ASSESSING LAND USE CHANGES AND IMPACT ON LAND TENURE IN THE CONTEXT OF CLIMATE CHANGE: A CASE IN NEPAL

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Enschede, The Netherlands, February, 2016

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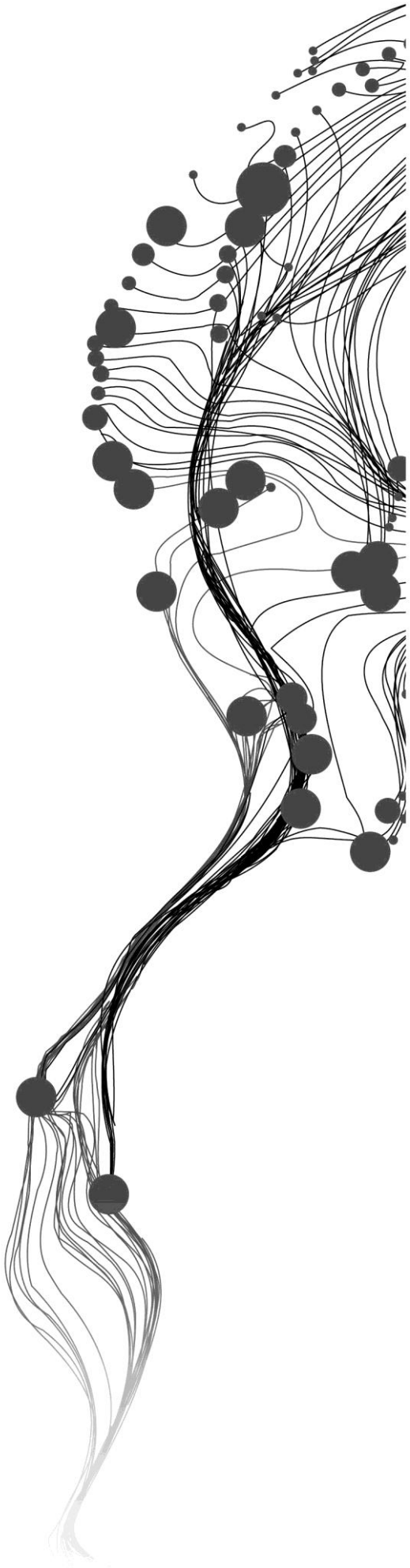

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Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
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ABSTRACT

Climate change is the change in climate condition due to the emission of anthropogenic GHG emission. It is affecting land, forestry, water and ultimately people's livelihood. It not only changes land use but could also affect land tenure. Many literature indicate that impacts of land use changes on land tenure in the context of climate change are not well documented. Thus, the purpose of the study is to assess the changes in land use for 26 years of the period and its socio-economic impacts on land tenure in the middle mountains of Nepal. The study aims to contribute new role for land administration in the context of climate change.

The study involves the desk study and field study in Lalitpur district in Nepal. Scientific literatures, journals articles, publications are reviewed to build the theoretical background for the study. Assessment of changes in land use is carried out by spatial analysis of temporal Landsat satellite images from the year 1989 to 2015 in the study area. Indication of climate change is assessed with the long term temperature and rainfall data from four different meteorological stations in the study area. Livelihood condition, major driving forces of land use change, major land tenure system and socio-economic impact of land use changes on tenure are studied using the interview with households, with local governmental officials and central governmental officials in the study area. Chi-square test for independency of attribute is used for testing the null hypothesis, "land tenure is independent of land use change caused by climate change".

Results from land use change by spatial analysis of temporal satellite image shows that forest is increasing from 1989 to 2006 and decreases in 2015. Agriculture land use is increasing from 1989 to 1996 and then it decreases in 2006 and slightly increases in 2015. Residential land use increases continuously from 1989 to 2015. Barren land use is decreasing from 1989 to 2015. Meteorological data analysis shows that temperature is increasing at the rate of $0.043\ ^{0}$c per year and rainfall is decreasing at the rate 10mm per year. Interview data analysis indicates the major land use change in the study area is by urbanization. Climate change is also playing an important role for land use change in agriculture by modification in the agriculture. Further, demography and economy are also drivers for the land use change in the area. Major land tenure system in the study area are ownership right, lease right, tenancy right, and sharing of crops. The major impacts of land use change identified from interview data analysis are the conflicts between land owner and tenant, changes in land tenure from tenancy to ownership right, informal land holding by encroachment of forest, conflicts in clear use of forest, termination of tenure such as lease and sharing of crops, effects on ownership right, increase in land transaction, decrease in enjoyment from the production and security of tenure. Further, chi-square test for independence of attribute statistically proves the research hypothesis "land tenure depends on land use change caused by climate change" in the area.

The research shows that urbanization is the major cause of land use change while climate change plays an unique role for changing land use within the agriculture. Though, the effects of climate change are not seen within one or two years but in long period of time, it decreases agriculture production and forces the changes on agriculture land use. This change in land use causes conflicts, changes land tenure from tenancy to freehold, develops informal land holding and affects the security of tenure.

Key words: C*limate change, Livelihood, Land tenure, Conflicts and impacts of land use change*, *Chi-square test*

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LIST OF ACRONYMS

ADB	Asian Development Bank
ADS	Agriculture Development Strategy
CO_2	Carbon Dioxide
CH4	Methane
CF	Community Forest/Forestry
DEM	Digital Elevation Model
DHM	Department of Hydrology and Meteorology
ETM	Enhanced Thematic Mapper
FAO	Food and Agricultural Organization (of the United Nations)
F-gases	Fluorinated gases
GDP	Gross Domestic Product
GHG	Green-house Gases
GO	Governmental Organization
GPS	Global Positioning System
IPCC	Intergovernmental Panel on Climate Change
INGO	International non-governmental organization
IOM	International Organization for Migration
ICIMOD	International Centre for Integrated Mountain Development
LULC	Land Use and Land Cover
MLC	Maximum Likelihood Classification
NGO	Non-Governmental organization
ROI	Region of Interest
SPSS	Software Package for Statistical Analysis
SAM	Spectral Angle Mapper
Sq.Km	Square kilometer
SF6	Sulfur Hexafluoride
SRTM	Shuttle Radar Topography Mission
TM	Thematic Mapper
UNFCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme
UN	United Nations
USA	United States of America
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VDC	Village Development Committee
WGS	World Geodetic System

1. INTRODUCTION AND JUSTIFICATION

1.1. Introduction

Climate change is *"a change in the state of climate that can be identified (e.g. using statistical tests) by change in the mean and /or the variability of its properties, and that persists for an extended period, typically decades or longer*"(IPCC, 2007a). The cause of climate change is the emission of anthropogenic Greenhouse Gas (GHG) such as CO2, CH4, SF6, etc. and are usually emitted by human activity such as burning of fossil fuels. Changing land use from the forest to agriculture or from the agriculture to the urban areas, also emits GHG and increases the temperature of the atmosphere. The rise in temperature affects agriculture by decreasing or damaging the crop production (Maharjan & Joshi, 2013). Decrease in crop yield forces for changing land use and can cause land use conflicts for better economic opportunities. These conflicts of land use interests can lead to informal use of land creating impacts on the formal land tenure arrangement (Okello, 2005). This study mainly focuses on assessing the land use changes and impacts on land tenure.

1.2. Background and justification

Climate is changing due to the increase in the emission of GHG which are mainly due to anthropogenic activities such as land use changes, infrastructure development etc. (UN-REDD, 2009). The effects of climate change are rise in temperature, glacier melting, droughts, floods, landslides, erosion etc. and these effects act as the drivers for land use change (Pollner, Watson, & Nieuwejaar, 2010).

Climate change adaptation is the systematic way of adjusting and coping with the impacts caused by climate changes. Climate change mitigation is the way of reducing the climate change by decreasing the greenhouse gas emissions. Land use sector not only emits GHG but forest land use also sequesters carbon from the atmosphere. Land use sector plays an important role in climate change adaptation and mitigation (Quan & Dyer, 2008). Adaptation to climate change are strategies to reduce the impacts of climate change while mitigations are strategies to reduce the energy uses and GHG emissions by increasing the carbon sink. The study shows that farmers try to adapt climate change with their local knowledge such as mixing of crops, changing of planting season & changing the crops for increasing agriculture production (Mensah, Vlek, & Carthy, 2012). The study conducted in Nepal indicates that policy and institution has vital role for climate change adaptation (Pradhan, Khadgi, Schipper, Kaur, & Geoghegan, 2012).

Land administration is the *"process of determining, recording, and disseminating information about the ownership, value, and use of land when implementing land management policies"* (UNECE, 2005). The study by Enemark (2014) also indicates that good land administration plays a key role for supporting environmental management and sustainable land administration provides the spatial information about land use and land tenure which can be used for developing strategies for climate change adaptation and mitigation. Further, cadastral data, land tenure, land use and land administration systems in the context of climate change can return tenure security (Arial, Lau, & Runsten, 2011). Climate change data can be integrated with the cadastral data containing the information building codes and tenure for developing strategies for climate change adaptation (FIG, 2014; Vranken & Broekhof, 2012). Carbon reporting consists of land use and changes in land use is dependent on land tenure as well. Linking land use change with the carbon provides the main concept for the formulation of climate change adaptation and mitigation strategies (Mitchell & Zevenbergen, 2011). Thus, land use and tenure are the important function of land administration in the context of climate change as well. Land use conflict arises due to degradation of resources especially

limited land resources suitable for farming and herding. Farmers and emigrant tries to settle in the productive land by informal claim on land by subdivision, lease or sharing of crop for their livelihood which creates impacts on formal land tenure (Campbell, Gichohi, Mwangi, & Chege, 2000).

According to IPCC (2007b), there will be 0.1^0c global rise in temperature per decade if the GHG emission is kept same as the year 2000. According to FAO (2010) temperature in Nepal rises at 0.41 ^{0}c per decade and in long period of time this rise in temperature could affect the agriculture land use. The recent study in Nepal also indicates that there is 0.06^0c rise in temperature per year (Gentle, Thwaites, Race, & Alexander, 2014). The study conducted in the middle hills of Nepal also indicates that there is an increase in temperature and *Chepang* (indigenous) community are coping with conventional judgement of changing land use (Piya, Maharjan, & Joshi, 2013). The study carried out in Koshi Basin, Nepal also shows that there is also increase in temperature and is affecting crop production (Bhatt, Maskey, Babel, Uhlenbrook, & Prasad, 2014). These studies reveal that Nepal is facing an increase in temperature which affects the agriculture land use significantly. Therefore, these changes in climate could change land use and also could impact land tenure. In this regards, scientific research for assessing changes in land use and impact on land tenure in the context of climate change is fruitful.

1.3. Research problem

Main occupation of the Nepalese people is agriculture. Livelihood of about 80% of population dependents on agriculture and it contributes 40% of the Gross Domestic Product (GDP). Agriculture of Nepal is highly dependent on the topography, climate and weather. It is reported that changes in agriculture land use are mainly due to decreased crop production which is related to increase in temperature and decreased rainfall (Manandhar, Vogt, Perret, & Kazama, 2011). The recent study in three different geographical regions of Nepal by Chapagain and Gentle (2015) also indicates that there is an increase in temperature and erratic precipitation. This rise in temperature and erratic rainfall is decreasing the production of crops, abandonment of the agricultural land and increase in food crisis which forces the people for migration in search of employment.

The study of Acharya and Kafle (2009) indicate that siwalik hills and middle mountain region in Nepal are suffering from land degradation problem due to the effects of change in temperature and rainfall. The impact of land degradation is the decrease in crop production and it also forces for changing the agricultural land use. The changes in agricultural land use could have a significant impact on land tenure e.g. changes in agriculture land use could change the land tenure and could also enhance conflict with using the natural resources. Therefore, in a long period of time there could be a problem in security of land tenure.

1.4. Conceptual framework

The conceptual framework shows main four pillars as concepts of the study and interaction between these pillars in relation to the research problem. Figure 1 given below, indicate that climate change not only causes land use change but also affects people's livelihood and eventually land tenure. Changes in land use may change the emission of GHG which may cause change in climate.

Change in agriculture land use could affect crop production and could impact on people's livelihood. On the other hand people can also change the land use for better socio-economic condition. Furthermore, land use change and livelihood could affect land tenure and changes in land tenure could also affect the livelihood and land use.

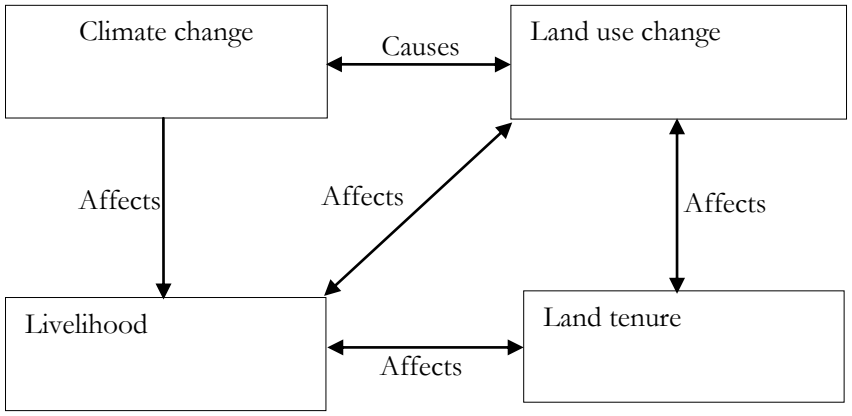

Figure 1: Conceptual framework

Therefore, the research assesses the changes in land use and its impacts on tenure. The study also assesses whether there is any indication of climate change in the area. Further, the hypothesis of the study is to test whether the land tenure is dependent factor on the land use change caused by climate change or not.

1.5. Research objectives

1.5.1. Main objective

The main objective of the research is to identify the changes in land use and its socio-economic impact on land tenure in the context of climate change.

1.5.2. Sub- objectives

i. To review the impacts of climate change on land and livelihood.
ii. To identify the changes in land use.
iii. To identify the conflicts and impacts of land use change on land tenure.

1.6. Research questions

i. To review the impacts of climate change on land and livelihood

1. What are the impacts of climate change on agricultural land use?
2. How does it effect on the people livelihood?

ii. To identify the changes in land use.

3. What are the driving forces for land use change?
4. What are the land use change pattern from past to recent years?

iii. To identify the conflicts and impacts of land use change on land tenure

5. Is climate change really taking place in the recent past?
6. What are the land tenure system in the study area?
7. What are the impacts of land use change on land tenure in the study area?

1.7. Hypothesis

Following two hypothesis were used to test the independency of land tenure and land use change caused by climate change at 95% confidence level and the significance level, α=0.05

Null hypothesis (Ho): Land tenure is independent on changes in land use caused by climate change.
Research hypothesis (Ha): Land tenure depends on changes in land use caused by climate change.

1.8. Research design

1.8.1. Research method and approach

Research method is the systematic way of collecting and deriving useful information from the data. Based on the objectives of the study both desk study and a field study are carried out. Desk study provides in depth understanding and information on the concept of the study for addressing the objectives of the research from the relevant literatures. Field study approach also identifies in-depth information from the site specific for investing the real situation for addressing the research objectives (Cavaye, 1996). The main specific methods for addressing the research questions are as follows:

1) Literature review and desk study:

Literature review and desk study is conducted to build the theoretical background. Research questions 1 and 2 are addressed by the relevant literature review and desk study of scientific literatures, journal articles, books, reports, publications etc.

2) Land use change analysis:

This method is used to analysis and identify the changes in land use in the study area by image processing and spatial analysis of temporal satellite images. Research question 4 is addressed by this method.

3) Analysis of meteorological data:

Long term meteorological data (temperature and rainfall) are analysed to identify deviations in temperature and rainfall from long term average temperature and rainfall. Interpolation of the average temperature and rainfall provides the spatial pattern of temperature and rainfall. Research question 5 is addressed by analysis of meteorological data.

4) Analysis of interview and observation:

Analysis of face to face interview is carried out to extract the in-depth information about socio-economic condition, livelihood of the people, land use change, climate change, and impacts of land use change on land tenure in the study area. Research questions 3, 6 and 7 are addressed by analysis of interview and observation. Following research design matrix (Table 1) provides the detail overview of the research.

Further, detail discussions on all the methods and materials applied for addressing the research questions are presented in the chapter 3.

Table 1: Research design matrix

Main objective	To identify the changes in land use and its socio-economic impact on land tenure in the context of climate change			
Sub-objectives	Research questions	Required data and software	Method of research	Anticipated result
1. To review the impact of climate change on land and livelihood	1. What are the impacts of climate change on agricultural land use?	Scientific literatures, journal articles, books, reports, expert knowledge	Literature review and desk research	1. Identified impacts of climate change on agriculture land use
	2. How does it effect on the people livelihood?			2. Identified impacts of climate change on people's livelihood.
2.To identify the changes in land use	3. What are driving force for land use change?	Interview data and observation	Analysis of the interview data and observation.	3. Identified driving forces for land use change.
	4. What are the land use change pattern from past to recent years?	Landsat image, ground truth, GPS, ArcGIS, Envi, Erdas Imagine	Image processing and spatial analysis.	4. Land use change map of the study area.
3. To identify the conflicts and impact of land use changes on land tenure	5. Is climate change really taking place in the recent past?	Meteorological data	Analysis of Meteorological data	5. Information on climate changes in the study area.
	6. What are the land tenure system in the study area?	Interview, and observation	Analysis of interview data and observation	6. Information on different land tenure in the study area.
	7. What are the impacts of land use changes on land tenure in the study area?			7. Information on impacts of land use changes on land tenure in the study area.

1.8.2. Study area selection

Lalitpur district in Nepal is selected as the study area for this research in the middle mountain geographic region of Nepal with high land degradation problems. Two VDCs Chapagaun and Lele were selected for conducting the fieldwork as they are located in peri-urban and rural area respectively with high land use change rate. Thus, this area is suitable for assessing changes in land use and its impact on tenure.

1.8.3. Research implementation phases

The details of research implementation phases (Figure 2) are as follows:

1) Pre-field work: In this phase research proposal was developed. Literature review and preparation for field work such as developing questions for the field interview with household, local governmental official, central governmental official, and detail planning for data collection were executed in this phase.

