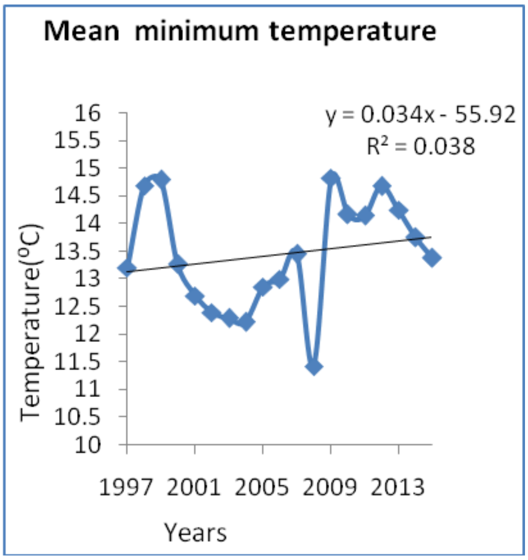


Figure 5: Mean annual minimum temperature

4.2.2 Change in rainfall

The present study revealed that early offset and delayed asset of rain and erratic rainfall are the major climatic shocks in Salyan, despite of their frequency and extent of their impacts varies in the time. Out of the total respondents interviewed, 58% respondents stated that there was decrease in the rainfall, 18% reported as the same trend of rainfall while 18% claimed the erratic rainfall in the study area. Similarly, 3 % of the respondents perceived as the same trend of rainfall as last 19 years. The pre-monsoon season in the region occurs from March to May, monsoon from June to September and post-monsoon falls in October to February and winter season from December to February. The monsoon season is supposed to have the highest rainfall which has significant impact on cropping time of several crops. There was erratic monsoon rainfall. The annual rainfall shows strong correlation with year (*r=0.633*), while pre-monsoon (*r=0.422*), monsoon (*r=0.445*) and post monsoon (*r=0.401*) shows positive correlation with years. The winter rainfall shows weak correlation with year (*r=0.007*).

Table 2: Linear regression statistics of rainfall

Rainfall	F-value	*P*-value (*0.05*)
Annual	11.389	0.004*
Pre-monsoon	3.691	0.072
Monsoon	4.201	0.056
Post-monsoon	3.258	0.089
Winter	0.001	0.979

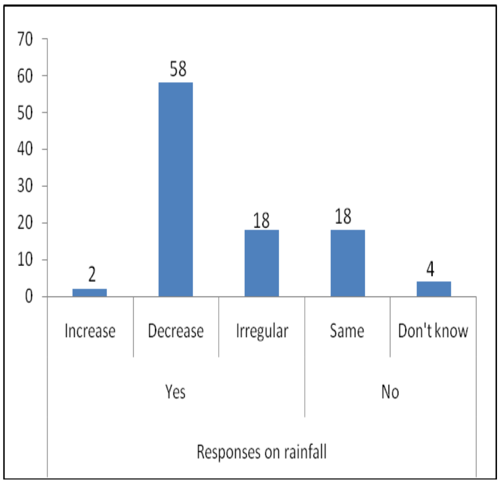


Figure 6: Responses on rainfall

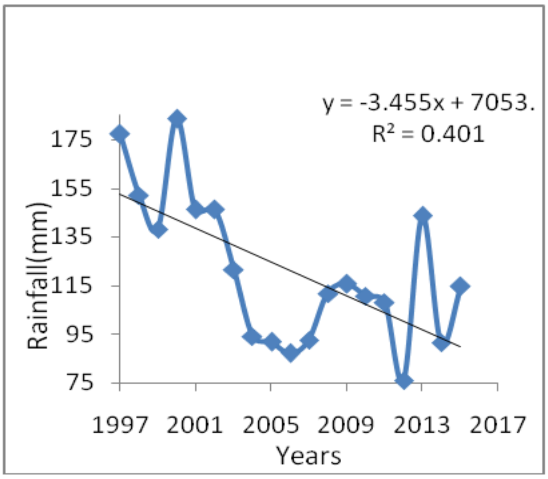


Figure 7: Annual rainfall

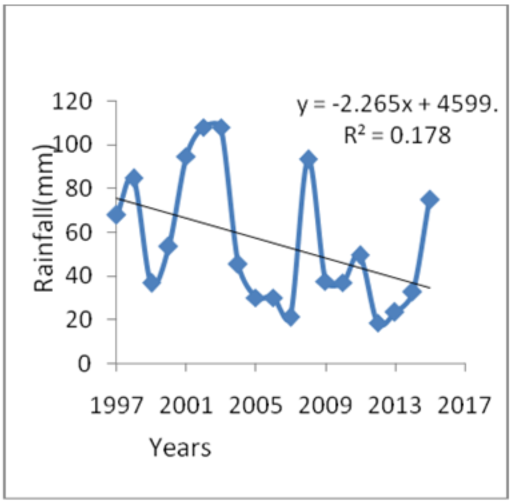


Figure 8: Pre-monsoon rainfall

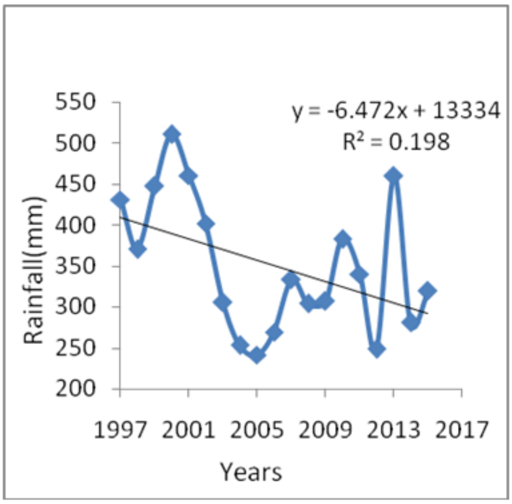


Figure 9: Monsoon rainfall

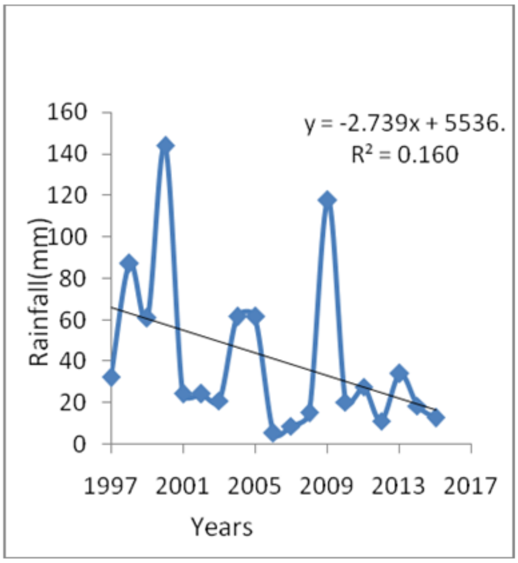


Figure 10: Post monsoon rainfall

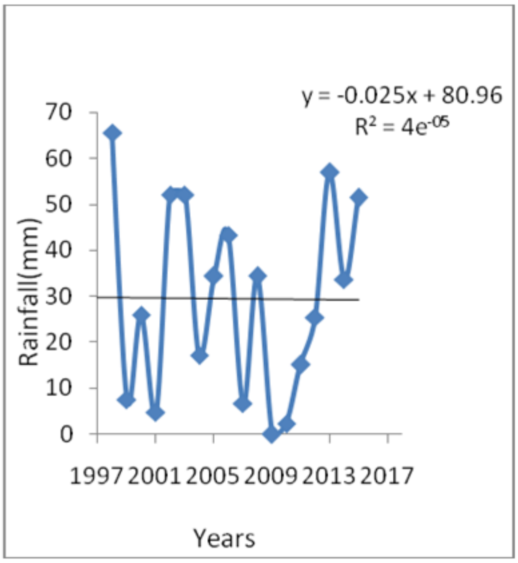


Figure 11: Winter rainfall

4.2.3 Impacts of Climatic change

Regarding the climate change, many respondents had experienced the climatic fluctuations. Farmers have faced a problem of drying up of water sources and also decrease in soil moisture. Many of the respondents (78%) perceived decrease in soil fertility or increase in hardness of soil due to uneven climatic conditions. Most of the farmers had observed an increased impacts on livestock (77%), increased outbreaks of pests and diseases (80%) in agricultural crops and invasion of new plants and weeds (72%) due to climatic changes. They reported invasive species like Kalo Banmara *(Ageratina adenophora*), Maobadi Jhar (*Parthenium hysterophorus*.) and Ghandhe Jhar (*Ageratum haustonianum*) which are non-edible for livestock and causes the disturbance in the growth and development of the major crops like rice, maize and vegetables.