2) Field work: In this phase both primary (interview and ground truths) and secondary (meteorological data, high resolution satellite image) data were collected from the field.
3) Post-field work: In this phase desk study, processing of data, analysis of data and synthesis of the results and discussions of the key findings of the study were also carried out for generalizing conclusions and recommendations of the research.

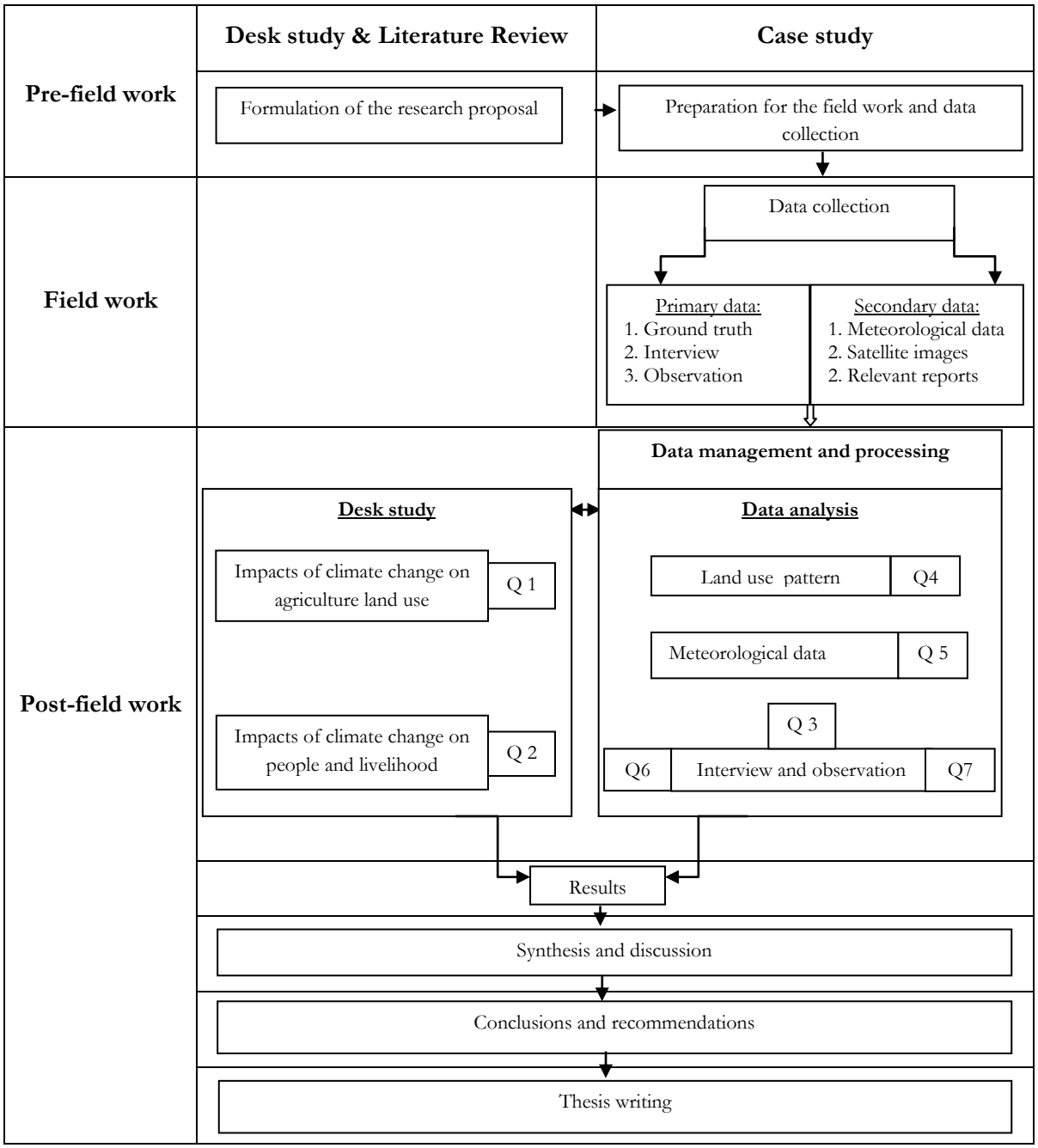

Figure 2: Research implementation phases

1.9. Thesis structure

Chapter 1: Introduction

This chapter in brief contains introduction, background and justification of the research, research problem, conceptual framework, main objective and sub-objectives of the research, research questions, hypothesis, research design and thesis structure for the research.

Chapter 2: Literature review: Theoretical background

This chapter includes the literature review for the impacts of climate change on land and livelihood, land use change and impact on land tenure, land use change detecting technique by using remotely sensed temporal images and climate change, land use and tenure issues in Nepal. This chapter also includes indicators for assessing the livelihood, land use change, land tenure and climate change.

Chapter 3: Methodology and data collection

This chapter includes a description of the study area, materials and methodology for data collection and analysis of both primary and secondary data. This chapter also includes preliminary processing of the collected data.

Chapter 4: Data analysis and results

This chapter contains the analysis and results of the classification of temporal satellite image, land use change detection, meteorological data, household interview, interview with local governmental officials and interview with the central governmental officials. Further, this chapter includes the statistical analysis for testing the hypothesis.

Chapter 5: Synthesis and discussion

This chapter includes the combination of results for land use change, climate change, and conflicts and impacts of land use change on land tenure based on objectives of the study. This chapter also includes discussions on land use change pattern, climate change pattern and conflicts and impacts of land use change on land tenure for addressing the objectives of the study.

Chapter 6: Conclusions and recommendations

This chapter includes the conclusions of key findings of the study based on discussions of the study. This chapter also includes the conclusion for the research hypothesis and recommendations for further study.

2. LITERATURE REVIEW: THEORITICAL BACKGROUND

2.1. Introduction

Climate is changing due to the increase in emission of GHG from different sectors. This increasing emission increases global temperature and ultimately causing global warming. Global warming has impacts on weather which affect land and land resources (IPCC, 2014). The objective of this chapter is to understand the climate change issues and its impact on land use, livelihood and land tenure. This chapter focuses on in depth understanding and answering of the following questions.

1. What are the impacts of climate change on agricultural land use?
2. How does it affect people livelihood?

For answering the above mentioned questions, scientific literatures, journal articles, books, reports, policy document with focus of concepts related to climate change, land use change, livelihood and tenure are reviewed. This chapter consists of seven sections. Section 2.2 focuses on climate change, its cause and impacts on land and livelihood in the rural area. Section 2.3 focus on land use change and impact on land tenure. Section 2.4 includes land use change detection from remotely sensed temporal images, section 2.5 includes land use, land tenure, and livelihood issues in Nepal. Section 2.6 includes indicators for assessing livelihood, land use change, land tenure and climate change for the study. Finally, section 2.7 includes concluding remarks for this chapter.

2.2. Climate change and impacts on land and livelihood

2.2.1. Climate change and its cause

Climate change is the change in the weather pattern for a long period of time usually from decades to millions of years (IPCC, 2007b). Further, Crowley (2000) has defined climate change as the rise in temperature due to the emission of GHG and decrease in carbon sink in the earth. Major cause of climate change is due to the emission of GHG by human activity on the earth such as energy use during transportation, burning of fossil fuels, deforestation, land use change usually from agricultural to urban.

Figure 3: GHG emissions from different sector (IPCC, 2014)

Figure 3 shows that GHG emission from the energy sector is 35%, from agriculture, forests and other land use is 24%, from industry is 21% from transport sector is 14% and from building sector is 6.4% (IPCC, 2014).

Synthesis report, IPCC (2014) also shows that there is an increase in total annual anthropogenic GHG emission from 1970-2010. Figure 4 shows the highest emission of GHG is 65% of CO2, fossil fuel, industrial emission and lowest emission is 2% by F-gases (Fluorinated gases). These emissions have effects on climate therefore, globally averaged land and ocean surface temperature is increasing from 1850 to 2010 by 0.3 °c. Further, global temperature is expected to rise 2 ^{0}c - 6 ^{0}c by 2100 (IPCC, 2014). The increase in temperature affects the rainfall pattern and could also affect land and livelihood as well.

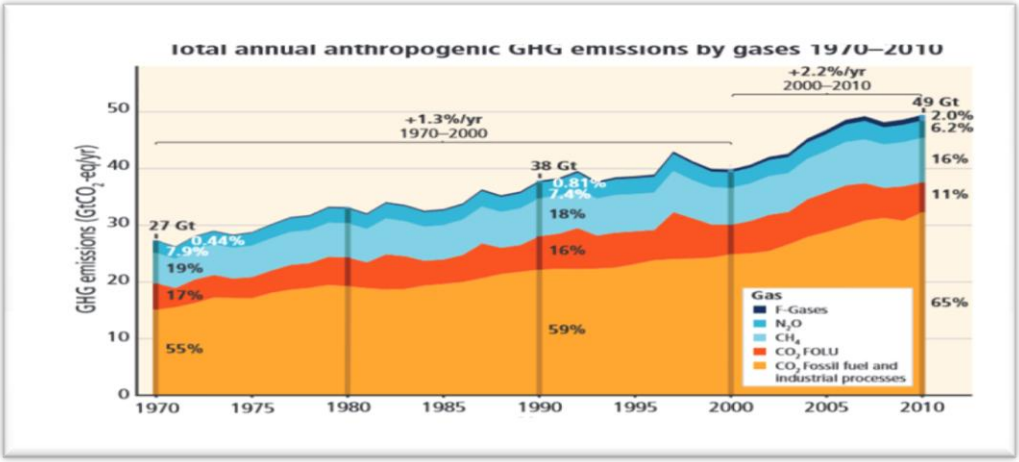

Figure 4: Emissions of GHG (IPCC, 2014)

2.2.2. Impacts of climate change on land

Climate change has impacts on different sector such as agriculture, forestry, water, coastal, and energy and these impacts directly affect people's livelihood. All impacts except energy are directly related to land (Robert, 2011). Agriculture and forestry are important land use. Water plays an important role for irrigation and decrease in water affects the crop yield.

2.2.2.1. Impacts of climate change on urban land

Major cause of GHG emission is contributed by energy, industry, transport and building sector as discussed in section 2.2.1. These sectors are usually in the urban land. Climate change could cause natural disasters on land and land resources such as landslides, floods, erosion, droughts etc. that make urban life difficult (Lohani, 2007). Droughts causes deficiency of water for drinking and plant growth in the urban land. In addition, high rainfall may cause landslide and flooding affecting the urban industries, human settlements, as well (IPCC, 2007a). Further, low altitude land on the coastal area may suffer from flooding due to rise in sea level which could also damage infrastructures such as buildings, and transportation system in urban land (Revi et al., 2014)

2.2.2.2. Impacts of climate change on rural land

Impact of climate change is high in agriculture land use. There are normal temperature and rainfall pattern for normal growth of the crop. Crop production is decreased if the temperature and rainfall pattern is deviated from the normal pattern for the normal growth of crops. If the temperature increases continuously, farmers change the land use by modification of the agriculture. Further, if the production is not satisfied, the farmers may migrate from the area as well (IPCC, 2007a)

Climate change has impact on agriculture based on topography. The study by Mendelsohn and Dinar (2001) in India and Brazil show that rise in temperature is harmful to agriculture in low altitude land. However, studies in the United kingdom (Maddison, 2000) and Germany (Lippert, Krimly, & Aurbacher, 2009) shows the mixed effects of increased temperature in cold countries. The study also shows that mild climate scenarios in the USA could make a loss of 12% where as harsh climate scenarios could make a loss of 50% of crop yield (Kurukulasuriya & Mendelsohn, 2008). Climate is the main factor that has an impact on weather pattern which affects the agriculture and crop production (Maharjan & Joshi, 2013). Furthermore, IPCC, (2007) reports also shows that only 2 ^{o}c rise in temperature can highly affect the crop production (IPCC, 2007b). Though, agriculture is influencing climate change by emissions of GHG, the effect of climate change is high on agriculture (Pye-Smith, 2011).

The recent study in West Africa shows that there is a decrease in crop production due to the effect of climate change which forces for the modification of agriculture land use to overcome the negative effects of climate change (Challinor, Parkes, & Villegas, 2015). Increase in temperature causes more evaporation and scarcity of water for irrigation in the agriculture land, this would force farmers to change land use and to shift from irrigated to rain-fed agriculture (IPCC 2007 a). Due to the effects of climate change and increase in temperature, glaciers melts which could also increase the sea level rise by 0.3-7m and which could cause flooding (IPCC, 2007b). Climate change has impacts on land use change by modification and changing the cropping area which could affect access to land, access to water, migration, and security of land tenure system as well (Quan & Dyer, 2008). Climate change could also lead to tropical cyclone, droughts, landslides, thunderstorms etc. The study shows that with increase in temperature, the possibility of thunderstorms in the United States is increased by 70% (Trapp et al., 2007). These, extreme effects could affect land use if they increase in the same area regularly. The drought area can be changed to grazing land instead of cropping.

2.2.3. Impacts of climate change on livelihood

Livelihood is the way of securing basic needs of life such as food, water, and clothing. Livelihood is closely related to the source of income for supporting the life (UNDP, 2010). Household size, occupation, household income, household assets, food security, community participation are the indicators for assessing the peoples livelihood (Gillingham & Isalm, 2004). Natural disasters resulted from climate change affects people by economic loss, infrastructure losses and loss of shelter and life as well (Mosha, 2011). Furthermore, as the temperature rises it creates several effects e.g. glacier melts, sea level rise that could lead to natural disasters such as landslides and floods, which force people to shift to safe area for coping the impacts of the climate change (Maldonado, Shearer, Bronen, Peterson, & Lazrus, 2013).

The International Organization for Migration (IOM) has pointed out that climate change can cause environmental degradation and natural disaster which could cause the migration of the victims and such migration affects ecosystem services and livelihood of the people (IOM, 2010). Further, the study in Nigeria, also shows that climate change has impacted on livelihood of people and households are facing difficulties for adapting the effects of climate change due to poverty (Amos, Akpan, & Ogunjobi, 2013). Thus, poverty is directly related to the capacity for combating climate change. Livelihood of people are affected more in developing countries as they have weak economic capacity to cope with the climate change (Burton, Diringer, & Smith, 2006). Further, the study by Gentle and Maraseni (2012) in Nepal also shows that climate change is affecting the rural people dependent on agriculture for their livelihood. Droughts and erratic rainfall are not only degrading the natural resource but also decreasing the agriculture products and the grazing land. Climate change has high impacts in poor people to run their livelihood and children are sent to labour work instead of school for their survival. Land is the main source of livelihood as land provides food, source of credit and housing. Climate change can also lead to loss of land and is

affecting the formal land tenure when there are no substitutes to livelihood (Reale & Handmer, 2011). Deforestation decreases the forest product, such as fuel wood, food for livestock and decrease in forest could increase the conflict for clear use of forest and ultimately affect the people's livelihood.

People livelihood in the rural area is directly affected by the impacts of climate change by a decrease in crop yield due to the increase in temperature and land degradation effect. The major impacts of climate change on livelihood are decrease in the income from farm due to decreased production, increase in epidemic disease due to increase in temperature, decrease in socio-economic activity and climate change also affects people's quality of life (Robert, 2011).

2.3. Land use change and impacts on land tenure

2.3.1. Land tenure:

Land tenure is way of holding land and it shows the relationship between people (individual or group) with land resources. Land tenure acts as an institution and guideline for defining the access to land, use of the land, control over land and also for transfer of the land in the society. Thus, it also guides the right, restriction, and responsibilities of the people in relation to the land (Palmer et al., 2009). Land tenure is an important aspects for livelihood especially for those whose livelihood is dependent on land and land resources. FAO voluntary guidelines also encourage tenure security, land use rights and land access in the context of climate change, with a priority on poor people (FAO, 2012). There are different forms of land tenure depending on the country context. Recently, there are four types of land tenure such as private, state, common and open access. There are several forms of land tenure systems such as non-formal (de facto) tenure, private freehold and leasehold, public freehold and leasehold, communal ownership (tribal and neighbourhood) (Tuladhar, 2004).

Security of tenure is the enjoyment of right to land and it is the people's perception for the enjoyment of production from the land and land resources (FAO, 2002). Land use planning and secure tenure plays an important role in improving the livelihood of the people. Changes in land use affect the production which pressurizes the livelihood and ultimately weakens the security of tenure (Eugene et al., 2015). Tenure security is the right on property and perception on the right to land which is recognized by the quality (or bundle) of rights and length of rights which together establish the assurance. Thus, increased in crop production increases the tenure security (Roth & Haase, 1998).

2.3.2. Land use change

Land use is the purpose in which human make use of land and land resources. This is the use of land cover by human activity. Land use change involves either conversion of one type of land use to another type of land use or modification of certain type of land use. Major driving forces for the land use change are demography, urbanization, economy, technology, climate change, energy transition, change in ownership and change in policy (Zondag & Borsboom, 2009). Land use sector plays an important role in relation to climate change as it not only emits carbon but it also removes carbon present in the atmosphere (Molen & Mitchell, 2014). Thus, land use perform both adaptation and mitigation for climate change.

2.3.3. Impacts of land use changes on tenure

Impacts of land use change are changes to landscape and degradation of landscape (Malek & Boerboom, 2015). Changes in land use can cause impacts on economy, society, and environment. Social impacts are the effects on employment, health and safety. Economic impacts are changing agriculture productivity affecting food security and economic growth. Environmental impacts are the degradation of soil quality and natural resource such as water (Helming, Soba, & Tabbush, 2008). Socio-economic impacts of the

land use change also affect land prices, employment, availability of agricultural workers, community group membership (Schirmer, Williams, & Dunn, 2009). Thus changes in land use affect the socio-economic elements and ultimately can affect tenure in many ways such as conflicts of land use, clear land use right, informal land tenure arrangement and insecurity in tenure. Figure 5, relates the climate change and its effects on land resources and tenure.