The farmers of the study area were aware of the several diseases occurring in the crop plants. They claimed that Gray leaf Spot (Dhowase Thegle), Southern leaf Blight (Dakshini Paat- daduwa), Northern leaf Blight (Uttari paatda duwa) and Smut (Kalo poke) were more abundant diseases in maize. Similarly, Brown rust (Khairo Sindure) and Yellow/stripe rust (Pahelo Sindure) were more frequent in wheat and rice plant these years. They also reported that many crop varieties that were cultivated during the past are being replaced by new improved/ hybrid varieties which are supposed to be resistant to the adverse climatic stresses. As perceived by the respondents, the crop varieties of the past and present are enlisted below in table 3. The millet varieties that were cultivated in upland of Phalabang VDC are no more cultivated.

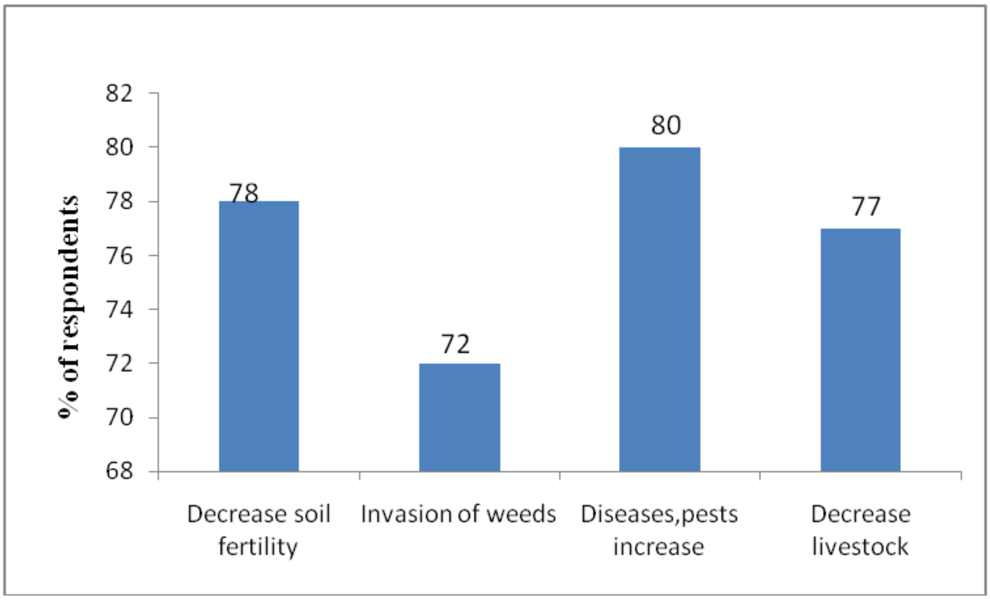


Figure 12: Impacts of climate change on agro-biodiversity

Table 3. Cereal crop varieties of the study area

Rice		**Wheat**		**Maize**	
Past varieties	Present varieties	Past varieties	Present varieties	Past varieties	Present varieties
Marsi	Kanchan	Kalipare	Gautam	Setomakai	Rampur
Gopal	Radha-4	Jumli	Aditya	Ratomakai	Manakamana
Tilki	Radha-12	Kathe	Bhrikuti	Deuti	
Thaurawa	Ramdhan		BL-2800	Chepte	
Bindeswori	Sabitri		BL-3264	Kavre	
	Hardinath		Kundan	Pahelo makai	

4.3 Adaptation measures taken by the farmers

Changing climatic conditions have resulted increase in the population of pests and diseases in the study area. Farmers perceived that there is no alternative to the use of chemicals for controlling the pest and disease problems. So, chemical input was found one of the adaptation strategies and majority of farmers (90%) used chemical fertilizers/pesticides. Majority (80%) of the respondents claimed the change in crop variety. They have replaced local varieties by improved/hybrid ones as adaptation to climate change. Mostly new varieties of maize, wheat and rice are prevalent in the study area. 65% of the farmers claimed as the change in time of cultivation. Farmers who followed the previous pattern were considered as the farmers with unchanged pattern (Figure 13). Maize–wheat pattern of cultivation appeared as popular instead of maize– millet pattern of cultivation in water and soil moisture stressed condition in upland.

The cropping calendar of the study area is given below in table 4. The time of planting the cereal crops was 15-25 days delayed than that of the past periods as perceived by the farmers. Farmers in the study area have diversified their farming (32%). They have started planting a variety of ginger and vegetables (cauliflower, cabbage, tomatoes, potatoes, beans, radishes, chillies, onions, garlic, carrot, leafy vegetables, and cucumber), medicinal plants and tree crops (such as oranges, lemons, pears, peaches, plums, walnuts). These vegetables, medicinal plants and tree crops contribute to food security and generate cash income of the study area. Thus, agricultural diversification can be called as possible adaptation strategies to cope with climate change.

Table 4: Cropping calendar of the study area

In Partial irrigated rain fed land

Crop/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maize			P	P				H	H			
Wheat			H	H	H					P	P	P

In irrigated land

Crop/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Paddy			P	P			H	H				
Wheat			H	H	H					P	P	P

P=Plantation, H=Harvest Source: Own field survey

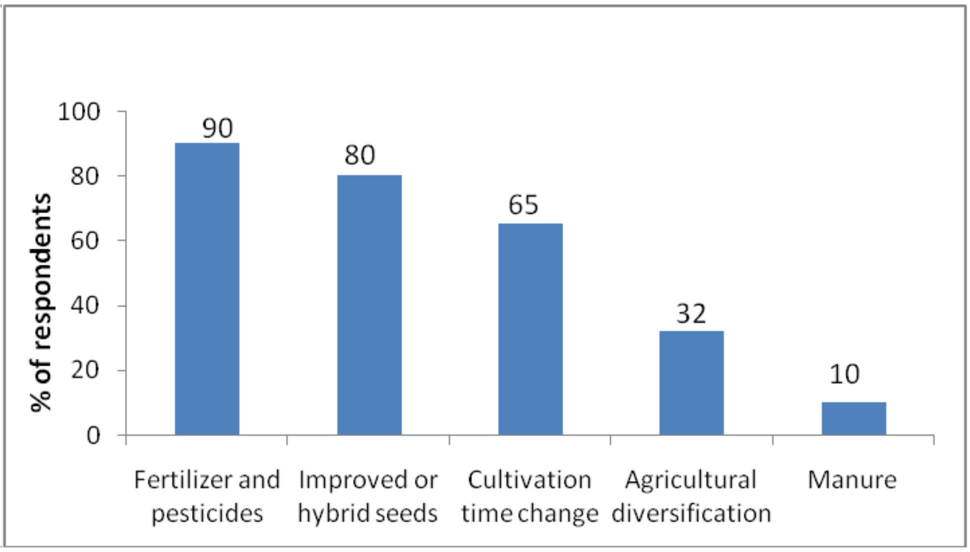


Figure 13: Adaptation strategies to climate change

4.4 Comparison of agro-ecosystem services of organic and conventional farms

The comparison was made between the organic quadrates (N = 10) and conventional quadrates (N = 20) for soil pH, soil organic carbon, bacterial colony, species richness and yield.