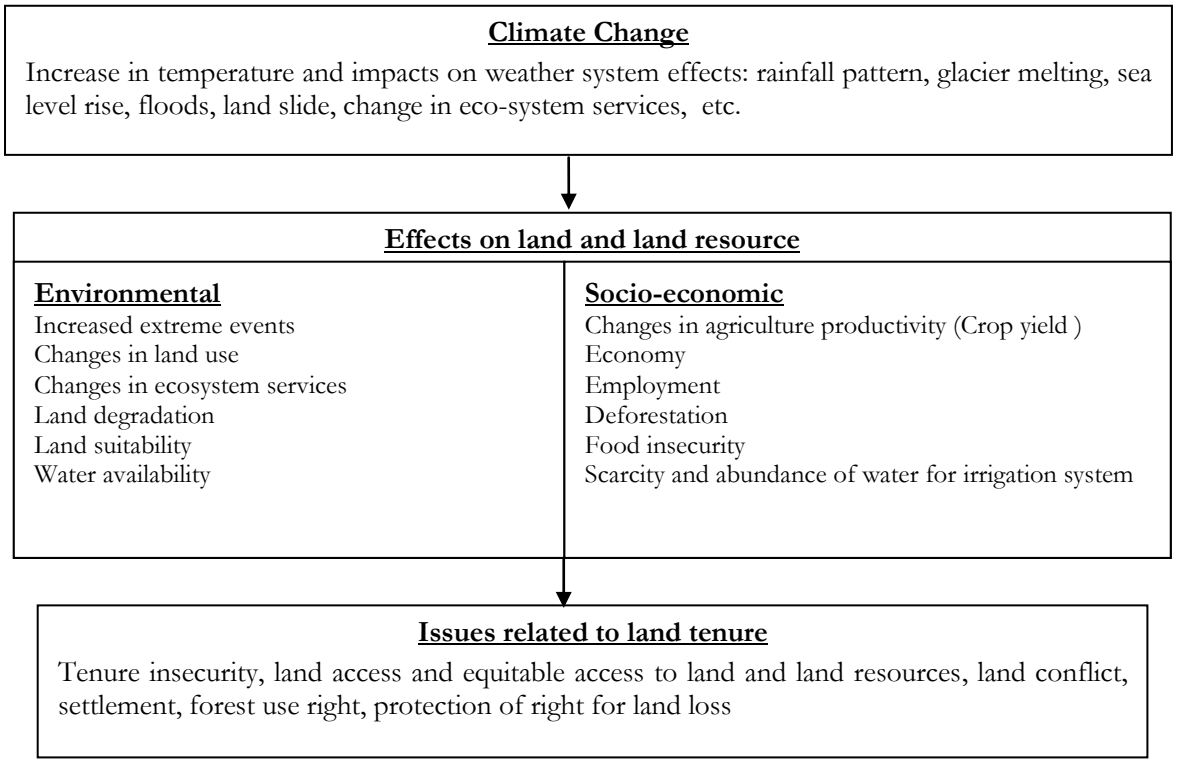

Figure 5: Effects of climate change on land and land resources and issues related to land tenure

2.4. Land use change detection by using remotely sensed temporal images

Various types of remotely sensed temporal satellite image with high resolution and low resolution are spatially analysed for land use change detection. Multi-temporal classified image of the same area are compared for detecting land use change. From Landsat image, classification of urban or built-up land, agricultural land, forest land, water, wetland, barren land and perennial snow or ice can be achieved (Anderson, Hardy, Roach, & Witmer, 1976). Classification of an image is the technique applied to extract the information from the remotely sensed satellite image. Basically there are three types of image classification techniques which are as follows:

1. Unsupervised image classification: in this method of classification, information are extracted directly by software based on reflection properties of the materials.
2. Supervised classification: this classification technique is based on training samples defined by the user.
3. Object based image classification: this classification method is based on the object in the image and rule sets defined by the users for the process multi-segmentation.

Usually training data for the different land cover are used for pixel based supervised image classification and testing data for the different land cover are used for accuracy assessment of classification (Sun, Ma, & Wang, 2009). Furthermore, there are various algorithm for image classification such as maximum likelihood (pixels are classified based on highest probability of that class and based on the training samples), support vector machine (is also based on the training samples), spectral angle mapper (based on

the spectral angle between reference vector and pixel vector) (Mallinis & Koutsias, 2012). Accuracy of the classified image is determined by comparing it with the reference data that are correct to the ground situation and are summarized with the confusion matrix. The use of Digital Elevation Model (DEM) and other supporting spatial data during the classification increases the accuracy of image classification (Fahsi, Tsegaye, Tadesse, & Coleman, 2000). Classified images based on the land cover are compared for assessing the changes in land use. Land use change detection can be performed on pixel by pixel basis. There are various methods for land use change detection such as image differencing method (the change is determined by the difference of two images), image regression (based on regression function), image ratioing (based on ratio of temporal images in which subtraction is carried out band by band), vegetation index differencing (based on vegetation index of temporal images), change vector analysis (based on change in magnitude and direction of temporal images). Results of land use change detection by image differencing method is simple and easy to understand (Lu, Mausel, Brondizio, & Moran, 2004).

2.5. Land use, land tenure and livelihood issues in Nepal

2.5.1. Land tenure in Nepal

Land is regarded as important property for livelihood of people in Nepal. Socio-economic activity of rural people is highly dependent on land. Landless people have also informal land tenure by tenancy, lease or sharing of crops (*Adhiya*). Poverty, health and education are closely related to land tenure in Nepal (Sharma, 2000). There are two forms of land tenure in Nepal *Guthi land* and *Raikar land*. *Guthi land* are trust land administered by the state and are sometimes owned by private for religious activities. *Raikar land* are further classified as *Private land*, *Public land*, and *Government land*. Ownership right with *Raikar land* is the strongest form of land tenure in which land owner can use, hold, inherit, sell, achieve benefits from the land, as long as the owner pays an annual tax to the government.

Figure 6, shows the land tenure system in Nepal. *Private land* is the land owned by individual, jointly, company or institutions by paying annual tax to the government, *Public land* is the land for use of public purpose such as playground, temple, roads and Government land the land for which government holds the ownership e.g. government office, forest etc. (Tuladhar, 2004)

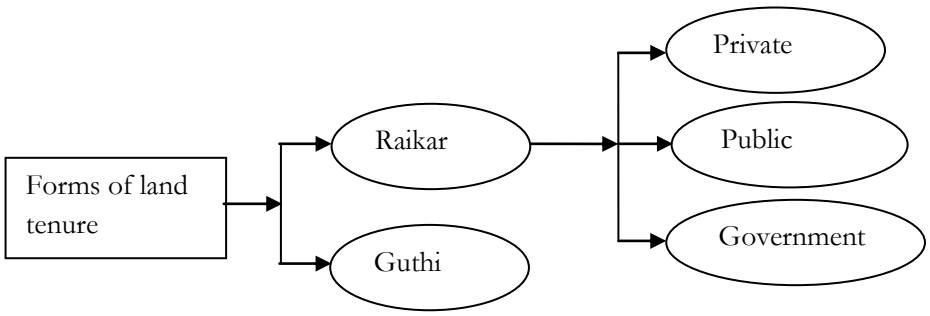

Figure 6: Land tenure system in Nepal (Tuladhar, 2004)

2.5.2. Land use in Nepal

In terms of land use, Nepal has 27% agriculture land, 40% forest, 12% pasture land, 18% snow covered and rocky land and 3% water area. Land in Nepal is classified in agriculture, residential, commercial, industrial, forest, public use, and other zone (Source: National land use policy, 2012). Changes in land use can be used to detect the influence of human activity on land and land resources. A large quantity of conflicts on land and land use is observed in Nepal. Sources of these conflicts are division of land between owner and tenant. Landless and unequal distribution of land is also creating conflict in using land by

squatter settlement and forest encroachment (FAO, 2010b). The following Table 2, shows the changes in land use in Nepal from 1986-2000.

Table 2: Land use changes in Nepal (Source: ADB, 2005:32)

Land use category	1986		2000		Changes(1986-2000)	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Agriculture	3,461,069	23.52	4,150,979	28.1	689,910	19.92
Forest(including shrubs)	6,211,522	42.20	6,788,292	46.12	576,770	9.29
Other	5,045,522	34.28	3778829	25.67	(1,266,680)	25.11
Nepal	14,718,100	100	14,718,100	100	-	-

Forest area is increased by 25.5% through the implementation of Community Forest (CF) between the period 1978 to 1992 and the cultivated area was also increased by 0.5% (Gautam, Webb, & Eiumnoh, 2002). Further, CF management reaches its peak in 1990's and study in middle hills in Dolakha district shows the positive results for increasing the forest (Niraula, Gilani, Pokharel, & Qamer, 2013).

According to the land (survey measurement) act 1963 and land (survey measurement) rules 1964, agriculture land use is graded as 1 and commercial and residential land use is graded as 2 in Nepal. These land use are further ranked from Class A to Class E. Table 3, gives the details information on different criteria used for marking in order to classify of land use in Nepal. Land is classified based on marks obtained from the criteria as mentioned in the figure. Land obtaining 46-50 marks based on the different criteria are assigned to a class (1 Class A), indicating high value land. Similarly land obtaining 01-15 the marks are assigned to a class (1 Class E) indicating low value land. For residential and commercial land, classification is also based on the marks obtained based on the different criteria e.g. land obtaining 41-50 marks are assigned to a class (2 Class A), indicating high value land and similarly the land obtaining 01-10 marks based on different criteria are assigned to a class (2 Class E), indicating low value land. These classifications of the land are especially for valuation of land and tax collection purpose. Therefore, these land use classification are mentioned in a land ownership certificate and land registration certificate (Acharya, 2008).

Table 3: Land use classes in Nepal (Acharya, 2008)

Agriculture land use			Commercial and residential land use		
Classification	Marks	Criteria	Classification	Marks	Criteria
1 Class A	46-50	Irrigation facility, road access, crops, soil types, altitudes from mean sea level, agriculture market facility, and landscape	2 Class A	41-50	Access to road, water facility, electricity facility, location, transportation, communication, sewerage, and settlement
1 Class B	36-45		2 Class B	31-40	
1 Class C	26-35		2 Class C	21-30	
1 Class D	16-25		2 Class D	11-20	
1 Class E	01-15		2 Class E	01-10	

2.5.3. Livelihood in Nepal

More than 80% of populations in Nepal are dependent on agriculture, which contributes 43% of the GDP. Land is regarded as property and means for survival in Nepal. Livelihood of the people are dependent on agriculture. Nepalese agriculture depends on natural rainfall for irrigation. It is reported that 38% of the population is below poverty line and livelihood of the people are also dependent on the forest for fuel wood, timber and fodder (Regmi, Albano, & Kumar, 2007)

Due to great deforestation in Nepal CF concept was introduced in 1970 and 25% of the forest in Nepal are CF. People are involved in CF to improve their household economy and these CF are not only reducing the poverty but also helping in nature conservation and carbon sink in Nepal (Hussin & Gilani, 2011). CF is playing an important role in reducing the poverty in Nepal (Dev, Yadav, & Soussan, 2003).

Climate change is affecting crop yield and the livelihood of poor people is mostly affected by changes in the weather pattern. Research conducted in Nepal also shows that poor families are more affected than the rich families from climate change (Gentle et al., 2014). These impacts of climate change on the livelihood of people forces for changing land use for improving the livelihood resulting socio-economic impacts on land tenure.

2.6. Indicators of climate change, land use change, livelihood, and land tenure

In this section, we develop indicators for assessing livelihood, land use change, land tenure and climate change based on the concept and objective of the study, with the theoretical background as discussed in the above section. Indicators help in quick overview and is also used for assessing the phenomenon in a simple way (UNDP, 2006). Indicators are used for data collection in the field for assessing the information about the phenomenon, socio-economic aspects of the household based on the concepts of the study (Tittonell et al., 2010). Indicators were used for developing structured questions for the interviews and were also used for analysis of the data. The following Table 4, includes the indicators developed for assessing livelihood, land use change land tenure and climate change.

Table 4: Indicators based on concept of the study

Concepts	Indicators
Livelihood	Household size Occupation Household income Household assets Food security Community participation
Land use change	Changes in agriculture land use Changes in forest land use Changes in urban land use Modification in agriculture land use (e.g. cereal crops to vegetable or vice versa) Driving force for land use change Demography Urbanization Economy Ecosystem services Land policy Ownership change Climate change
Land tenure	Ownership right Lease hold Adhiya (Sharing of crops) Tenancy right
Climate change	Change in temperature Change in rainfall pattern

2.7. Concluding remarks

This chapter builds theoretical background for the study by reviewing literature such as scientific journal, articles, books, publications and reports based on the concepts of the research. Literatures suggests climate change is an increase in temperature due to emission of GHG and land use sector contributes 24% of the total GHG emission, is also capable of removing the carbon from the atmosphere. Climate change affects on weather pattern which ultimately impacts agriculture, forest and water. Thus, these impact further affects agriculture land use and people's livelihood by decreasing and damaging the crop yield. This chapter also reviews the techniques for detecting land use change by remotely sensed temporal images and socio-economic impacts of land use change on land tenure.

The major land tenure system in Nepal are *Guthi land* and *Raikar land. Guthi land* is especially for religious activities whereas *Raikar land* is for private, public and government land activities. The study in Nepal, by FAO indicates that agriculture and forest land use were increased from 1986 to 2000. Livelihood of the Nepalese people are dependent on agriculture and forest product for socio-economic activities. Further, this chapter also develops indicators for livelihood, land use change, land tenure and climate change based on the concept and objective of the study. The next chapter focus on methodology and data collection for assessing the changes in land use, indication of climate change and impacts of land use change on tenure in the context of climate change.

3. METHODOLOGY AND DATA COLLECTION

3.1. Introduction

This chapter focus on materials and methods applied for answering the research questions in order to achieve the objective of the study. This chapter consists of 8 sections. Section 3.2 provides information about the study area and selection of the sites for conducting the field work. Section 3.3 includes various materials and resource used for the study, section 3.4 includes methods used for answering the research questions, section 3.5 includes pre-field work planning and preparation for data collection, section 3.6 includes collection of field data for applying the research method to answer the research questions, and section 3.7 includes pre-processing of both satellite image and data collected from the field. Finally section 3.8 presents the concluding remarks of this chapter.

3.2. Study area

Nepal, a land locked country with a surface area 147181 Sq.km has five physiographic regions such as Terai, Siwalik, Middle Mountains, High Mountains and High Himalayas (Source: Land Resource Mapping Project report, 1986). The study area is located in Lalitpur district which lies in the Middle Mountain region and has a high rate of land use change. The area is thus, very suitable for studying the changes in land use and impact on land tenure.

Geographically, Lalitpur district extends from 27°22' to 27°50' North and 85°14' to 85°26' East covering a surface area of 385 km^2. The elevation ranges from 457m-2831m above the mean sea level. The climate varies depending upon elevations e.g. tropical (elevation < 1000m), sub- tropical (with elevation 1000m-2000m) and temperate (elevation >2000m). In the Lalitpur district, agriculture land is 44%, forest is 53% and other land use comprises 3% (Source: Land Resource Mapping Project report, 1986).

Two study sites for detail field investigation were selected which are Chapagau and Lele Village Development Committee (VDC). Chapagaun VDC extends from 27°34'43" to 27°36'38" North and 85°18'48" to 85°20'56" East covering the surface area 6.18 Sq.km with elevation ranging from 1420 m-1764 m. Further, climate of Chapagaun VDC is sub-tropical and mean monthly maximum temperature 22.16^0 c. Lele VDC extends from 27°32'10" to 27°34'57" North and 85°17'19" to 85°22'58" East covering the surface area 25.16 Sq.km with elevation ranging from 1446 m-2378 m. Climate of Lele VDC is subtropical and monsoon and has mean monthly maximum temperature 21.95^0 c. (Source: VDC profile 2009/2010)

In Chapagaun VDC agriculture land use is 57%, forest is 26%, residential land use is 10% and other land is 7% whereas in Lele VDC agriculture land use is 29%, forest is 65%, residential land use is 2% and other land is 4%. Total number of households in Chapagaun and Lele are 2532 and 964 respectively. Socio-economic activity and livelihood of the people in both the VDC is highly dependent on agriculture. Further, agriculture acts as the main source food and income in both the VDCs (Source: National land use project report, 2014). From the above facts, VDC Chapagaun is with high agriculture land use and Lele with high forest. Land use is changing at a high rate in both the VDCs (Source: National land use project report, 2014). Thus, the two VDCs are very much suitable for assessing changes in land use and its impact on tenure. The following, Figure 7 shows the study area. The figure consists of a map showing Nepal, Chapagaun and Lele VDCs of Lalitpur district.

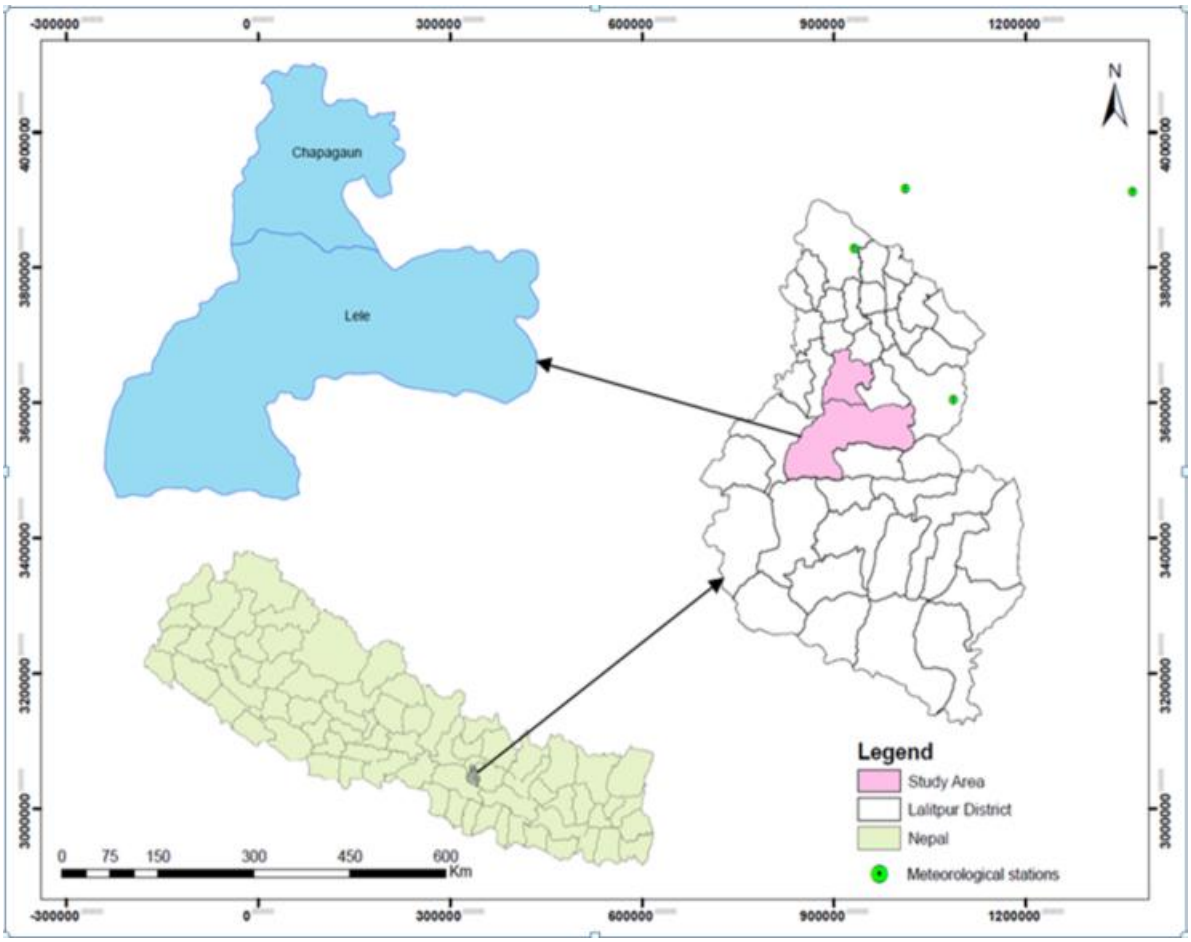

Figure 7: Study area

3.3. Materials

3.3.1. Resource used

Various hardware are used for the study such as laptop, GPS for ground truth collection, voice recorder for recording interviews, camera for taking photographs. Software and tools used are ArcGIS 10.3 for spatial processing and analysis of data, Erdas Imagine 2015.1 and ENVI 5.2 for digital image classification, Microsoft office 2007 (Word, PowerPoint, Excel etc.) for writing thesis, presentation, graphical representation of data, and SPSS version 23 for statistical analysis of the interview data.

3.3.2. Satellite data

For land use change analysis cloud free multi-temporal satellite data were acquired as from the year 1989, 1996, 2006, 2015 (Table 5). The imageries were selected from the same season in order to make the comparison easier. Landsat image was chosen because of availability of long temporal imageries with less than 10% cloud cover. Geo-referenced Landsat image scenes in Universal Transverse Mercator (UTM) projection system with zone 45 North and datum WGS 1984 were downloaded from the United States Geological Survey (USGS) from the website (http://earthexplorer.usgs.gov/). Atmospherically corrected reflectance image of the same scenes were also ordered from USGS and downloaded. Further, SRTM

digital elevation data at 30 m resolution was also downloaded from the USGS for the correction of atmospheric errors in the satellite image.

Table 5: Satellite images used for the study

Image and Spacecraft_Id	Acquisition date	Remarks
Landsat_5	02 Dec. 1989	-
Landsat_5	18 Oct. 1996	-
Landsat_5	30 Oct. 2006	-
Landsat_7	16 Nov. 2015	Image was used for making ROIs
Landsat_8	07 Oct. 2015	-
GeoEye-1	2 March 2013	For comparing classification

3.4. Methods

Research method is the systematic and scientific way of collecting and deriving information on the phenomenon. Based on the objective and research questions, this research is a combination of qualitative and quantitative method. Qualitative method is used for desk study and literature review to extract the information based on the concept of study for addressing research questions. For capturing data and identifying the real situation a field study in Nepal was studied. Quantitative method of research is carried out for image processing and spatial analysis of multi-temporal satellite image for detecting land use change.

Further, for identifying the drivers of land use, land tenure systems and impact of land use change on tenure in the study area is also studied by quantitative research method. Structured interviews were conducted for collecting the in-depth information of the field reality. Main methods of the research for addressing the research questions are as follows:

3.4.1. Methods related to research question on the impacts of climate change on agriculture land use and its effect on people's livelihood

Literature review and desk study method are used for in-depth understanding and answering the research questions related to the impacts of climate change on agriculture land use and its effect on people's livelihood. This method also improves the theoretical background and understanding on the concepts of study for answering the research questions 1 and 2. This method uses in-depth review and desk study of relevant scientific literatures, journal articles, books, publications, reports, documents etc. for in-depth understanding of impacts of climate change on land and livelihood

3.4.2. Methods related to assessing the land use change and its driving forces in the study area

Land use change analysis

Spatial analysis of remotely sensed temporal satellite data is used for assessing the changes in land use for answering the research question 4. First, of all the downloaded satellite image data were brought to same comparable units (i.e. spatial, spectral and radiometric resolutions). For land cover mapping in different years digital image classification techniques were applied. Landsat TM data from 2015 was classified using Maximum likelihood algorithm. In this method, all the cells are assigned to the particular class based on a training sample defined by the user and the spectral reflectance information of the cell. Thus, this method of classification is pixel based classification and depend on signature file created by the training samples. Further, the accuracy of the classified image is obtained by comparing the classified image with a separate set of test samples collected in the field.

For classifying, satellite images from the previous year's e.g. 1989, 1996, 2006 Spectral Angle Mapper (SAM) classification algorithm is used. This method of supervised digital image classification was chosen because training data collected from the field in 2015 could not truly represents all the details of the past years 1989, 1996, 2006 as we are interested in land use changes and training data of 2015 representing particular land use could be different land use in the years 2006 or 1996 or 1989. Thus, SAM classification algorithm is suitable for classifying the images from the past years.

This method of classification calculates the angle between each pixel test spectra and endmember reference spectra as shown in figure (Figure 8).

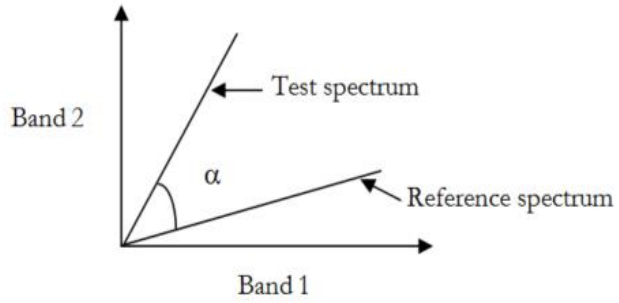

Figure 8: Angle between test and reference spectrum

Angle between the test and reference spectra is given by the following equation (Kruse et al., 1993):

$$\alpha = \cos^{-1}\left(\frac{\sum_{i=1}^{nb} t_i r_i}{\left(\sum_{i=1}^{nb} t_i^2\right)^{1/2}\left(\sum_{i=1}^{nb} r_i^2\right)^{1/2}}\right) \quad \text{.....1}$$

Where,

nb= Number of bands
t = test spectra
r = reference spectra

In this method, each land cover will be represented by a typical reflectance spectra, the so called endmember. Each unknown pixel is then classified based on its spectral angle with the reference spectra. Lower the angle higher is the matching with the reference spectra (Yonezawa, 2007).

Thus, for classification of the images from 1989, 1996, 2006, endmember spectra for SAM classification are created from landsat_7 image from the year 2015 with the training data collected in the field. Classified temporal satellite images with similar number of classes are compared for assessing the changes in land use over the periods. Figure 9, shows the detail flowchart of a process used for land use change detection.

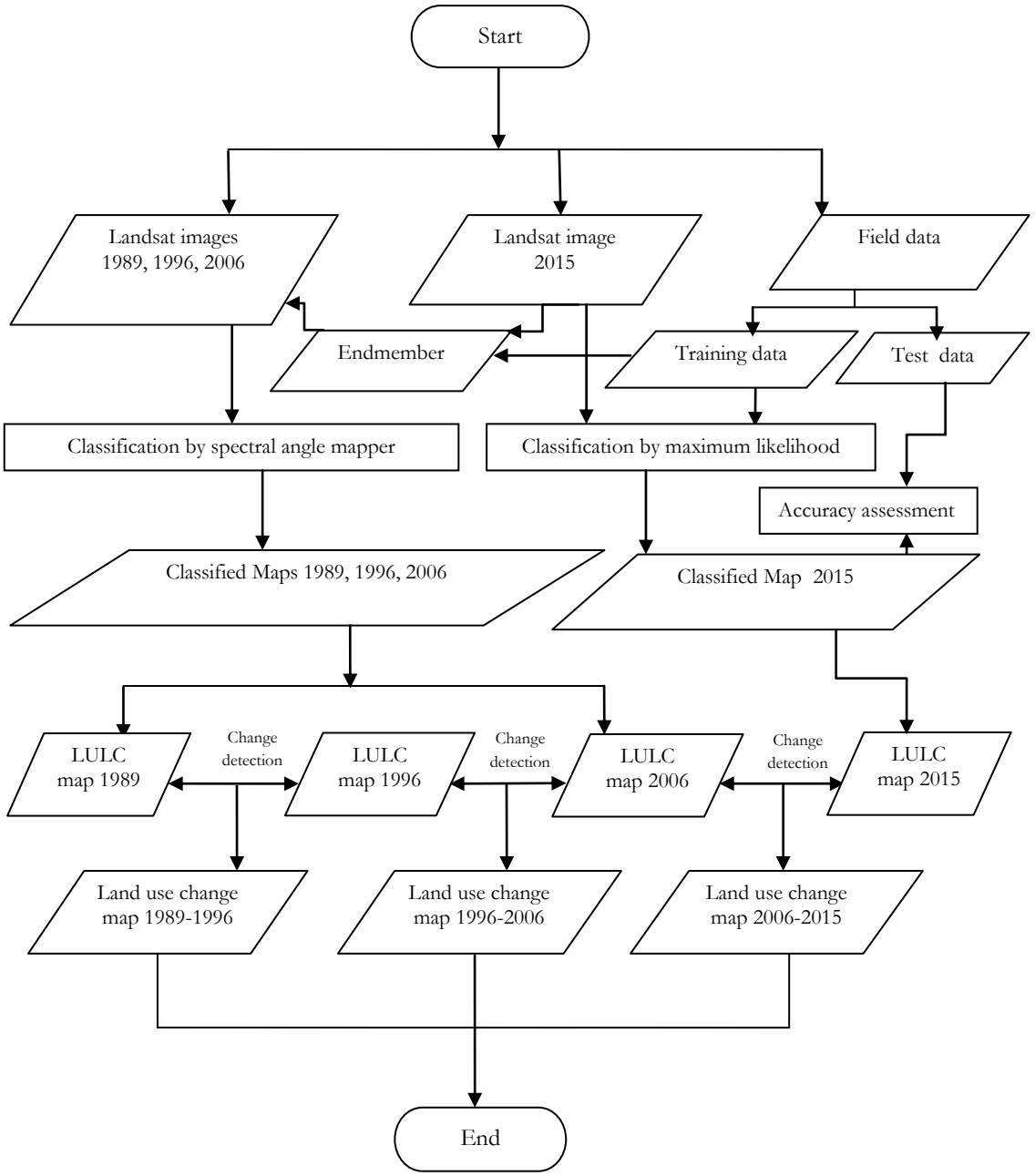

Figure 9: Flowchart of the process used for land use change detection

Driving forces for land use change

Analysis of face to face interviews were carried out in the field with households, local government officials and central governmental officials to collect data for identifying the main driving forces of land use change for answering the question 3. Structured interviews with households, interviews with local governmental officials, and interviews with central governmental officials were analysed for identifying the major causes of land use change in the area. The quantitative interview data were entered in excel, SPSS and were further analysed in SPSS. The responses of interviews were compared and statistical chi-square test for goodness of fit was also tested.

3.4.3. Methods related to assessing the indication of climate change

For addressing the research question 5 i.e. assessing the indication of climate change in the area, long term average temperature and rainfall values were compared with the annual temperature and rainfall of the

years. The deviations of temperature and rainfall from the normal pattern of temperature and rainfall from all the stations were estimated in Microsoft excel. These deviations from the normal pattern are plotted to generate the graph indicating the change pattern for temperature and rainfall variations. Further, long term average temperature and long term average rainfall of all stations were also interpolated using ordinary kriging technique for generating spatial pattern of temperature and rainfall variation in the study area (Hunter & Meentemeyer, 2005). The kriging is reported to provide good result for interpolation of temperature and rainfall (Holawe & Dutter, 1999). This analysis gives an indications whether the climate in the study area is changing or not.

3.4.4. Methods related to identifying land tenure system and impacts of land use change on land tenure

The household interview data from the study area are analysed for identifying the land tenure system and impacts of land use change on tenure. This analysis addresses the research question 6 and 7. The interview responses are entered in excel and SPSS and analysis of household interview data was carried out in SPSS. Nominal interview responses are also compared and chi-square test for goodness fit was also tested to test the significant difference between observed and expected frequency of land tenure in SPSS (Heimer et al., 2006). Household interview responses were analysed for identifying the impacts of land use change on tenure. Further, responses from the interview with local governmental officials were also compared and analysed. Chi square test statistics for goodness of fit (χ^2) is given by the relation $\chi^2 = \Sigma (O-E)/E$ where, O and E are the observed and expected frequencies respectively. Expected frequency is the expected cell count when there is no significant difference between observed and expected cell frequency (E= (row total frequency*column total frequency)/total frequency) (Moore, McCabe, & Craig, 2009).

3.4.5. Methods related to hypothesis testing

χ 2 - test for independence of attributes was used for testing null hypothesis, "land tenure is independent of land use change caused by climate change". In order to determine dependency or independence of attributes in categorical responses, χ 2 - test for independence is mostly used (Sharma & Chaudhary, 2012). Further, likelihood ratio is the alternate of chi-square test for testing the independency of attributes. If the asymptotic significance value of likelihood ratio and chi-square value are greater than 0.05, the null hypothesis is accepted at 95% level of confidence and if the asymptotic significance value of likelihood ratio and chi-square value are less than 0.05 alternative hypothesis is accepted at 95% level of confidence (Field, 2015). Under null hypothesis χ^2 - test statistic is given by the following relation,

$$\chi^2 = \Sigma (O-E)/E \quad \text{.....2}$$

Where,
O = Observed frequency
E = Expected frequency
The expected frequency is given by the following relation,

$$E= (RT *CT)/N) \quad \text{.....3}$$

Where,
RT = Row total frequency
CT = Column total frequency

3.5. Pre-field work

In this phase preparation for field work was carried out for collection of data from the field. Detail activity, schedule and planning for conducting the field work was prepared. Structured questionnaires were

developed for household interview, interview with local level governmental officials and interview for the central level governmental officials based on the indicators developed in the previous chapter (Appendix 1). These structured questionnaires are closed questions which are provided with possible answers. Structured household interview was selected as this method is suitable for gathering information from a large sample quickly and responses can be compared easily. Landsat image of 2015 was classified with the help of base map (imagery) from ArcGIS online (These are the map services provided by ArcGIS online only) for ease of fieldwork and ground truth data collection. Relevant literatures were also reviewed for successful completion of the field work.

3.6. Field data collection

3.6.1.1. Primary data collection

Ground truth data collection

A set of training data for land use classification and a separate set of test data for accuracy assessment were collected from the field for different land covers such as forest, urban, agriculture and barren. 38 training data for classification and 26 test data for the accuracy assessment were collected. The coordinates of all, 64 ground truths (training as well as test data) with UTM projection system, zone 45 North and datum WGS 1984 were collected with hand held GPS.

Interview data collection

Based on the objective of the research primary information related to livelihood, land use change, land tenure issues in the context of climate change from households, local governmental officials and central governmental officials were collected by structured interview to address the research questions. These interviews were conducted so as to address the research questions 3, 6, and 7.

Sampling design

Sampling is the approach of selecting a few units from the entire population for studying and generalizing the information about the population (Kumar, 2011). Simple random sampling for the selection of respondent was adopted. This method is simple and each unit has the equal chance of selection from the total population. Therefore, there is no preference in the selection of the respondent.

Household interview

Slovin's formula was applied for determining the sample size (Eludoyin, 2015) The sample size for the household interview is given by the following relation.

$$n=N/(1+(N*e^2)) \quad \text{.....4}$$

Where,
n= Number of sample
N= Total population
e= Margin of error
For this study margin error is taken at 12.5% (87.5% confidence level) and the population size (N) is 3496 The required sample size is given by,

$$n=3496/(1+(3496*.125^2))=62.85$$

For the full information, we took the sample size 64. Thus, 64 household interviews were conducted with the pre-defined structured questionnaires in the study area. The spatial position of the household

interviews were also recorded with GPS (appendix 4). This method of structure interviewing encourages to gather more relevant information in a short period of time (Groenendijk & Dopheide, 2003).

Interview with the local level government officials

In total 9 interviews were conducted with local governmental officials from VDC office, district survey office and district land revenue office with the pre-defined structured questionnaire. These organizations were chosen for the interview because VDC is the main entry point for local government which deals with all the aspects of local people. District survey office and district land revenue office also deal with the land issues such as recording land tenure, perform subdivision and full transfer of ownership, record land use and solve the conflict between land owner and tenant when a written application is filed.

Interview with the central level government officials

A total number of 14 interviews were conducted with the central governmental officials from the Ministry of Land Reform and Management, Ministry of Forest and Soil Conservation, Ministry of Agriculture Development, Ministry of Federal Affairs and Local Development, Ministry of Science, Technology and Environment, Ministry of Irrigation, National land use project and Department of Hydrology and Meteorology with defined structured questionnaire. These organizations were chosen for the interview because their function is related to the concepts of this research.

Observation

Walking, watching, listening and observing the study area with farmers, was also adapted to collect more information about the ground reality. This method is used to observe the land tenure and changes in land use in the field. Observation in the field was noted and was used during processing of data.