Table 5: Mean difference between agro-ecosystem services in organic and conventional farms after t-test at ($P<0.05$)

Different Features	Type of farm (Sample number)	Mean±SE	F value	P value
Soil pH	Organic (10) Conventional (20)	6.18± 0.09 5.71± 0.04	4.02	<0.001
Carbon (%)	Organic (10) Conventional (20)	4.02± 0.08 3.43± 0.06	0.019	<0.001
Bacterial colony	Organic (10) Conventional (20)	102.6± 4.5 65.10± 4.37	1.831	<0.001
Weed diversity index	Organic (10) Conventional (20)	1.5 ± 0.04 1.25± 0.02	0.401	<0.001
Yield (mt/ha)	Organic (10) Conventional (20)	60.8± 1.2 71.50± 0.68	1.65	<0.001

4.4.1 Soil pH

The comparison of mean soil pH between organic and conventional farm showed higher soil pH in organic farms (*M* =6.18, *SE*=0.28) than conventional farms (*M*=5.71, *SE*=0.18) which is statistically significant (P=<0.001) (Figure 14, Table 5).

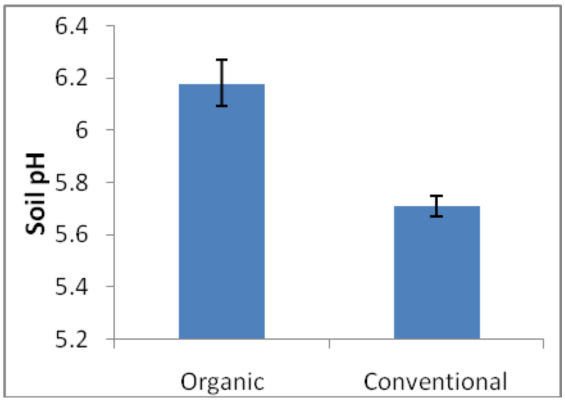


Figure 14: Comparison of mean soil pH of organic and conventional farms

4.4.2 Soil organic carbon

The mean soil carbon of organic farms (*M*=4.01, *SE*=0.08) was greater than that of the conventional farms (*M*=3.43, *SE*=0.06) which is statistically significant (*P=<0.001*) (Figure 15, Table 5). The higher soil organic content in organic farms suggested that organic farms are more fertile than the conventional farms.

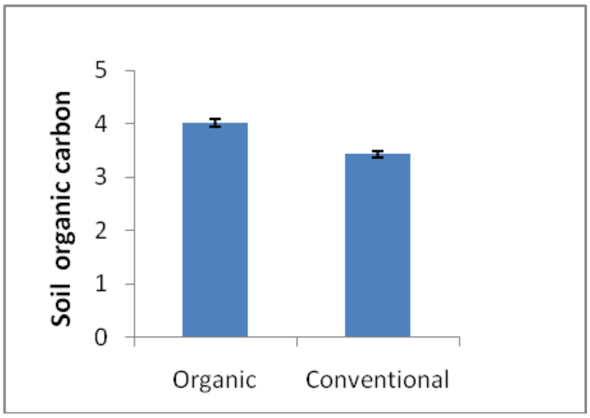


Figure 15: Comparison of mean soil carbon of organic and conventional farms

4.4.3 Bacterial colony

The mean bacterial colonies in the organic farms (*M*=102.6, *SE*=4.5) were more than that of conventional farms (*M*=65.10, *SE*=4.37) and statistically significant (*P=<0.001*). Beneficial fungal pathogen like *Trichoderma* sp. was recorded from organic while harmful pathogens like *Fusarium* sp. was recorded from the conventional farms (Figure 16, Table 6).

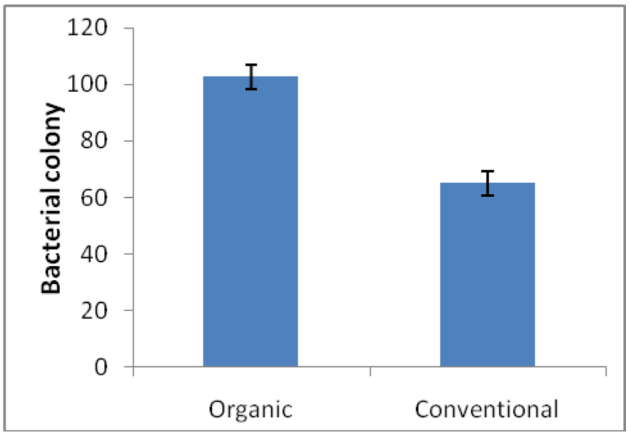


Figure16: Comparison of mean bacterial colony of organic and conventional farms

Table 6: Name of pathogens isolated from organic and conventional farms

S.N.	Names of pathogens	Types of farm	
1	*Trichoderma* sp.	OF	
2	*Fusarium* sp.	CF	
3	*Aspergillus niger*	OF	CF
4	*Aspergillus brevipes*	OF	CF
5	*Alternia alternate*	OF	CF
6	*Rhizopus* sp.	OF	CF
7	*Mucor* sp.	OF	CF
8	*Penicillium* sp.	OF	CF
9	*Aspergillus flavus*	OF	CF

Note: *OF= Organic farms; CF= Conventional farms*

4.4.4 Weed diversity index

The mean weed diversity index in organic farms (*M*=1.5, *SE*=0.04) was significantly greater than that of the conventional farms (*M*=1.25, *SE*=0.02, *P=<0.001*) (Figure 17). The weeds recorded from the organic and conventional farms are listed in Annex IV.

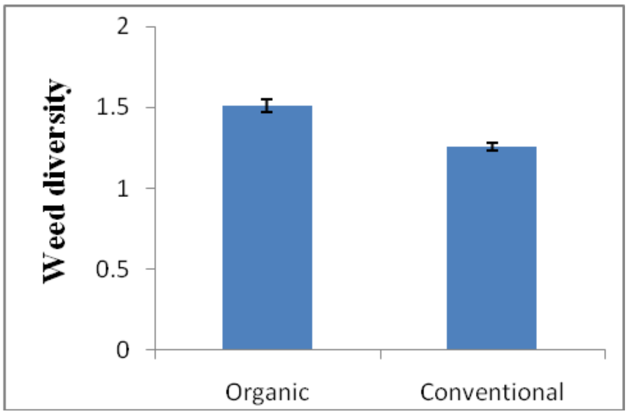


Figure17: Comparison of mean species richness of organic and conventional farms

4.4.5 Yield

The mean yield of tomato fruits from organic farms (*M*=60.8, *SE*=1.2) was found less than the mean value of yield of tomato fruits from the conventional farms (*M*=71.44, *SE*=0.68) which is statistically significant (*P=<0.001*). This result is reverse of other comparisons.