3.6.1.2. Secondary data collection

Meteorological data collection

Meteorological data were acquired as follows: daily maximum and minimum temperature, and rainfall data from the station Khumaltar of Lalitpur district for the period 1968-2014, monthly maximum and minimum temperature, and rainfall data from the station Tribhuvan airport, Kathmandu district for the period 1990-2014, monthly maximum and minimum temperature, and rainfall data from station Godavari, Lalitpur district for the period 1990-2014 and monthly maximum and minimum temperature, and rainfall data from Nagarkot, Bhaktapur district for the period 1990-2014. Location information of the meteorological stations are shown in Table 6.

Table 6: Coordinates of the meteorological stations

Station	Latitude	Longitude	Elevation (in meter)	Type of data set
Khumaltar	$27^0 40'$	$85^0 20'$	1350	Temperature and rainfall
Kathmandu airport	$27^0 42'$	$85^0 22'$	1337	Temperature and rainfall
Godavari	$27^0 35'$	$85^0 24'$	1400	Temperature and rainfall
Nagarkot	$27^0 42'$	$85^0 31'$	2163	Temperature and rainfall

Satellite image

High resolution satellite image (GeoEye-1) of the study area was also collected from the National Land Use Project, Ministry of Land Reform and Management.

Reports

Reports from governmental organizations related to this study were also collected e.g. VDC level land use profile of Chapagaun and Lele VDCs from National Land Use Project, Population census report for the Lalitpur district (Appendix 6) from Central Bureau of Statistics, report on Agriculture Development Strategy (ADS) from Ministry of Agriculture Development etc.

3.7. Preliminary processing of the data

3.7.1. Pre-processing of the image data

Four periods of Landsat images of the study area were selected such as 1989, 1997, 2006, 2015 usually in October months. Layer stacking was performed for each image with the band 1, 2, 3, 4, 5, and 7. A subset of the image was prepared for the study area in Erdas Imagine. Digital elevation SRTM data were geo-referenced to the Universal Transverse Mercator (UTM) projection system with zone 45 North and datum WGS 1984. Further, atmospheric error correction such as haze reduction and topographic normalization with solar azimuth and solar elevation was also carried out in Erdas Imagine. Required information for the correction was obtained from the metadata which came from the satellite data. Further, subset of the surface reflectance image (atmospheric error corrected by USGS) were also prepared. Spectral reflectance of the atmospherically corrected images were compared with surface reflectance image (atmospheric error corrected by USGS). Surface reflectance images were chosen for further land use change analysis due to their better comparability and better spectral reflectance response.

3.7.2. Pre-processing of the field data

Both primary and secondary data collected from the field were entered in excel sheet and SPSS. Data collected were processed to eliminate possible errors. Spatial pattern for the household interview (Appendix 4) and shape file for the training data were also prepared in ArcGIS. Household interview data were entered in SPSS 23 for quantitative data analysis.

3.8. Concluding remarks

This chapter provides brief information on materials and methods for collection and analysis of data. 64 household interviews, 14 interviews with the central government officials and 9 interviews with the local government officials were conducted from the structured questionnaires. 64 Ground truth data were collected from the field for classification of the image and accuracy assessment of the classified map. Furthermore, high resolution satellite image and meteorological data of the study area were also collected. In the next chapter, analysis of both primary and secondary data are executed for deriving results of the research.

4. DATA ANALYSIS AND RESULTS

4.1. Introduction

Data collected from the field as discussed in the previous chapter are processed and analysed to derive meaningful information. This chapter highlights data analysis and results derived from the processed data based on objective and indicators of the study. This chapter focuses on in depth analysis of the collected data to answers the following research questions.

3. What are the driving forces for land use change?
4. What are the land use change pattern from past to recent years?
5. Is climate change really taking place in the recent past?
6. What are the land tenure system in the study area?
7. What are the impacts of land use change on land tenure in the study area?

This chapter contains 3 sections. Section 4.2 includes analysis and results the classification of image, accuracy assessment of the classification, land use change detection, meteorological data analysis, spatial pattern of temperature and rainfall, interview data analysis, and statistical testing of the hypothesis as well. Section 4.3 includes concluding remarks for this chapter.

4.2. Data analysis and results

4.2.1. Classification of the image

Surface reflectance images of 2015 was classified by Maximum Likelihood classification (MLC) algorithm with the training data for different land cover, collected from the field with GPS. MLC method estimates the probability of class and assigns the cell to the class with having the highest probability. Classification was carried out in Erdas Imagine. For MLC, signature file was created with the training data for different land cover in the Landsat image of 2015 and then the image was classified with the signatures.

For the images of the years 1989, 1996 and 2006 Spectral Angle Mapper (SAM) algorithm was used for the classification. For SAM classification Region of Interest (ROI) for different land cover were created from the Landsat_7 image of 2015 with the same set of training data collected from the field with GPS. These ROIs were used to generate endmembers representing various land cover units for the classification of an image of the year 1989, 1996, and 2006. Figure 10 shows the reflectance curves of the endmembers of mean reflectance for different land cover (Appendix 5). The SAM classification for the image of the years 1989, 1996, and 2006 was carried out in ENVI. Pixel with zero or small spectral angle is assigned to a class of the reference spectrum (Ibraheem, 2015).

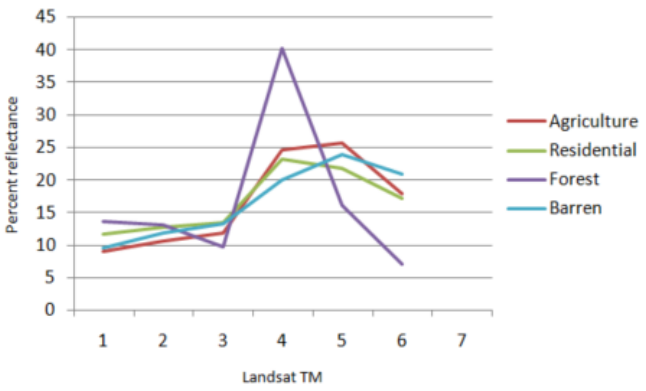

Figure 10: Reflectance curves of the selected endmembers

The following, Figure 11 display land use land cover classified maps for the year 1989, 1996, 2006, 2015.

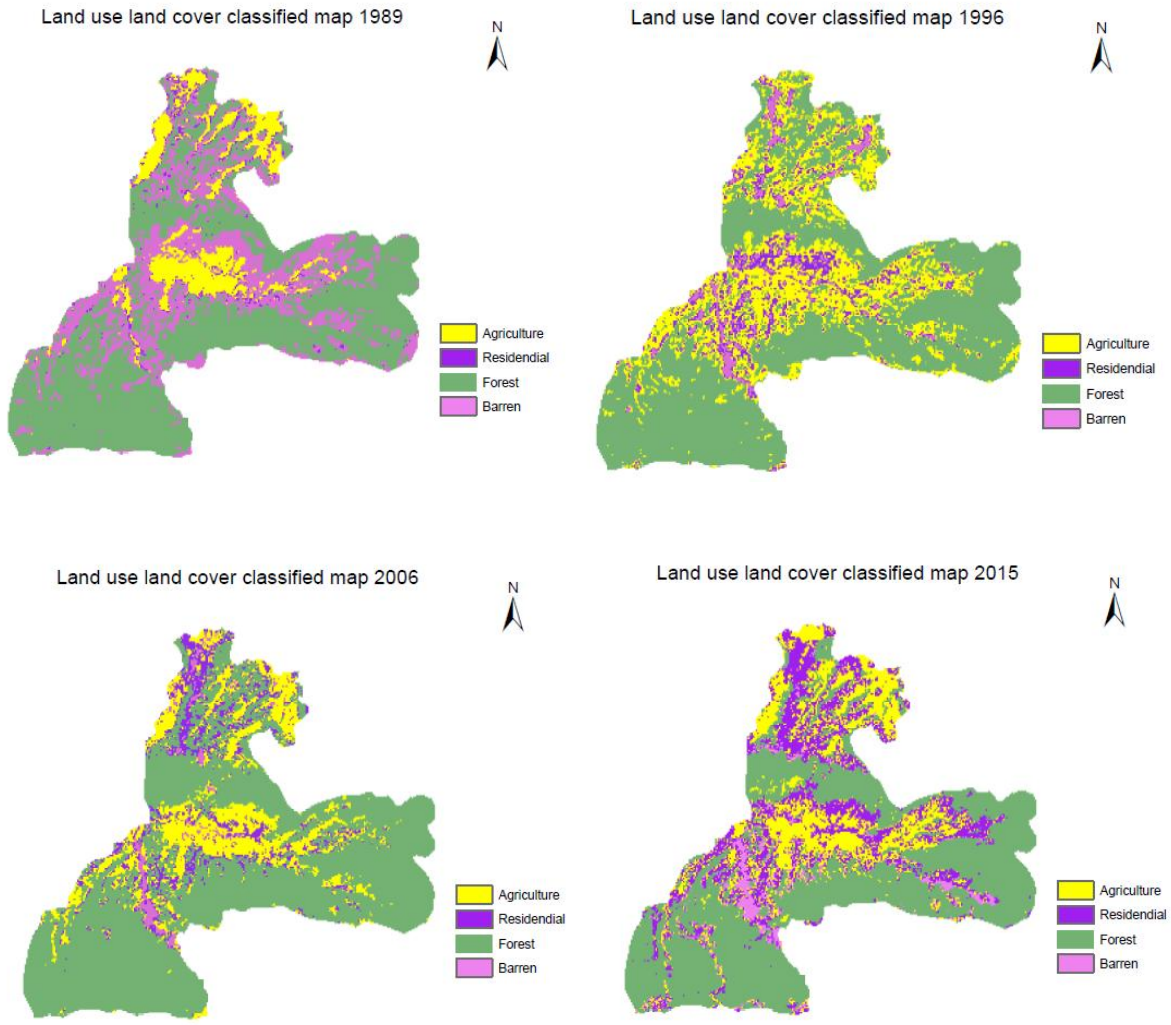

Figure 11: Land use land cover classified maps

4.2.2. Accuracy assessment of the classification results

Accuracy assessment of the classified map shows how accurately the classification was carried out. Accuracy of the classified image of 2015 was assessed by comparing the classified image with the test points collected from the field with GPS and additional points were also taken as test samples, using high resolution satellite image (GeoEye-1) for different land cover types.

Accuracy assessment of classification was carried out in Erdas Imagine. Accuracy assessment of the classified image 2015 was expressed with confusion/error matrix and kappa coefficient. Kappa coefficient is the coefficient for the satisfaction of accuracy and its value varies from 0 to 1. According to Yan (2007), kappa coefficient value above 0.75 has perfect satisfaction. Over all accuracy is the ratio of correctly classified reference point to the total no. of points. Producer accuracy is the ratio of accurate reference points (training points) classified to the total number of reference points (training point) for that class and it gives the accuracy of a class for the producer. User accuracy is the ratio of correctly classified reference point of the class to the total number of reference point assigned to the class in the classified map.

Table 7 shows an overall classification accuracy of 84.38% and overall kappa statistics of 0.7825 for the classified map of 2015.

Table 7: Confusion matrix for the classification accuracy of the classified map 2015

Land use land cover map	Land use land cover classes	Ground truth data					Classification accuracy	
		Agriculture	Residential	Forest	Barren	Total	Producer accuracy	User accuracy
2015 Classified map	Agriculture	17	4	1	0	22	85%	77.27%
	Residential	2	13	1	0	16	76.47%	81.25%
	Forest	1	0	18	1	20	90%	90%
	Barren	0	0	0	6	6	85.71%	100%
	Total	20	17	20	7	64	-	
	Overall accuracy						84.38%	
	Overall kappa statistics						0.7825	

4.2.3. Land use change detection

For the classified image, image differencing technique was used for deriving change detection in the image. Thus, temporal classified land use maps were compared for detecting land use change statistics. Detail land use change detection is obtained by spatial analysis of the multi-temporal satellite imageries and following statistics for land use change were derived from attribute table (Appendix 6).

Land use change from 1989-1996

The classified land use map from the year 1989 and 1996 are compared for detecting land use change from 1989-1996 and is presented in Figure 12.

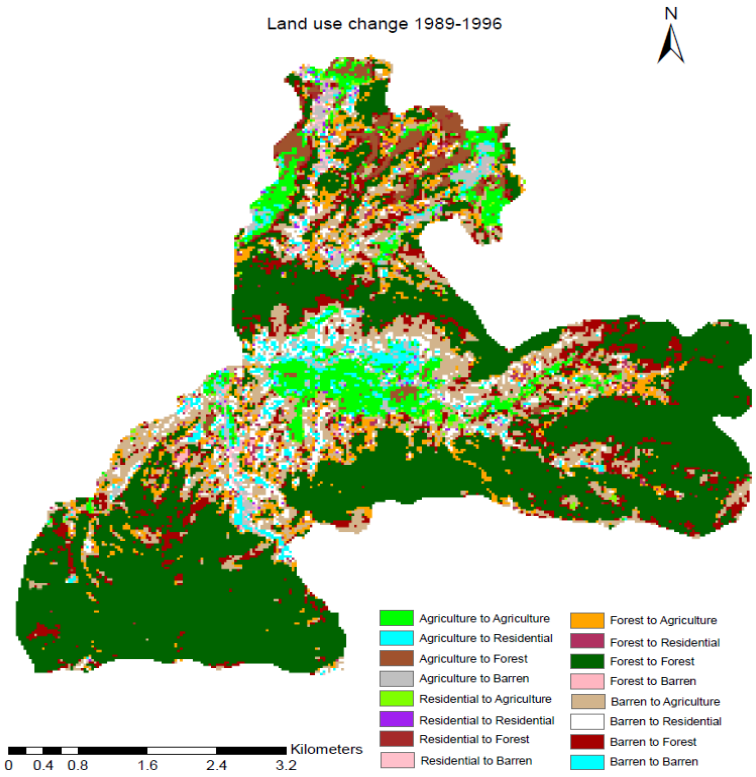

Figure 12: Land use change map (1989-1996)

The land use change statistics for the year 1989-1996 is presented in Table 8 and the detail land use change statistics from year 1989 to 1996 is as follows:

Agriculture:
Out of 3.654 Sq.km of agriculture land use only 1.7937 Sq.km was intact, 0.5463 Sq.km was changed to residential land use, 0.8163 Sq.km was changed to forest and rest 0.4977 Sq.km was changed to barren from the year 1989-1996. Agriculture land use was increased to 8.568 Sq.km from the year 1989-1996.

Residential:
Out of 0.8739 Sq.km of residential land use was changed to 0.3114 Sq.km agriculture, 0.2727 Sq.km was changed to forest, 0.171 Sq.km was changed to barren and rest 0.1188 Sq.km residential land use was intact from the year 1989-1996. Residential land use was increased to 2.4993 Sq.km from the year 1989-1996.

Forest :
Out of 17.9127 Sq.km of forest, only 15.3945 Sq.km was intact, 2.0313 Sq.km was converted to agriculture land use, 0.3501 Sq.km was changed to residential and rest 0.1368 Sq.km was changed to barren from the year 1989-1996. Forest land use was increased to 18.9909 Sq.km from the year 1989-1996.

Barren :
Out of 8.8965 Sq.km of barren only 0.4734 Sq. km was intact, 4.4316 Sq.km was changed to agriculture land use, 1.4841 Sq.km was changed to residential and rest 2.5074 Sq.km was changed to forest from the year 1989-1996. Barren land is decreased to 1.2789 Sq.km from the year 1989-1996.

Table 8: Land use change statistics for the year 1989-1996

Change detection statistics		Area in Sq. km of the classified map 1996				
Classified map for the year 1989	Land use	Agriculture	Residential	Forest	Barren	Total
	Agriculture	1.7937	0.5463	0.8163	0.4977	3.654
	Residential	0.3114	0.1188	0.2727	0.171	0.8739
	Forest	2.0313	0.3501	15.3945	0.1368	17.9127
	Barren	4.4316	1.4841	2.5074	0.4734	8.8965
	Total	8.568	2.4993	18.9909	1.2789	31.3371

Land use change from 1996-2006

Land use change from 1996-2006 is presented in Figure 13. The land use change statistics for the year 1996-2006 is presented in Table 9 and the detail land use change statistics from year 1996 to 2006 is as follows:

Agriculture:
Out of 8.568 Sq. km of agriculture land use only 3.1707 Sq.km was intact, 1.3032 Sq.km was changed to residential land use, 3.9402 Sq.km was changed to forest and rest 0.1539 Sq.km was changed to barren from the year 1996-2006. Agriculture land use was decreased to 5.8428 Sq.km from the year 1996-2006.

Residential:
Out of 2.4993 Sq.km of residential land use 0.7227 Sq.km was intact and 1.1619 Sq.km was changed to agriculture, 0.513 Sq.km forest, and rest 0.1017 Sq.km was changed to barren from the year 1996-2006. Residential land use was increased to 2.8809 Sq.km from the year 1996-2006.

Forest :
Out of 18.9909 Sq.km, only 17.3898 Sq.km was intact but 1.0323 Sq.km is converted to agriculture land use, 0.5247 Sq.km was changed to residential and rest 0.0441 Sq.km was changed to barren from the year 1996-2006. Forest land use was increased to 21.9816 Sq.km from the year 1996-2006.

Barren :
Out of 1.2789 Sq.km of barren only 0.3321 Sq.km was intact, 0.4779 Sq.km was changed to agriculture land use, 0.3303 Sq.km was changed to residential and rest 0.1386 Sq.km was changed to forest from the year 1996-2006. Barren land was decreased to 0.6318 Sq.km from the year 1996-2006.

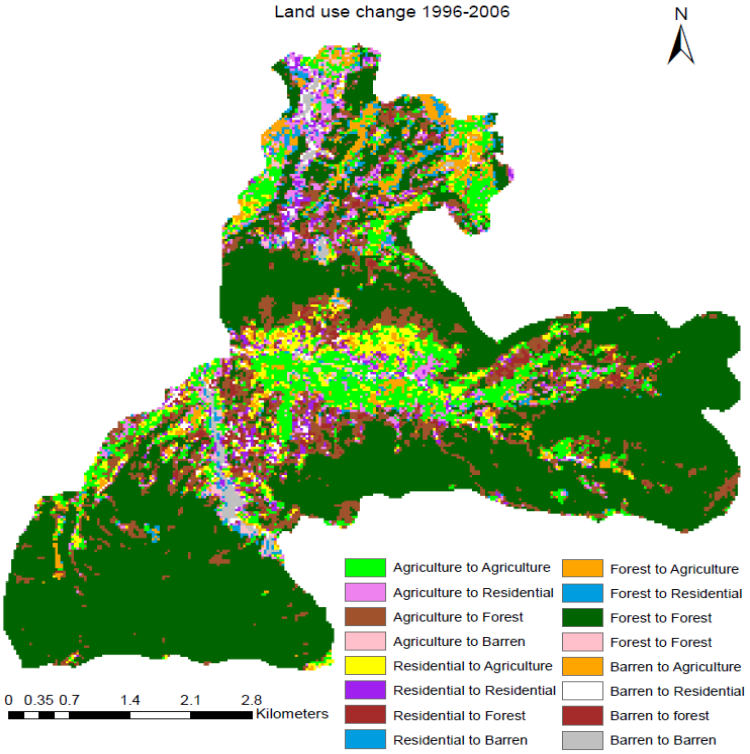

Figure 13: Land use change map (1996-2006)

Table 9: Land use change statistics for the year 1996-2006

Change detection statistics		Area in Sq. km of the classified map 2006				
Classified map for the year 1996	Land use	Agriculture	Residential	Forest	Barren	Total
	Agriculture	3.1707	1.3032	3.9402	0.1539	8.568
	Residential	1.1619	0.7227	0.513	0.1017	2.4993
	Forest	1.0323	0.5247	17.3898	0.0441	18.9909
	Barren	0.4779	0.3303	0.1386	0.3321	1.2789
	Total	5.8428	2.8809	21.9816	0.6318	31.3371

Land use change from 2006-2015

Land use change from the year 2006-2015 is presented in Figure 14. The land use change statistics for the year 2006-2015 is presented in Table 10 and the detail land use change statistics from year 1996 to 2006 is as follows:

Agriculture:
Out of 5.8428 Sq.km of agriculture land use only 3.1959 Sq.km was intact, 2.0142 Sq.km was changed to residential land use, 0.36 Sq.km was changed to forest and rest 0.2727 Sq.km was changed to barren from the year 2006-2015. Agriculture land use was increased to 6.2577 Sq.km from the year 2006-2015.

Residential:
Out of 2.8809 Sq.km of residential land use 1.3788 Sq.km was intact and 0.9936 Sq.km was changed to agriculture, 0.2547 Sq.km was changed to forest, and rest 0.2538 Sq.km was changed to barren from the year 2006-2015. Residential land use was increased to 6.1272 Sq.km from the year 2006-2015.

Forest :

Out of 21.9816 Sq.km of forest, 16.8489 Sq. km was intact, 1.9323 Sq.km was converted to agriculture land use, 2.5245 Sq. km was changed to residential and rest 0.6759 Sq.km was changed to barren from the year 2006-2015. Forest land use was decreased to 17.4699 sq.km from the year 2006-2015.

Barren :

Out of 0.6318 Sq.km of barren only 0.2799 Sq.km was intact, 0.1359 Sq.km was changed to agriculture land use, 0.2097 Sq.km was changed to residential and rest 0.0063 Sq.km was changed to forest from the year 2006-2015. Barren land was increased to 1.4823 Sq.km from the year 2006-2015.

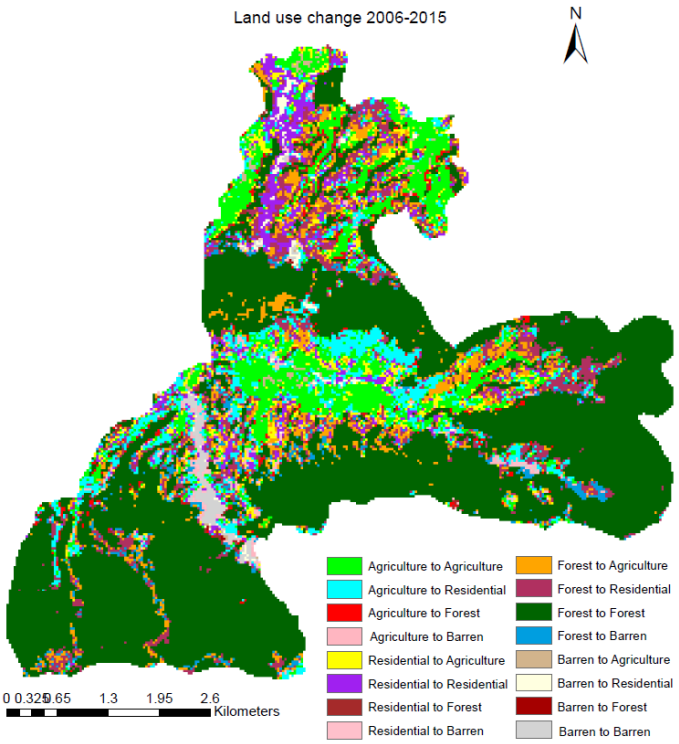

Figure 14: Land use change map (2006-2015)

Table 10: Land use change statistics for the year 2006-2015

Change detection statistics		Area in Sq. km of the classified map 2015				
Classified map for the year 2006	Land use	Agriculture	Residential	Forest	Barren	Total
	Agriculture	3.1959	2.0142	0.36	0.2727	5.8428
	Residential	0.9936	1.3788	0.2547	0.2538	2.8809
	Forest	1.9323	2.5245	16.8489	0.6759	21.9816
	Barren	0.1359	0.2097	0.0063	0.2799	0.6318
	Total	6.2577	6.1272	17.4699	1.4823	31.3371

4.2.4. Analysis of Meteorological data

All the meteorological data provided by DHM were analysed in Microsoft excel. Analysis of the rainfall pattern was obtained by comparing the rainfall of different years with the long term average rainfall of the station (Lebel & Ali, 2009). Analysis of temperature pattern of a station was also obtained by comparing the temperature of different years with the long term average temperature (Jain & Kumar, 2012).

4.2.4.1. Meteorological data of Khumaltar station:

Rainfall pattern:

Long term average of rainfall from the year 1968-2014 is 1227mm.

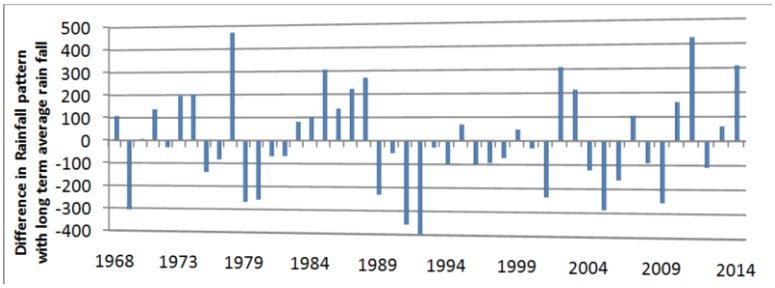

Figure 15: Rainfall pattern from 1968-2014 (Khumaltar station)

The above, Figure 15 shows the variation of rainfall from the long term average (normal) rainfall 1227mm with the rainfall of different years. Though rainfall data analysed from the period 1968-2014 does not show any specific pattern, but the rainfall pattern is changing.

Temperature pattern:

Maximum temperature (Tmax):

Long term average for Tmax from the year 1968-2014 is 24.3 ^{0}c. Figure 16 shows the maximum temperature is increasing at the rate 0 .042 ^{0}c per year.

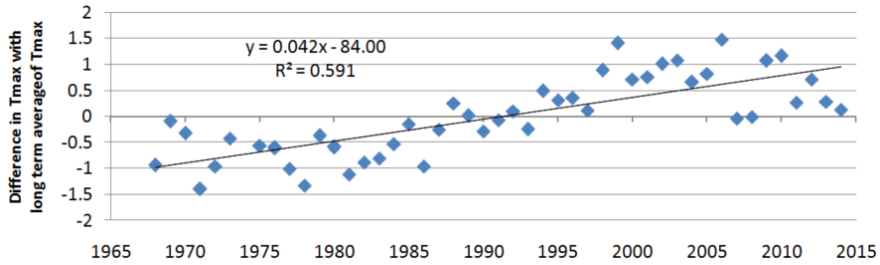

Figure 16: Temperature (Tmax) pattern from 1968- 2014 (Khumaltar station)

Minimum Temperature (Tmin)

Long term average for minimum temperature from the year 1968-2014 is 11.6 ^{0}c. Figure 17 shows the minimum temperature is increasing at the rate 0 .034 ^{0}c per year.

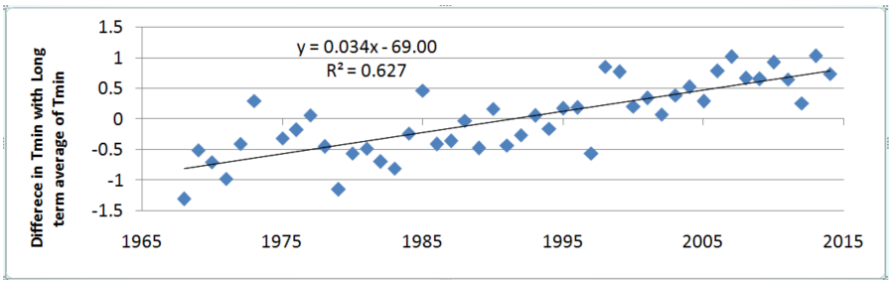

Figure 17: Temperature (Tmin) pattern from 1968- 2014 (Khumaltar station)

4.2.4.2. Meteorological data of Godavari station:

Rainfall pattern:

Long term average rainfall from the 1990-2014 is 1658mm. Figure 18 shows rainfall is decreasing at the rate 16.97mm per year.

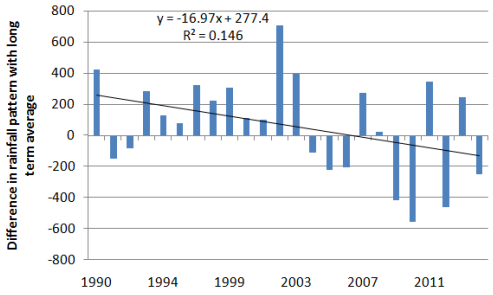

Figure 18: Rainfall pattern from 1990-2014 (Godavari station)

Temperature pattern

Long term average for maximum temperature from the year 1990-2014 is 22.6 ^{0}c. Figure 19, indicates the annual maximum temperature is increasing at the rate 0.089 ^{0}c per year.

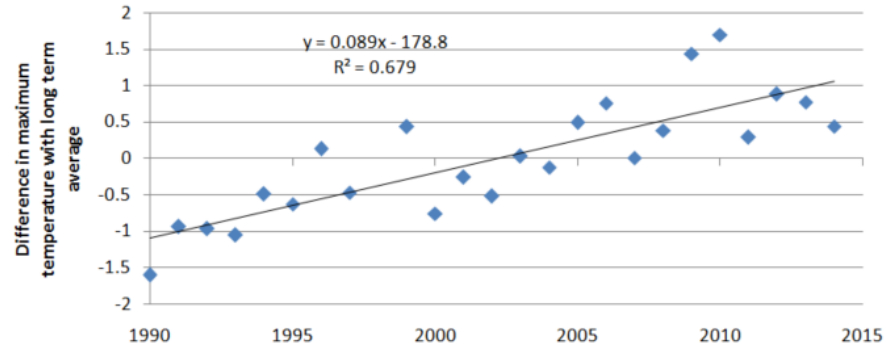

Figure 19: Temperature (Tmax) pattern from 1990- 2014 (Godavari station)

For the minimum temperature, long term average from the year 1990-2014 is 11.5 ^{0}c and the following, Figure 20 indicates that that minimum temperature is decreasing at the rate 0.083 ^{0}c per year.

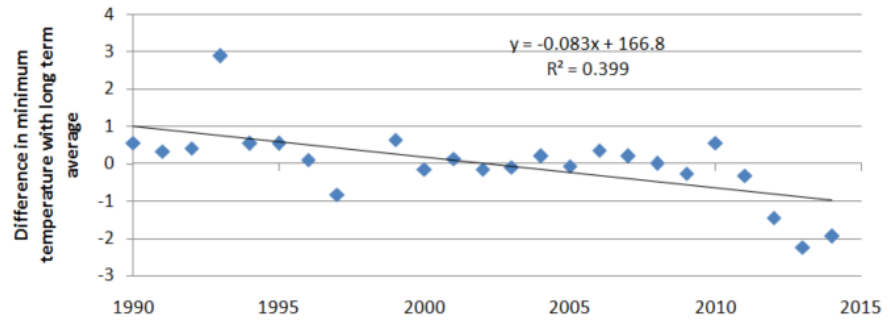

Figure 20: Temperature (Tmin) pattern from 1990- 2014 (Godavari station)

4.2.4.3. Meteorological data of Kathmandu airport station:

Rainfall pattern

Long term average rainfall from the year 1990-2014 is 1478mm. Figure 21 shows the rainfall is decreasing at 2.391mm per year.

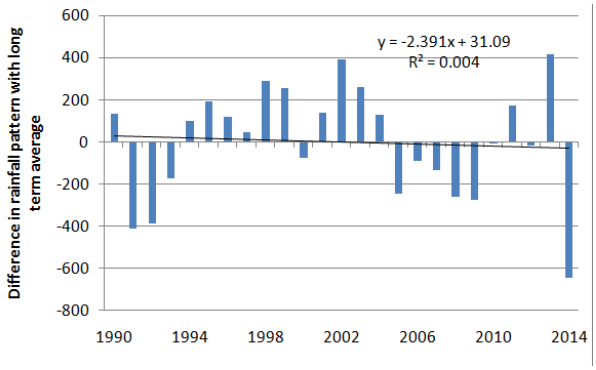

Figure 21: Rainfall pattern from 1990- 2014 (Kathmandu airport station)

Temperature pattern

Long term average for maximum temperature (Tmax) from the year 1990-2014 is 25.9 ^{0}c. Figure 22 shows that the maximum temperature is increasing at the rate 0 0.058 ^{0}c per year.

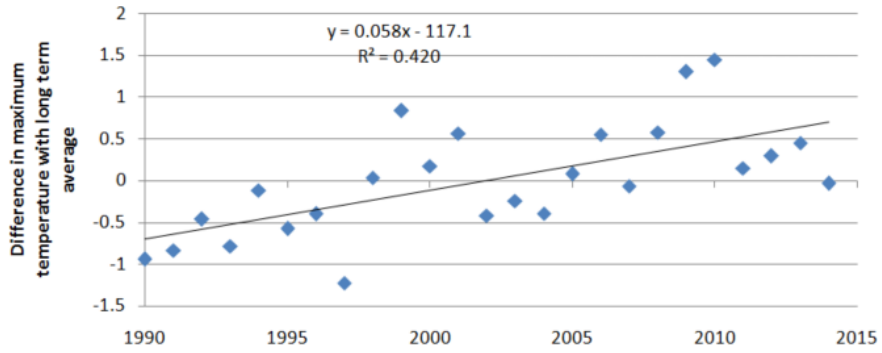

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Figure 22: Temperature (Tmax) pattern from 1990- 2014 (Kathmandu airport station)

Long term average for minimum temperature (Tmin) from the year 1990-2014 is 12.3 ^{0}c. Figure 23 shows the minimum temperature (Tmin) is increasing at the rate 0.061 ^{0}c per year.

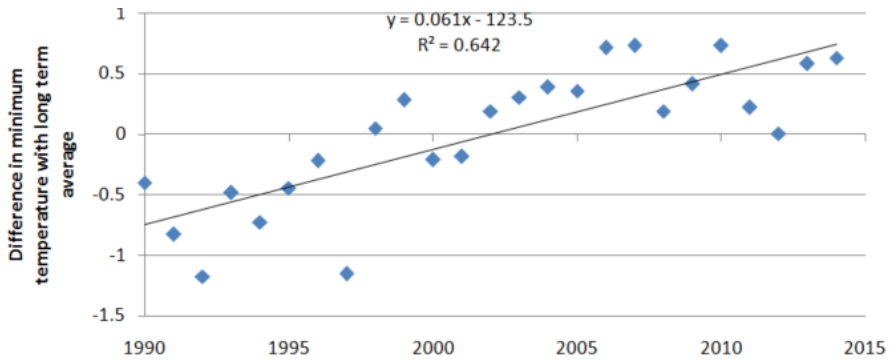

Figure 23: Temperature (Tmin) pattern from 1990- 2014 (Kathmandu airport station)

4.2.4.4. Meteorological data of Nagarkot station:

Rainfall pattern:

Long term average rainfall from the year 1990-2014 is 1926mm. Figure 24 shows rainfall is decreasing 15.75mm per year.

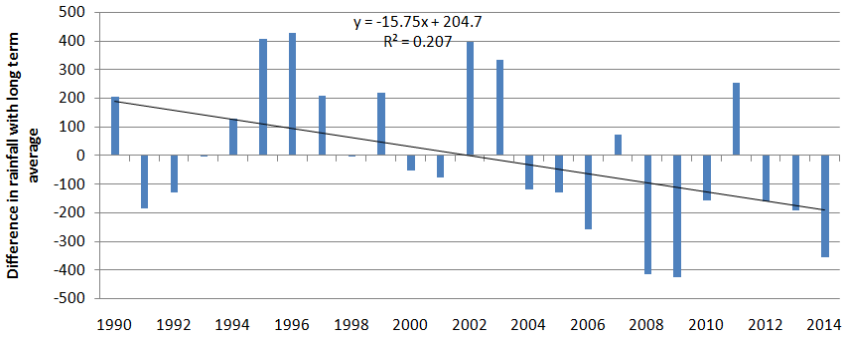

Figure 24: Rainfall pattern from 1990- 2014 (Nagarkot station)

Temperature pattern

Long term average for maximum temperature (Tmax) from the year 1990-2014 is 19.5 ^{0}c. Figure 25 shows the maximum temperature is decreasing at the rate 0.018 ^{0}c per year.