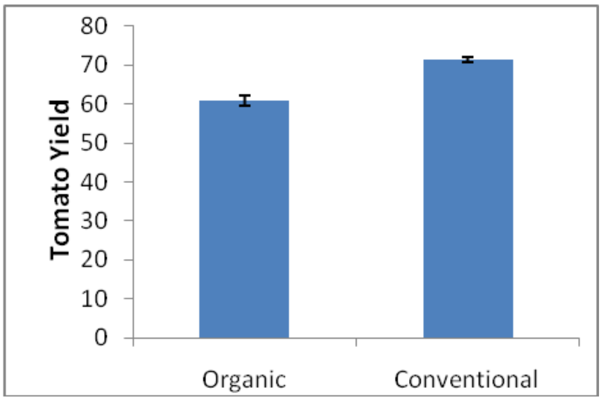


Figure18: Comparison of mean yield of organic and conventional farms

4.5 Relationship between bacterial colony and soil organic carbon

The correlation between bacterial colony and soil carbon was calculated for both organic and conventional farms. The bacterial colony increases with the increase of soil organic carbon in both organic and conventional farms. There was positive correlation between the amount of soil carbon and bacterial colony in organic farms (*r>0*, Table 8) and conventional farms (r>0, Table 9).

Table 7: Pearson Correlation between bacterial colony and carbon for organic farms

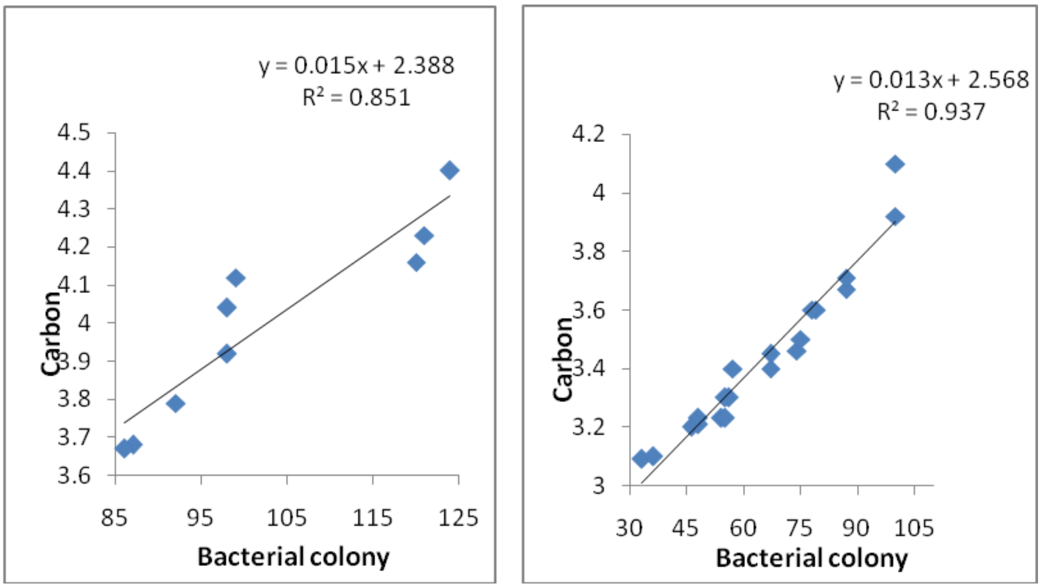
	Bacterial colony	Carbon
Bacterial colony	1	0.894**
Carbon	0.894**	1

** Correlation is significant at the 0.01 level (2- tailed).

Table 8: Pearson Correlation between bacterial colony and carbon for conventional farms

	Bacterial colony	Carbon
Bacterial colony	1	0.968**
Carbon	0.968**	1

** Correlation is significant at the 0.01 level (2-tailed).



Organic farm Conventional farm

Figure19: Graph of soil carbon with bacterial colony

4.6 Relationship between soil carbon and weed diversity

The correlation between weed diversity and carbon was calculated for both organic and conventional farms. The amount soil organic increases, the weed diversity also increases. The species diversity increased with amount of soil organic carbon in both organic and conventional farms. Positive correlation was found between weed diversity and the amount of soil organic carbon in organic farms (*r>0*, Table 10) and conventional farms (*r>0*, Table 11).

Table 9: Pearson Correlation between weed diversity index and carbon for organic farms

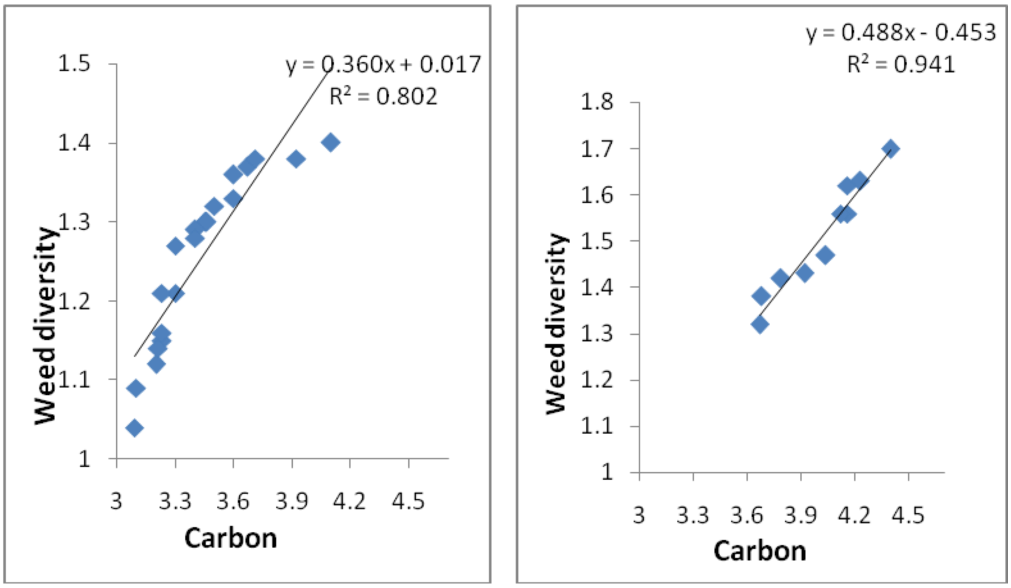
	Weed diversity index	Carbon
Weed diversity index	1	0.970**
Carbon	0.970**	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 10: Pearson Correlation between weed diversity index and carbon for conventional farms

	Weed diversity	Carbon
Weed diversity	1	0.896**
Carbon	0.896**	1

** Correlation is significant at the 0.01 level (2-tailed).



Organic farms　　Conventional farms

Figure 20: Graph of species richness with carbon

CHAPTER FIVE

DISCUSSION

5.1 Climatic trends and farmers' perceptions

Farmers in the Phalabang VDC were aware of the climate and have somehow clear opinions on changes, especially temperature and rainfall patterns. The result of mean annual, mean annual maximum and mean annual minimum temperature showed the increasing trends (Table 1, Figure 2-5). This result is in agreement with those of Gyampoh *et al.* (2007) from rural Ghana, where farmers' perceptions were corroborated by a meteorological recording of a gradual rise in average temperature of 1.3°C between 1961 and 2006. In general, farmers' thoughts and experiences are in congruence with scientific studies (IPCC, 2007). They also match with the studies conducted by Kansakar *et al*. (2004) and Shrestha *et al.* (1999) where an estimated rate of temperature increase of 0.41 0C per decade was predicted, based on meteorological data in Nepal.

In present study, the annual, pre-monsoon, monsoon, post monsoon and winter rainfall pattern showed decreasing trend (Table 2, Figure 6-11). Both annual and monsoon rainfall showed the significant relationship with the year which ensure higher rainfall in monsoon in upcoming years. Other periods of rainfall showed the weak correlation values which reveal the variation rainfall pattern in other seasons. The meteorological data to a large extent were consistent with the farmers' perceptions and observations in the study site. Increased temperature and decreased precipitation appeared to be in accordance to farmers' perceptions. Poudel *et al.,* (2008) also suggested that the temperature change appeared to be in accordance to farmers' perception in Pokhara, Nepal. However, contrasting results were presented by Poudel *et al.* (2014), in which farmers' perception and observed annual and seasonal rainfall showed insignificant trends in Chitwan, Nepal. It is obvious that the timing and duration of rainfall is changing.

5.2 Impacts of climate change on agro-biodiversity

Farmers of the study area perceived decreased soil fertility, replacement of local crop varieties, invasion of weeds and proliferation of vector born diseases and pests of crops, trees, humans and livestock as the impacts of climate change on overall agro-biodiversity. Malla (2008) suggested that the increased temperature lead to reduce the level of soil organic carbon, micronutrients and also microorganisms. Occurrence of pests and diseases has been reported as a major problem and become more pronounced in cooler zones as the temperature increase favoured proliferation of insect pests (Bale *et al.,* 2002). Another important impact on agro-biodiversity reported was invasion of weeds which depend on the increase of temperature (Baul *et al.,* 2013), the dispersal rate of species and on measures taken to combat non-indigenous species (Bale *et. al.,* 2002). Similarly, aggressive and fast spreading nature of weeds directly impacts on agricultural crops and reduced grazing resources due to declined local grass species ultimately harming livestock (Baul *et al.,* 2013).

5.3 Adaptation measures taken by farmers to combat climatic changes

Agriculture is sensitive to short-term changes in weather that affect the production of crops. In Nepal, the production varies with rain brought by monsoon. That’s way the coping strategy to the seasonal change of climate was changing and adjusting the cropping time. Malla (2008) classified farmers on the basis of cultivation practices, the farmers who followed the previous pattern were considered as the farmers with unchanged pattern. The climatic variability in the study area directed the farmers to follow the new adapted farming strategies as change in cropping patterns use of fertilizers/pesticides, improved/hybrid seeds, and crop diversification. The farmers were known to make decisions on cropping patterns based on local predictions of climate and decisions on planting dates based on complex cultural models of weather.

Farmers’ perception about improved varieties of seeds was as fast and high yield, drought resistance, and time flexible of planting. But some of the farmers reported that improved varieties of seeds were susceptible to insects, pests, and diseases with higher amount of chemical fertilizer and pesticides had contribution in lowering the land productivity and suggested that locally bred varieties were well adapted to local climate. Jinachu, (2009) and Regmi *et al.* (2007) also suggested that intensified crop production by modern varieties of seeds become untenable and might be vulnerable to changes in ecosystems. They emphasized on conservation of local varieties of seeds adapted to the site for high productivity through reduced application of fertilizers.

The diversification of crops provide additional income and improve nutrition in addition to reducing the risk of crop failure. Farmers have started cultivating different kind of vegetables where farmers used to cultivate cereal crops in the past. Similarly, Ascota *et al.*(2008) reported that the American farmers were shifting land use form water and labor intensive traditional crops to high yielding and high value cash crops especially fruits and vegetables. Diverse cropping through mixing different types of cereal crops rather reduced susceptibility to pest and diseases. Thus, crop diversification was the indication of increased production enterprises per farm, which helps assure the crops against various types of risks (Beets, 1990).

5.4 Comparison of agro-ecosystem services in organic and conventional farms

In this study, there was difference between agro-ecosystem services (soil pH, soil organic carbon, soil microbes, weed species richness and yield) in organic and conventional farms. Much of the research that compares different types of production systems is conducted in fields at experimental stations, because of the inherent difficulties associated with using grower fields for comparisons. Tomato agro-ecosystems were studied under conventional or organic production systems in grower fields.

In our study, conventional farms had an average soil pH value 5.71±0.089 which was more acidic as compared to the average soil pH of organic farms *i.e* 6.18±0.040. This result showed that organic farms had higher pH value than that of the conventional farms which is similar to the result of Liu *et al.* (2007). However, other researchers have shown that pH was not significantly different between organically and conventionally managed soils (Clark *et al.,* 1998; Mader *et al.,* 2002). Thus, conventional management resulted acidification of the soil. The acidification of the conventional fields is attributed to the intensive application of mineral fertilizers, mainly, ammonical N [Urea and $(NH_4)_2So_4$] and superphosphate. On the other hand, the organic farms were less acidic, probably as a result of the intensive use of compost. Compost increases the cation in a higher buffering capacity. Enzyme activities tend to increase with soil pH and soil organic matter (Ekenler and Tabatabai, 2003: Stamatiadis *et al.,* 1999). Extremely and strongly acidic soils can have high concentration of soluble aluminum (Al^{3+}) ions and manganese, which may be toxic to the growth of some plants. A pH range of approximately 6-7 promotes the most readily available plant nutrients, while a pH above 7 (alkaline) reduces the ability of the plants to absorb elements such as iron, manganese, boron and other trace elements aluminum (Al^{3+}) ions and manganese, which may be toxic to the growth of some plants, A pH range of approximately 6-7 promotes the most readily available plant nutrients, while a pH above 7 (alkaline) reduces the ability of plants to absorb elements such as iron, manganese, boron and other trace elements (Stamatiadis *et al.,* 1999).

Similarly, organic farms had an average extractable soil organic carbon 4.017±0.077 which was significantly higher than conventional farms with average soil carbon 3.435±0.060. These results were in agreement with other studies of soil from California (Paudel *et al.,* 2002). Depending on the soil type, climate, management and the capacity of the soil to store organic matter, organic carbon level may increase linearly with the amount of organic matter input. But the loss of soil organic carbon has often been documented when cultivation of natural ecosystems began or land use has changed and in many agricultural long term experiments possibly due to more intensive plot management - a decrease in soil organic carbon has been stated (Liu *et al.,* 2007). Soil organic matter is an important source of nutrients and can help increase biodiversity, which provides vital ecological services, including crop protection (Pimentel *et al.,* 1992). For example, adding compost and other organic matter reduces crop diseases and increases the number of species of microbes in the agro-ecosystem (Van Elsen, 2000). In addition, in the organic systems, not using synthetic pesticides and commercial fertilizers minimizes the harmful effects of these chemicals on non-target organisms (Pimentel *et al.,* 1992). Thus, organic farmers supply more organic carbon to their fields to maintain the organic matter in their soils, which might simultaneously increase the species richness above and below the ground.

The higher number of bacterial colony in soils with organic amendments than in soils with synthetic fertilizers of the present study showed similarity with study conducted in California (Drinkwater *et al.,* 1995). They observed higher numbers of enteric bacteria in soils with organic amendments than in soils with synthetic fertilizers. Similarly, Weller (1988) and Mader *et al.* (2002) also demonstrated that the organically managed soils exhibited greater biological activity than the conventionally managed soils detected by DGGE analysis. Bacteria are responsible for the degradation of plant debris and conversion into organic matter and also inhibition of soil born diseases. The results of the present study showed some *Trichoderma* sp. in organic farms was in agreement with the result of Bulluck *et al.* (2002). In this study, the higher *Trichoderma* sp. were probably related to colonization by the fungus to compost that were incorporated into grower fields.