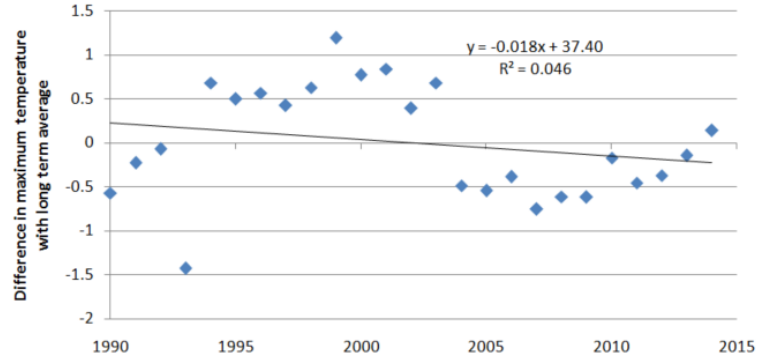

Figure 25: Temperature (Tmax) pattern from 1990- 2014 (Nagarkot station)

Long term average for minimum temperature (Tmin) from the year 1990-2014 is 9.9 ^{0}c. Figure 26 shows the minimum temperature is increasing at the rate 0 .04 ^{0}c per year.

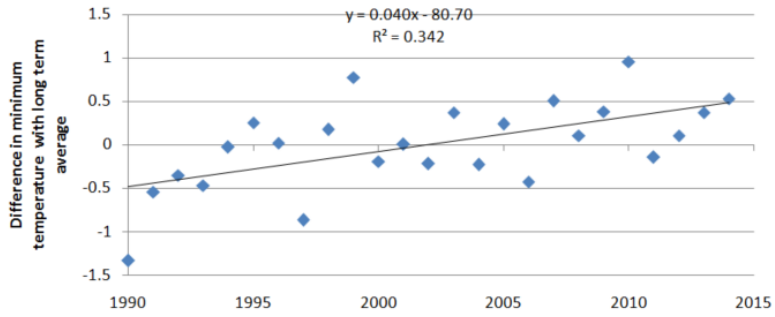

Figure 26: Temperature (Tmin) pattern from 1990- 2014 (Nagarkot station)

Spatial pattern of average temperature and average rainfall

Thus, combining the deviations of maximum temperature and rainfall from all the stations indicates that average maximum temperature is increasing at the rate of 0.043 ^{0}c per year and average rainfall is decreasing at the rate 10mm per year. Interpolation is the technique applied for converting spatial vector

variation to regular raster variation of temperature and rainfall (Serrano, Sánchez, & Cuadrat, 2003). Spatial pattern of the long term average maximum temperature and rainfall from the four meteorological stations was obtained by kriging in ArcGIS and is presented in the following Figure 27.

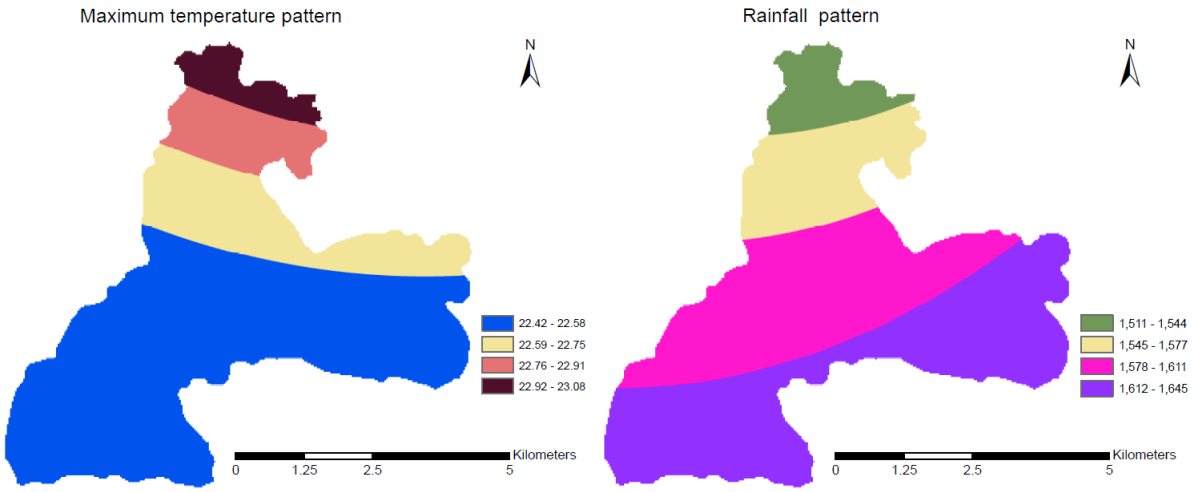

Figure 27: Spatial pattern for average maximum temperature and rainfall

Figure 28, indicates the relation between the long term average temperature and long term average rainfall of four stations which indicates that temperature is inversely proportional to the rainfall. Thus, as the temperature decreases the rainfall increases and vice versa.

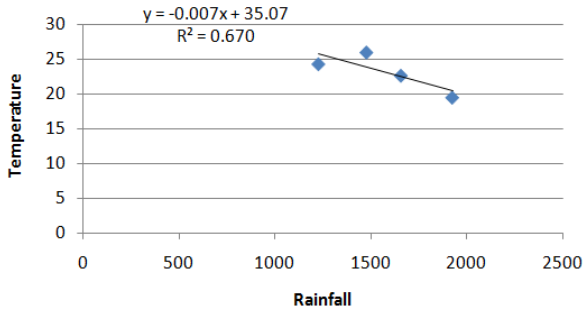

Figure 28: Pattern of average temperature verses rainfall

4.2.1. Analysis of interview data

4.2.1.1. Household interview

Analysis of household interview indicates, 55% of the respondent are dependent only on farming, 34% of the respondent are dependent on farming and business, 5 % of the respondent are dependent only on business, 3% of the respondent are dependent on farming and remittance and 3 % respondent are dependent on labour works (e.g. others) (Figure 29).

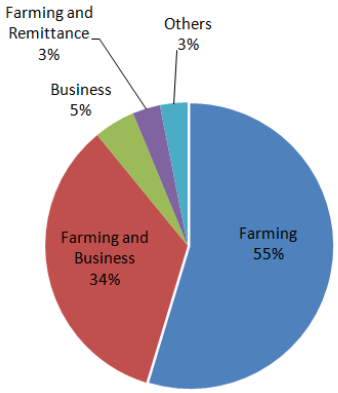

Figure 29: Major occupation in the study area

Sources of income of the household are sale of crops (56%), sale of crops and nonfarm activities (36%), nonfarm activities is (5%) and Others (e.g. agriculture labour 3%).

Livelihood and socio-economic condition of the people in the study area is presented in the following Table 11.

Table 11: Socio-economic condition of the household in the study area

Household information	Value
Total sample size	64
Average household size	6.5
Average annual income per household (in US $)	1971.54
Average annual per capita income (in US $)	303.31
Land area per household	2468.68 m ^{2}

36% of the respondent from the households reported that they have sufficient fuel wood from the community forest. All the respondent reported that there is increase in temperature and decrease in rainfall in recent years which is also decreasing water in the area. 72% of the respondent reported that there is a decrease in agriculture production. Further, 35% of the respondent has the agriculture production sufficient for 12 months, 39% of the respondent agriculture production is sufficient for 6 months, 17 % of the respondent has the agriculture production for 3 months and 9% of the respondent has agriculture sufficient less than 3 months.

The household interview identifies urbanization (53%), climate change(31%), demography (13%), and economy(3%) are the major driving forces of the land use change in the area, (Figure 30).

Further, they also reported that climate change is highly affecting the agriculture land use. We also perform a chi-square test for goodness of fit for testing significant difference between the observed frequency and the expected frequency of the driving force of land use change at 95% of confidence level (Lehmann & Romano, 2014).

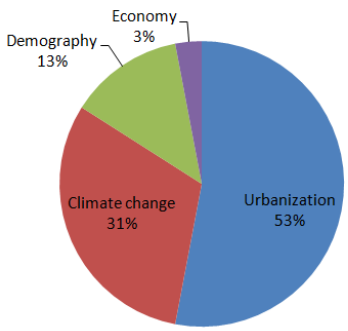

Figure 30: Driving forces for land use change in the study area

The following, Table 12 shows the observed and expected frequency of the driving force for the land use change.

Table 12: Observed and expected frequency of driving forces for land use change

Forces	Observed N	Expected N
Demography	8	6.4
Urbanization	34	32.0
Economy	2	6.4
Climate change	20	19.2
Total	64	64

Table 13, shows the statistics for the chi-square test. The p value (Asymp. sig) 0.310 is greater than 0.05 which indicates that there is no significant difference between observed and expected frequency of driving force of land use change.

Table 13: Chi-square test statistics of driving forces for land use change

Statistics	Driving force for land use change
Chi-Square	3.583
df	3
Asymp. Sig.	.310

3.1% of the total respondent reported that there is deforestation in the study area which is decreasing the forest product and is also increasing conflict with using the forest as well. Figure 31, shows major land use change in the study area. Major changes in land use in the study area on the basis of respondent response are agriculture to urban (58%), modification in agriculture land use (37%) and forest to agriculture (5%)

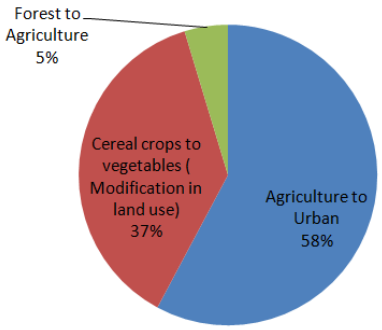

Figure 31: Land use changes in the study area

Figure 32 indicates the major land tenure for the *private land* in the study area from the studied sample (64), major tenure are ownership right (58), lease right (4), tenancy right (1), and sharing of crops (*Adhiya*) (1). Out of 58 ownership right one was obtained from the division of tenancy right with the land owner.

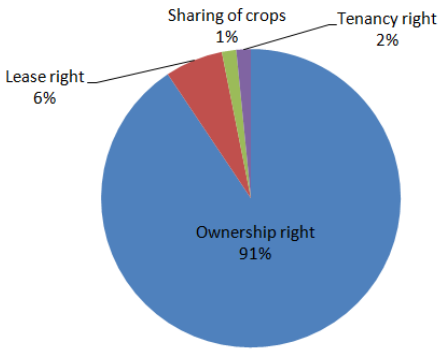

Figure 32: Land tenure systems in the study area

We perform chi-square-test for goodness of fit for testing the significant difference between observed and expected frequency for land tenure in the study area. The following Table14 presents the observed and expected frequency for the land tenure in the study area.

Table 14: Observed and expected frequency of land tenure in the study area

Land tenure	Observed N	Expected N	Residuals
Ownership right	58	57.6	.4
Lease right	4	3.2	.8
Sharing of crops	1	1.6	-.6
Tenancy right	1	1.6	-.6
Total	64	64	0

Further, Table 15 shows the statistics for the chi-square test. The p value (Asymp.Sig.) 0 .884 is greater than .05. Thus, it indicates that there is no significant difference between observed and expected frequency for land tenure in the study area at 95% of confidence level.

Table 15: Chi-square test statistics of land tenure in the study area

Statistics	Land tenure in the study area
Chi-Square	.653
df	3
Asymp. Sig.	.884

From the household interview 25% of the respondent reported that there is conflicts between land owner and tenant due to change in land use, 42% of the respondent reported there is decrease in agriculture production and migration due to the land use change (Table 16). These effects of land use change are to overcome from the negative impacts of climate change.

Table 16: Responses for effects of land use changes

Effects of land use change	Response	Frequency	Percent
Conflicts between land owner and tenant due to land use change	Yes	16	25
	No	48	75
Decrease in employment in agriculture due to land use change:	Yes	27	42
	No	37	58
Migration due to decreased agriculture production	Yes	27	42
	No	37	58

Analysis of the interview data indicates 39% of the respondent cope by credit, 17% by selling their land, and 22% cope by other means during the crop failure by the effect of climate change and 22% are well to do household that do not require coping.

Table 17, shows that 41% of the respondent were the member of CF and forest product was sufficient only for 42% of the respondent. Majority of respondent reported that changes in forest is decreasing the forest product and creating conflict for clear use right for forest and impacting on CF tenure as well.

Table 17: Information on household activities.

Household activities	Response	Frequency	Percent
Community participation from the household	Yes	6	9
	No	58	91
Subsidy from the local government in extreme events	Yes	4	6
	No	60	94
Member of community forest	Yes	26	41
	No	38	59

Responses from the household also indicate that ownership right is highly affected by land use change and decreased production. Sharing of crops and lease tenure are also affected by the decreased agriculture production but they are terminating the land holding.

Key findings of the household interview:

Livelihood:

Average size of the household in the study area is 6.5, and land per household is 2468.68 Sq.m People livelihood is highly dependent on farming some family are also dependent on remittance and small business from shops by selling daily requirements of the area. Economy is also mostly dependent on the sale of crops. People are the member of the community forest and are getting forest product from the CF. Livelihood is highly affected by a decrease in agriculture, forest and forest product.

Climate change:
All the respondent from the study area are realizing the increase in temperature in the recent years. 72% of the respondents reported that agriculture production is decreasing in the recent years due to the increase in temperature and decrease in rainfall and change in the weather pattern. Thus, the agriculture is highly affected by climate change in the area.

Land use change:
Major driving force for land use change in the study area is due to urbanization but climate change, demography and economy are also playing role for changing land use. 36% of the respondent are modifying the agriculture land use due to the decreased agriculture production. Land use change from forest to agriculture is also taking place. 42% respondent also reported that changes in land use are decreasing the employment in agriculture and this is forcing to migrate in search of alternate earning.

Land tenure:
Major land tenure in the study area is an ownership right, lease right, tenancy right and sharing of crops. Ownership right is highly affected by the change in land use and a decrease in agriculture production as lease, sharing of crops and tenancy right are terminated if they are not satisfied with the production. Changes in land use are also creating conflicts between land owner and tenant and land tenure is changing from tenancy right to ownership right. Forest tenure is also decreasing by the encroachment of the forest. Conflict for using forest product was also increasing due to the decreasing forest product.

4.2.1.2. Interview with the local level governmental officials

Figure 33 shows the response of the local governmental officials regarding the driving force for the land use change. According to the local governmental officials the major causes of land use change are urbanization (56%), climate change(33%) and demography (11%)

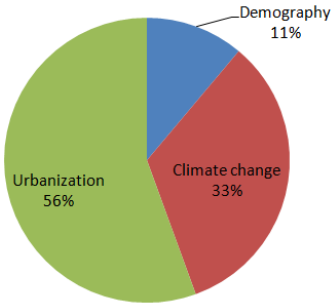

Figure 33: Cause of land use change

Table 18 shows the response from local governmental officials about the effects of land use changes which shows that 56% of the respondent reported conflict between land owner and tenant for changing land use, 78% of the respondent reported decrease in employment in agriculture due to land use change and 67% of the respondent reported migration from agriculture in search of employment due to dissatisfaction from the land use change and benefits from the farm.

Table 18: Responses from local governmental officials on effects of land use changes

Effects of land use change	Response	Percent
Conflicts between land owner and tenant due to land use change	Yes	56
	No	44
Decrease in employment in agriculture due to land use change	Yes	78
	No	22
Migration due to decreased agriculture production	Yes	67
	No	33

Responses of local governmental officials regarding the effects of land use change, also indicates the effect of land use change is high on ownership right (78%) and less in lease (22%).

All the respondent from local government reported that there is not any official recording for land use change. Table 19 shows that there is low community participation (33%), and weak coordination among GO's, NGO's and INGO's for addressing land use change issues (22%). Further, 56% of the respondent reported that land use change has effects on tenure in the context of climate change and 67% of respondent reported that local government is providing subsidy to farmer in the extreme events caused by climate change.

Table 19: Information from the local government officials

Information from local government officials	Response	Percent
Community participation	Yes	33
	No	67
Effects of land use change on tenure in the context of climate change	Yes	56
	No	44
Coordination among different organizations	Yes	22
	No	78
Subsidy during the extreme events	Yes	67
	No	11
	Not sure	22

Key findings from the interview with local governmental officials:
Local government also indicates urbanization as the major cause of land use change. Climate change and demography are also influencing land use change. Local government is also realizing the change in climate, conducting community participation programme, and providing subsidy for supporting farming system. There is no official recording of land use change which is encouraging informal way of land holding, using and ultimately affecting the revenue as well. Land use change is also decreasing the employment in agriculture and promoting migration for searching job.

Local governmental officials also indicate that effect of land use change is high on the ownership right. Local government is also realizing the conflict between land owner and tenant due to land use change which is also changing land tenure. They also realize that the land transaction is increasing in the recent years.

4.2.1.3. Interview with the central level governmental officials

Figure 34, indicates the responses from the central governmental officials for driving forces of the land use change. According to the central governmental officials, the major driving forces for land use changes are urbanization (57%) climate change (36%), and demography (7%).

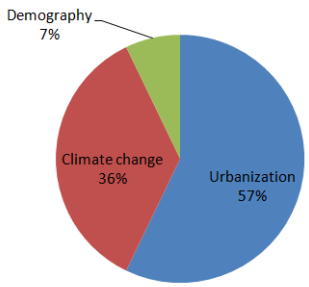

Figure 34: Major causes of land use change

The following, Table 20 shows the response and information from central governmental officials. 50% of the respondent reported that there is the effect of land use change on tenure in the context of climate

change and 93% of the respondent reported that there is good coordination among different organization for addressing climate change issues.

Table 20: Information from the central governmental officials

Information from central government officials	Response	Percent
Effects of land use change on tenure in context of climate change	Yes	50
	No	50
Coordination among different organizations	Yes	93
	No	7
Planning for climate change adaptation at local level	Yes	57
	No	43

Key findings from the interview with central governmental officials:
Central government seems conscious for climate change and is also developing a policy for farming in extreme events by developing ADS and is also planning for climate change adaptation at the local level. Central level also visualizes urbanization as the major cause of land use change and climate change, demography are also playing role for land use change. There is forest policy for preserving forest. There is good coordination for policy formulation at the central level and they also realize that the land use change can affect land tenure in the context of climate change.

4.2.2. Statistical analysis

From the discussion in the previous chapter, land use changes caused by climate change are modification of agriculture land use and changes in cropping pattern in agriculture land use in order to adapt the effect of climate change.