The higher species richness of weeds in organic farms than that of conventional farms in present study shows similarity with the finding of Romero *et al.* (2008). They reported that the β- and γ-diversity were 2-3 times higher in organic farms compared to conventional ones despite the marked differences in the species composition of the arable weed communities in the two study regions. Similarly, Hole *et al.* (2005) deduced that the organic farms often had higher weed species density and diversity, and the potential immigration rate of weeds from the farms is likely to be higher compared to the conventional farms. The inputs of herbicides and mineral fertilizers and the less-diverse rotational schemes in conventionally managed arable fields had often been shown to reduce weed species richness, whereas chemical-free management and more complex crop rotations in organic fields could favour species-rich weed communities, as shown in present study for grasses. A higher number of species could also act as a potential buffer against environmental fluctuations as suggested by Loreau *et al.* (2002). In this regards, it cannot be excluded that the organic farms contribute to a higher biological integrity and more sustainable development of the landscape.

In present findings, the yield of tomato was higher in the conventional farms than that of organic farms. Similarly, O'Connor *et al.* (1990) and Lambert *et al.* (1990) clearly demonstrated that on hill-country soils in the North Island of New Zealand that the average crop yields of two organic systems were markedly lower (17% less) than conventional systems which was mainly attributed to the lower nutrient input and lower plant protection achieved. Generally, differences in crop yield between organic and conventional systems were larger for crops with a relatively short vegetation period, such as tomato, than for crops with a relatively long vegetation period, such as cereals and grass. However, different crops respond in different ways to organic fertilizers. No differences in the yields of tomato were observed between organic and conventional production in California (Drinkwater *et al.*, 1995).

Mader *et al.* (2002) reported that organic farming ‘‘enhanced soil fertility’’, by various measures. But that purportedly higher fertility apparently did not increase organic yields, which were 20% lower than in the conventional system. Mader *et al.* (2002) also reported that the organic system had higher energy efficiency, despite its lower yields, mainly due to the energy cost of fertilizer used in the conventional system. However, the validity of any extrapolation to commercial agriculture depends on whether fertilizer rates used in their experiment were optimum, a question that was apparently not addressed. In this study, the yield difference may be due to the variation in the variety of tomato used in organic and conventional farms.

Soil organic carbon is positively correlated with the bacterial colonies and weed species richness in both the organic and conventional farms. Decomposition of organic input into organic carbon is controlled by the population of decomposers (bacteria) present and so there are positive correlations between the bacterial population and the soil organic carbon. This positive correlation reveals that more the organic carbon input, more is the bacterial population and more will be the soil organic carbon. This result is in consistent with Gunapala & Scow (1998).

Correlation between the soil organic carbon and weed species richness was positively significant in both the organic and conventional farming practices. Similar result was recorded by Benizri and Amiaud (2005). Stephan *et al.* (2000) recorded the positive correlation between plant diversity and soil microbial functional diversity in the grassland. Plant provide a source of carbon and other nutrients for the soil decomposer community in the form of litter and root exudates and in turn the soil biota decomposes soil organic matter stabilizes soil structures and through its essential role in cycling of elements releases nutrients for the plant. Above ground and belowground components of terrestrial ecosystems are implicitly dependent on each other growths (Porazinska *et al.,* 2003). For instance, the loss of plant species in a certain ecosystems can lead to the changes in the community of soil decomposers which in turn affects the mineralization of organic matter with the consequences for the other ecosystem processes (Stephan *et al.,* 2000).

In this regard, the use of animal manure as alternative soil fertility amendments as a coping strategy to changing climatic conditions' impact in the agricultural farms can result in increased organic matter and biological activity in soils. Present results demonstrate that alternative soil amendments can enhance soil biological, chemical and physical attributes of soil compared with synthetic fertilizers and ultimately enhances ecosystem services and minimize the impacts of changing climate on cultivation practices.

Climate is changing slowly and gradually in the study area. This pattern of climate change is observed and experienced by the local farmers. Those farmers perceived that the adaptation of modern farming was the compulsion to cope with the climatic stresses. While there are still few farmers following the traditional organic farming. Thus, there was necessity to understand the fundamental differences between the modern and the traditional farming to explore the reason behind leaving the traditional and adapting the modern farming practices. As the organic farming from field to laboratory experiment has been considered as the beneficial system of farming for the conservation of agro-biodiversity, this system of farming should not be neglected rather should be used as environmental form.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

- Perception of farmers of Phalabang VDC of Salyan district on temperature and rainfall favors the trend shown by the meteorological data. The mean annual temperature is rising and the mean annual rainfall is decreasing.
- Climate change has decreased soil fertility and livestock has been reduced. On the other hand aggressive weeds and pests or crop diseases are becoming major threats to the livelihood of community people.
- The main adaptation strategies of farmers identified include change in crop types (Hybrid/improved), changing planting dates, application of inorganic fertilizers/ pesticides and crop diversification. This modern cropping pattern is anticipated to bring changes in past condition of agro-ecosystems.
- Farmers' observations and perceptions of climate change and its impact corresponds to the field and lab based findings.
- Bacterial colony is higher in organic farms than that of modern farms showed the clear indication of improved soil quality and affect the soil processes as carbon cycling.
- Higher organic carbon showed higher weed diversity in the organic farms than the conventional ones.
- The yield in conventional farm was higher than the organic farms probably due to application of inorganic fertilizers or selection of different variety of tomato in different farms.
- Therefore, it is recommended that the policy makers and scientists should come forward to incorporate people’s traditional knowledge and wisdom into scientific explanation for efficient utilization and management of agro-biodiversity. This will be helpful for developing more effective and accurate strategies to cope with the risks of climate change.

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ANNEX I: Perceptions of the respondents

Reference No.	Gender	Age	Respondent's perception	
			Temperature	Rainfall
R1	F	34	I	Ir
R2	F	22	I	S
R3	F	26	I	D
R4	F	29	D	I
R5	F	30	I	Ir
R6	M	27	I	D
R7	M	29	I	S
R8	M	30	D	D
R9	F	31	I	D
R10	F	39	I	Ir
R11	F	38	I	D
R12	F	39	I	S
R13	F	36	S	*
R14	F	36	I	D
R15	M	39	S	Ir
R16	M	38	I	D
R17	M	35	I	D
R18	M	34	S	S
R19	M	40	I	D
R20	F	49	I	D
R21	F	48	S	Ir
R22	F	49	I	D
R23	F	50	I	S
R24	M	50	I	D
R25	M	49	S	D
R26	M	48	I	D
R27	M	47	I	S
R28	M	48	I	Ir
R29	M	49	I	D
R30	M	46	I	D
R31	F	56	I	D
R32	F	54	I	S
R33	F	57	S	D

Reference No.	Gender	Age	Respondent's perception	
			Temperature	Rainfall
R35	F	58	I	Ir
R36	M	56	I	S
R37	M	57	I	D
R38	M	54	*	*
R39	M	53	S	D
R40	M	56	I	S
R41	M	57	I	D
R42	M	58	I	D
R43	M	59	I	Ir
R44	M	57	*	S
R45	M	59	I	D
R46	M	56	I	D
R47	M	55	I	D
R48	M	56	I	D
R49	M	57	I	Ir
R50	M	54	I	Ir
R51	F	65	I	D
R52	M	66	I	D
R53	M	67	S	S
R54	M	69	I	D
R55	M	65	I	Ir
R56	M	57	I	D
R57	M	64	I	D
R58	M	68	I	D
R59	M	74	I	D
R60	M	75	I	D
*Note: R= Respondents, F= Female, M= Male, D= Decrease, I= Increase, Ir = Irregular, S= Same, *= Don't know, No= Disappear*				

ANNEX II: Socio- economic status of the study area

a. Respondents age and gender composition of sampled households

Respondents age	Gender		Total
	Male	Female	
<30	3	5	8
31-40	5	6	11
41-50	7	4	11
51-60	15	5	20
61-70	7	1	8
>70	2	0	2

b. **Caste composition of sampled households**

Caste	Sampled household number
Chhetri	40
Brahmin	2
Dalit	4
Magar	14

c. **Educational status of samples households**

Literacy	Sampled household number
Illiterates	38
Literates	17
Higher Education	5

d. Occupation of the sampled households

Occupations	Sampled household number	Percentage(%)
Agriculture	43	71.67
Government services	5	8.33
Business and others	12	20

ANNEX III: Mean value of microbes, soil PH, soil carbon, species richness and yield

S.N	Types of farms	Carbon	Bacterial colony	Species richness	PH	Yield
1	ORG	4.16	101	1.62	6.4	63
2	ORG	4.04	98	1.47	6.1	59
3	ORG	4.4	124	1.7	6.6	67
4	ORG	3.68	87	1.38	5.9	57
5	ORG	4.16	120	1.56	6.3	64
6	ORG	3.67	86	1.32	5	56
7	ORG	3.79	92	1.42	6	58
8	ORG	4.23	121	1.63	6.6	66
9	ORG	4.12	99	1.56	6.1	60
10	ORG	3.92	98	1.43	6	58
11	CNV	3.2	46	1.12	5.5	67
12	CNV	3.46	74	1.3	5.8	73
13	CNV	3.09	33	1.04	5.4	66
14	CNV	3.3	56	1.21	5.6	71
15	CNV	3.92	100	1.38	6	75
16	CNV	3.3	55	1.27	5.6	71
17	CNV	3.1	36	1.09	5.4	66
18	CNV	3.23	54	1.16	5.6	69
19	CNV	3.67	87	1.37	5.9	74
20	CNV	3.4	67	1.28	5.7	72
21	CNV	3.21	48	1.14	5.6	68
22	CNV	3.4	57	1.29	5.7	72
23	CNV	3.23	55	1.15	5.6	70
24	CNV	3.45	67	1.3	5.8	73
25	CNV	3.6	79	1.33	5.9	74
26	CNV	3.5	75	1.32	5.8	73
27	CNV	3.6	78	1.36	5.8	74
28	CNV	3.71	87	1.38	5.9	75
29	CNV	3.23	48	1.21	5.6	69
30	CNV	4.1	100	1.4	6	76

Annex - IV: Weeds collected from organic and conventional farms

Local name	Botanical name	Family
Dubo	*Cynodon dactylon* (L.) Pers.	Poaceae
Suire	*Imperata* sp.	Poaceae
Kuro	*Bidens pilosa* L.	Asteraceae
Kaney	*Commelina diffusa* Burn. f.	Commelinaceae
Maubadij har	*Parthenium histerophorus* L.	Asteraceae
Bonsu	*Digitaria* sp.	Poaceae
Raunne	*Ageratum haustonianum* Mill.	Asteraceae

ANNEX V: Agro-biodiversity Conservation Survey Questionnaire

Date………………..

A. Farmers general information

1. Name……………………………………..
2. Age………………………..
3. Gender……………………………………
4. Caste/Ethenicity……………………..
5. Address………………………………….
6. Occupation…………………………….

a. Farmer b. Business c. Others

7. Family size

a. marginal b. Small c. Medium d. Large

8. Education level

Level/Gender	Male	Female	Age group	Occupation
Illiterate				
Literate				
Below SLC				
SLC or above				

9. Household size

Male	Female	Total

Family member	Age	Education	Activities	Earning

10. Land size

    i. Khet ( )   ii. Bari ( )   iii. Home garden( )

11. Different level of household food security;

    a. Less than 3 months

    b. 3-6 months

    c. 6-9 months

    d. Greater than 9 months

B. Information about climate change.

12. Have you observed about climate change?

    a. Yes   b. No

13. What type of variation have you observed about climate change?

    a. Temperature

    i. Increase   ii. Decrease   iii. No change

Reason for increase or decrease, what do you think

………………………………………………………………………………..

………………………………………………………………………………..

b. Rainfall

i. Increase   ii. Decrease   iii. No change

Reason for increase or decrease in rainfall

………………………………………………………………………

………………………………………………………………………

c. Change in frost occurrence

i. Increase   ii. Decrease   iii. No change

Reason for increase or decrease, what do you think?

…………………………………………………………………………………..

…………………………………………………………………………………..

C. Information about impact of climate change

Year	Flood	Drought	Landslide	Outbreak of diseases	Impacts

o= No impact , 1= Low impact , 2= Moderate impact, 3= significant impact

14. What type of climatic impacts have you observed?

a. Decline in crop yield

i. Yes ii. No

b. Decrease in soil fertility

i. Yes ii. No

c. Disappearances of landraces/ cultivars

i. Yes ii. No

d. Outbreak of diseases and pests

i. Yes ii. No

e. Change in crop pattern

i. Yes ii. No

D. Responses to conserve agro-biodiversity under climate change

15. a. Change in agricultural practices

i. Yes ii. No

If Yes

Activities/ Crops	Past		Present	
Sowing	Months	Week	Months	Week

Activities/ Crops	Past		Present	
Planting	Months	Week	Months	Week

b. Change in cropping pattern

i. Yes ii. No

Land Type	Past	Present
Khet		
Bari		
Kitchen garden		

16. Change in crop varieties

Crop Varieties	Past	Present

17. Fertilizer use

i. Yes ii. No

	I/D/S
Chemical Fertilizes	
Compost	

18. Diseases management practices

a. Do you have diseases and pest problems?

i. Yes ii. No

If yes, what are the major diseases and pest problems in principle crops?

Crop species	Insects	Diseases	Weeds

b. Diseases and pest problems increasing or decreasing or same?

Crop species	I/ D/ S	Reasons

c. Do you adapt management practices to solve diseases and pest problems?

i. Yes ii. NO

If Yes

Crop species	Mitigating measures	Effectiveness

1= High 2= Medium 3= Low

19. Land management

a. Do you think soil characteristics have changed when compared to 10 years?

i. Yes ii. No

If Yes,

Soil Characteristics	Increase	Decrease	No change	Reason
Fertility				
Hardness				
Labor for land preparation				

20. Live stocks :

i. Yes ii. No

Species	Present	Past	Reason
Cow			
Buffalo			
Goat			
Sheep			
Hens			

21. Productivity: Do you think the productivity has increased compared to past?

i. Yes ii. No

If yes list of crops

Crops

22. How have you managed till now?

a. Spraying inorganic pesticides whatever found in market. ( )

b. Through crop rotation practice. ( )

c. Using Bio-pesticides. ( )

d. Others ( )

23. Have you planted trees in your farmland?

a. YES ( ) b. ( )

24. What is your general practice to enrich the soil nutrients?

a. Adding inorganic fertilizers. ( )

b. Adding organic fertilizers. ( )

c. Adding organic and inorganic fertilizers. ( )

25. What type of seeds do you use in the farm?

a. Local b. Hybrid

26. What types of tools do you use?

a. Modern tools ( ) b. Indigenous tools ( )

Any suggestions

……………………………………………………………..

………………………………………………………………

27. Have you taken any training for conservation of agro species

a. YES ( ) b. NO ( ).

28. If yes what type of training mention.

…………………………………………………………………………………………

29. Who decide the use of income?

a. Male b. Female c. Both

30. Who spend most time in farm?

a. Male b. Female c. Both

31. Do you sale your products in the market?

a. YES ( ) b. NO ( )

Thank you

ANNEX V: PHOTO PLATES

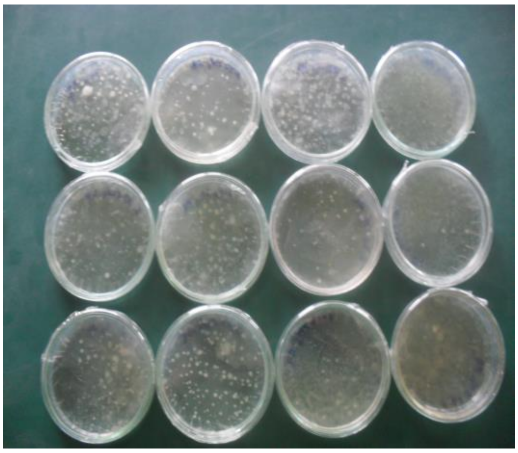
Questionnaire survey

Questionnaire survey

Quadrat in the field

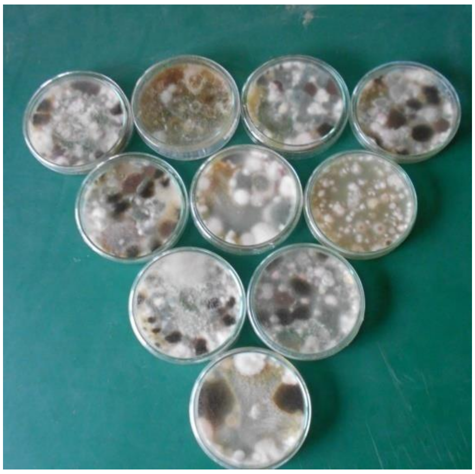
Tomato fruits in the plant

Carbon test

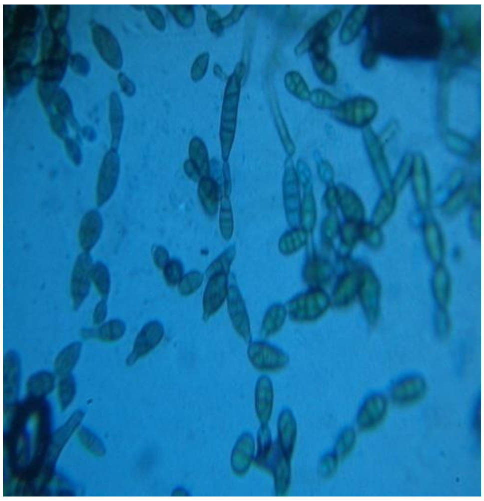


Bacterial colony

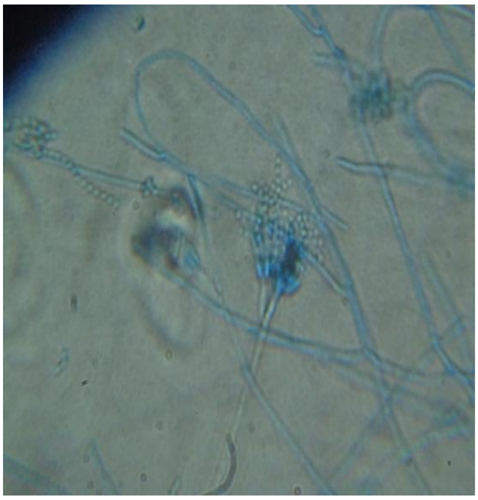
Bacterial colony in the petriplate



Fungal colony in the petriplates

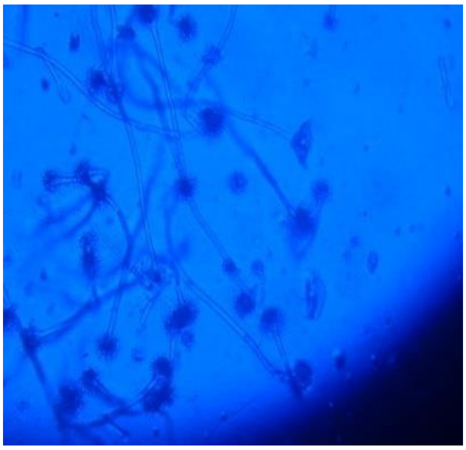


Alternaria alternata

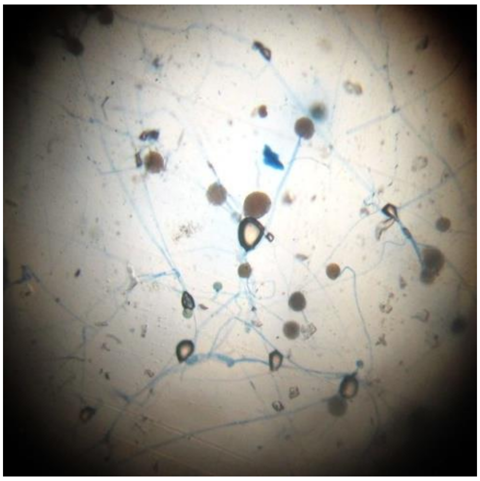


Penicillium sp.

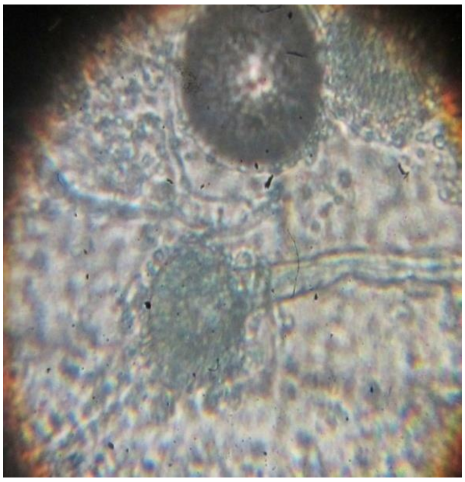
Aspergillus niger



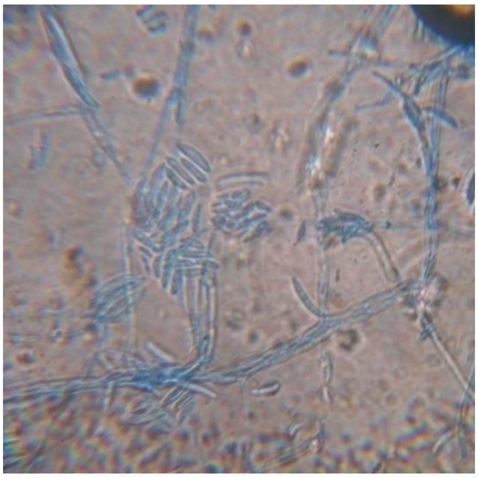
Aspergillus flavus



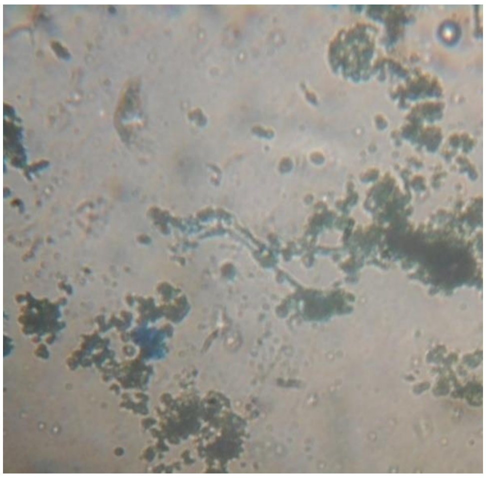
Mucor sp.



Rhizopus sp.



Fusarium sp.



Trichoderma sp