Therefore, we statistically test responses of three questions interviewed with the households which were related to the changes in land use caused by climate change. We carried out statistical testing of hypothesis by χ 2 - test for independence of land tenure and land use change caused by climate change at 95% of confidence level and level of significance, α=0.05.

1. Are you changing cropping pattern in your farming? (In the context of climate change)
Table 21 shows the observed and expected frequency for the cross tabulation of change in cropping pattern and land tenure in the study area.

Table 21: Cross tabulation for land tenure and change in cropping pattern in the study area

S. No.	Land tenure	Count	Change in cropping pattern		Total
			Yes	No	
1	Ownership right	Observed count	16	42	58
		Expected count	19.0	39.0	58.0
2	Lease right	Observed count	4	0	4
		Expected count	1.3	2.7	4.0
3	Sharing of crops	Observed count	1	0	1
		Expected count	.3	.7	1.0
4	Tenancy	Observed count	0	1	1
		Expected count	.3	.7	1.0
Total		Observed count	21	43	64
		Expected count	21.0	43.0	64.0

expected frequency is the frequency count expected if the two attributes land tenure and land use change (cropping pattern) are independent. Table 22 shows the value of chi-square test statistics for 3 degree of

freedom. The table shows the value for asymptotic significance of likelihood ratio (.005) and person chi-square(.010) are less than 0.05

Table 22: Chi-square test statistics for cross tabulation for land tenure and changes in cropping pattern in the study area

Chi-square test-statistics	Value	Df	Asymptotic Significance (2-sided)	Remarks
Pearson Chi-Square	11.445[a]	3	.010	a. 6 cells (75.0%) have expected count less than 5. The minimum expected count is .33.
Likelihood Ratio	12.680	3	.005	
Linear-by-Linear Association	2.634	1	.105	

2. Have you ever modified the agriculture land use by changing annual cereal crops (Rice, wheat, maize etc.) to vegetable crops (potato, tomato, cauliflowers, etc.)? (In the context of climate change)

Table 23 shows observed and expected count for the cross tabulation of modification in the agriculture land use and land tenure in the study area.

Table 23: Cross tabulation for land tenure and modification in agriculture land use in the study area

S. No.	Land tenure	Count	Modification in the agriculture land use		Total
			Yes	No	
1	Ownership right	Observed count	18	40	58
		Expected count	20.8	37.2	58.0
2	Lease right	Observed count	4	0	4
		Expected count	1.4	2.6	4.0
3	Sharing of crops	Observed count	0	1	1
		Expected count	.4	.6	1.0
4	Tenancy	Observed count	1	0	1
		Expected count	.4	.6	1.0
Total		Observed count	23	41	64
		Expected count	23.0	41.0	64.0

The following Table 24 shows the value for chi-square test statistics for 3 degree of freedom. The table shows the value of asymptotic significance of likelihood ratio (.008) and person chi-square (.018) are less than 0.05

Table 24: Chi-square test statistics for cross tabulation for land tenure and modification in agriculture land use in the study area

Chi-square test-statistics	Value	Df	Asymptotic Significance (2-sided)	Remarks
Pearson Chi-Square	10.080[a]	3	.018	a. 6 cells (75.0%) have expected count less than 5. The minimum expected count is .36.
Likelihood Ratio	11.744	3	.008	
Linear-by-Linear Association	3.853	1	.050	

3. Do you think changes in land use can affect land tenure in the context of climate change?

Table 25 shows the observed and expected frequency (count) of the responses from the household for the cross tabulation of land use change in the context of climate change and effects on land tenure in the study area.

Table 25: Cross tabulation for changes in land use in context of climate change and affects on land tenure in the study area

S. No.	Land tenure	Count	Land use change in context of climate change and affects on land tenure		Total
			Yes	No	
1	Ownership right	Observed count	23	35	58
		Expected count	26.3	31.7	58.0
2	Lease right	Observed count	4	0	4
		Expected count	1.8	2.2	4.0
3	Sharing of crops	Observed count	1	0	1
		Expected count	.5	.5	1.0
4	Tenancy	Observed count	1	0	1
		Expected count	.5	.5	1.0
Total		Observed count	29	35	64
		Expected count	29.0	35.0	64.0

Table 26 shows the value for chi-square test statistics for 3 degree of freedom. The table shows the value asymptotic significance of likelihood ratio (.017) and person chi-square(.046) are less than 0.05

Table 26: Chi-square test statistics for cross tabulation for changes in land use in context of climate change and affects on land tenure in the study area

Chi-square test-statistics	Value	df	Asymptotic Significance (2-sided)	Remarks
Pearson Chi-Square	7.990[a]	3	.046	a. 6 cells (75.0%) have expected count less than 5. The minimum expected count is .45.
Likelihood Ratio	10.255	3	.017	
Linear-by-Linear Association	6.116	1	.013	

key findings from the hypothesis testing:

From above analysis of chi-square test, asymptotic significance value of likelihood ratio and chi-square values in all the interview questions are less than 0.05. Thus, null hypothesis is rejected and our research hypothesis (alternative hypothesis) is selected. Hence, land tenure depends on land use change caused by climate change.

4.3. Concluding remarks

This chapter analyse all the collected data for answering the research questions 3, 4, 5, 6, and 7. Results from analysis of the temporal remote sensing images shows that all the land use are changing from 1989 to 2015. Results from the analysis of meteorological data from four stations shows that average temperature is increasing whereas average rainfall is decreasing. Analysis of interview data also provides information on livelihood, climate change, land use change, and tenure in the study area. Interview data analysis also identify the urbanization as the major cause of land use change while climate change, demography, economy are also causing land use change in the study area. Ownership right, lease right, tenancy right, sharing of crops are the tenure system in the study area. Analysis of interview also identifies the conflicts and impacts of changes in land use on tenure. Furthermore, chi-square test for the hypothesis supports that land tenure is dependent on changes in land use caused by climate change. In the next chapter, synthesis and discussions contains the combination of results to interpret the key findings and discussions on the key findings for addressing the objectives of the study.

5. SYNTHESIS AND DISCUSSIONS

5.1. Introduction

This chapter synthesizes and discusses the results obtained from the previous chapter to derive the key findings for addressing the objectives of the study. Further, this chapter also discusses and compares the key findings with the findings of other researchers in previous chapter. This chapter consists of five sections. Section 5.2 contains synthesis and discussions on land use change pattern, section 5.3 includes synthesis and discussions on climate change pattern, section 5.4 includes synthesis and discussions on conflicts and impacts of land use change on land tenure and finally section 5.5 includes the concluding remarks for this chapter.

5.2. Land use change pattern

Driving force for land use change

From the analysis of interview data in the previous chapter shows that urbanization is the major driving force for land use change in the area. It is due to the location of Lele VDC in rural area but Chapagaun VDC in peri-urban area influencing urbanization. Further high rate of population growth Lalitpur district from 1981 to 2011 (Appendix 8) also supports high urbanization in the area. Demography and economy are also playing some roles for land use change in the study area as culture for Nepalese society is still joint family in rural areas where each and every socio-economic activity depends on land and land resources. The study also shows that climate change is a main driver for land use change especially in agriculture in the area. These findings for the major driving forces for the land use change are similar to the findings of Zondag and Borsboom (2009) indicating urbanization, demography, economy, climate change, as the major driving forces for land use change. This study shows, technology, energy change in ownership and policy has no role for land use changes, it is due to the location of study area in peri-urban and rural area.

The, changes in the agriculture land use are due to the change in the weather pattern for decades more which is degrading the productivity of land and forcing for changing agriculture by modification due to the increased temperature and decreased rainfall. Analysis of the household interview also indicates that there is a decrease in agriculture production due to the changes in temperature and rainfall pattern and people are also modifying and changing the cropping pattern with their local knowledge. These findings are also similar with the study findings of Piya et al. (2013), Bhatt et al. (2014) and Manandhar et al. (2011) in Nepal indicating decrease in agriculture production by land degradation due to the effect of increase in temperature and decrease in rainfall for which people are coping with the locally available knowledge by changing land use.

Land use change pattern

The study aims to assess the changes in land use and the findings from the spatial analysis of temporal satellite images of the year 1989-1996, 1996-2006, and 2006-2015 from the previous chapter indicates land use is changing from past to recent years. Further, land use change statistics shows that land use change is not only from agriculture and forest to urban but is also from urban to agriculture and forest over the period. The combination of land use change statistics over the period, provides the land use change pattern from the past to recent years. Figure 35, presents the percentage change in land use over the period of time. 57% of the forest was increased to 61% from 1989-1996. Further, it was increased to 70% from 1996 to 2006. This strange increase in forest is due to the active CF management system in the area

and conversion of barren land to forest. It is also due to the plantation of the forest in the private land. Some respondent has also reported that they have their own private forest as well. The findings for increased forest from the year 1989 to 2006 is similar to the findings of Gautam et al. (2002) and Niraula et al. (2013) indicating increased forest in Nepal by the implementation of CF between 1978 to 1992. Further, the increased forest from 1989 to 2006 is also similar to the findings of FAO (2010b) indicating 9% increase in the forest of Nepal from the year 1986-2000. The forest was decreased to 56% from the year 2006-2015. This decrease in the forest is due to forest encroachment for residential and agriculture use. 3% of the respondent from households also reported that there is forest encroachment for agriculture purpose.

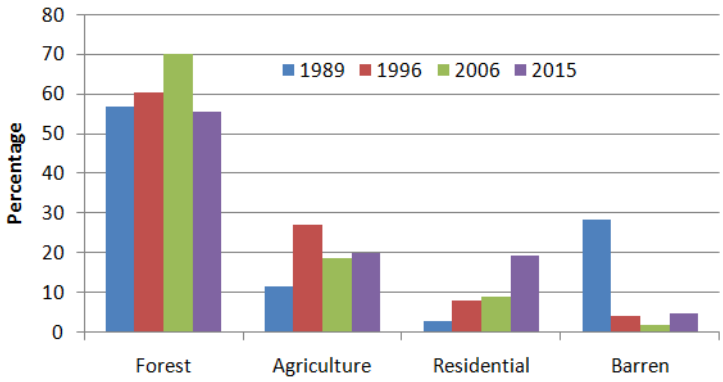

Figure 35: Percentage change in land use over the period of time

Agriculture land use was increased tremendously from the year 1989-1996 from 12% to 27%, it is due to conversion of barren land to agriculture, and good production from agriculture as the analysis of meteorological data from all stations in the previous chapter shows that there was increased rainfall in comparison to long term average rainfall in the period 1989-1996. The findings for this increase in agriculture land use is similar to the findings of FAO (2010b) indicating 25% increase in agriculture land use in Nepal from the year 1986 to 2000. Agriculture was decreased to 19% from the year 1996-2006. This decrease in agriculture land use is due to the urbanization which is also in line with the high population growth during the period in the area (Appendix 8). Agriculture land use was then slightly increased to 20% from the year 2006-2015. This increase in agriculture land use is due to the forest encroachment. The increase in agriculture is also due to the encouragement for the extension of agriculture and provision of subsidy by local government for decreased agriculture production during the extreme events.

3% the residential land use was increased to 8% from the year 1989-1996, it was again increased to 9% from the year 1996-2006 and finally it was increased to 20% from the year 2006-2015. This continuous increase in residential land use is due to high influence of urbanization with high population growth in the study area (Appendix 8). Barren land has decreased from 28% to 4% from the year 1989-1996, it was further decreased to 2% from the year 1996-2006 but from 2006-2015 it was increased to 5%. In general barren land is decreasing, it is due to conversion of barren land to forest, agriculture and residential purpose.

Though long term temporal satellite images were classified with the help of GPS control points collected from the field for detecting the changes in land use. There could be some error in classification in the image of early December as the season for harvesting the major cereal crop (paddy) is from October to November. Furthermore, there could be also error in classifying the images due to mixed land use in small patches of agriculture, forest and residential land use in the area. The classification accuracy is highly satisfactory and land use change pattern are also similar with the findings of other researcher as discussed above. Thus, the findings from the spatial analysis of the temporal images conforms forest is decreasing,

agriculture land use is more or less intact but residential land use is continuously increasing and barren land is decreasing in the area from the year 1989 to 2015.

5.3. Climate change pattern

Indication of the climate change

Study aims to assess the indication of climate change in the study area in the recent past. Analysis of meteorological data and synthesis of results from all stations shows that the temperature is increasing at the rate 0 .043 ^{0}c per year whereas the rainfall is decreasing at rate 10mm per year in the study area with respect to the long term average temperature and rainfall. Further, all the respondent from the household interview also reported that the temperature is increasing and rainfall is decreasing in the recent years, which is decreasing the crop yield as well. Thus, this increase in temperature is due to the effect of change in climate which is affecting weather pattern and decreasing the crop yield.

Climate on land use change zone

Combining land use change with the spatial pattern of temperature and rainfall provides mean temperature and mean rainfall in the land use change zone (Yang et al., 2009). Combination of land use change with temperature and rainfall are achieved by spatial analyst with zonal statistics (Jusuf, Wong, Hagen, Anggoro, & Hong, 2007). Detail zonal statistics for temperatures and rainfall is obtained by combining the land use change from the years 1989-1996, 1996-2006 and 2006-2015 with the spatial pattern for the temperature and rainfall by zonal statistics in ArcGIS (Appendix 7) which shows that average temperature for agriculture land use zone is 22.64 ^{0}c, for residential land use zone is 22.66 ^{0} c, for forest zone is 22.53 ^{0}c, for barren zone is 22.55 ^{0}c. This indicates, all the land use change zone has different average temperature. Further, forest zone has minimum average temperature where as residential land use zone has maximum average temperature. Thus, different land use change zone have different average temperature due to the fact that different land use sector have different GHG emission level as discussed in the previous chapter.

The findings of this study regarding the increase in temperature is similar to the findings of FAO (2010) and Gentle et al. (2014) in Nepal, indicating rise in temperature at the rate 0.041 ^{0}c and 0.06 ^{0}c per year respectively. The finding for the increase in temperature is also similar with the findings of Bhatt et al. (2014) in Koshi Basin, Nepal. Further, the findings of this study for zonal statistics indicating different temperature for different land use zones is similar to the study findings by Yang et al. (2009) in China and Jusuf et al. (2007) in Singapore.

Though, there could be some error in interpolation and deriving spatial pattern of temperature and rainfall but the findings of this study for indication of climate change is very similar to the findings of other researcher as we discussed above. Thus, the study indicates the change in climate in the area.

5.4. Conflicts and impacts of land use change on land tenure

Land tenure systems

Analysis of interview data from the previous chapter indicates ownership right, lease right, tenancy right, and sharing of crops are the major land tenure systems in the study area. However, only few tenancy and sharing of crops (*Adhiya*) were detected due to the small study area. These findings are similar with the findings by Sharma (2000) and Tuladhar (2004) for land tenure system in Nepal.

Conflicts and impacts of land use change on land tenure

Main objective of the study is to identify conflict and socio-economic impact of changes in land use on tenure in the context of climate change. The synthesis and discussions for the major conflicts and impacts of land use change identified from the analysis of interview data in the previous chapter are as follows:

Conflicts between land owner and tenant were identified due to the changes in land use. It is caused by the dissatisfaction with the decreased benefit from agriculture due to the effect of changes in temperature and rainfall. Conflict is also due to the intention of the tenant to divide the land to get better productive land and full ownership right. Majority of respondent reported that agriculture production is decreasing due to land use change caused by climate change which is also similar to the findings of study by Maharjan and Joshi (2013) in Nepal, indicating decreased crop production due to effect of climate change. Changes in land tenure from tenancy right to ownership right was also detected. Analysis of household interview also showed that one ownership right was obtained from the change of tenancy right to ownership right. This change in tenure is due to the conflict between land owner and tenant due to land use change in the context of climate change.

Changes in land use especially in forest is also creating conflict in clear forest use right. 3% of the respondent reported that there is conflict for using the forest. This is due to the degradation of natural resource e.g. forest, water etc. and this conflict is also due to the unclear forest use right from decreased forest and forest product in the area usually by forest encroachment. Only 42% of household have access forest products and they also reported that decrease in forest product is encouraging the conflict for clear forest use right. Changes in land use is also developing informal land holding by forest encroachment and using land without formal recording. This informal land holding is due to the passive land use recording and monitoring system in the area. People are also using land informally with the intension for saving the tax. The analysis of the interview shows that people are changing land use due to the effect of increased temperature and decreased rainfall but changes in land use are not officially recorded. These findings are in line with study findings by Campbell et al. (2000) in Kenya indicating increased conflict and informal land holding due to the land use change caused by limited land resources available for the livelihood. The study by Acharya (2008) in Nepal reported that land use change in agriculture land use is graded and ranked as discussed in chapter two especially for valuation and revenue generations but our findings did not find any official recording for land use change. This contradiction may be due to the passive information recording of land administration organization.

Changes in land use is also increasing the termination of land leasing and land transaction. It is also due to the decreased production from the land and increased migration of people from the agriculture due to the dissatisfaction with the production from the land use change in the context of climate change. Analysis of the interview from the household and local government also indicate that land use change in agriculture is not able to address decreased production due to the effect of increased temperature and decreased rainfall. Various socio-economic impacts of land use changes in the area were identified from the analysis of interview data in the previous chapter such as decreased economic benefits, decreased employments, decreased agriculture worker, increased migration in search of employment due to the decreased benefits in the context of climate change. The above findings of the study are also in line with the study of Helming et al. (2008) and Schirmer et al. (2009) indicating the similar impacts of land use change such as decrease in agriculture production, degradation of forest and water, decreased employment, decreased agricultural workers.

Further, people are coping with the decreased crop yield and by credit and selling of land. Thus, decreased production is affecting access to land by encouraging termination of lease and sharing of crops.

Few respondent on the other hand has also reported that sharing of land is also evicted by the land owner due to the decreased crop yield from land use change. These effects are encouraging for selling of land and ultimately supporting to increase land transaction. Changes in land use is highly affecting ownership right. Majority of the respondent reported that changes in land use has high effect on ownership right. It is due to the fact that lease, tenancy, and sharing of crops can terminate the tenure if the changes in land use don't satisfy the production but land owner has no substitute for holding and using the land and in the end land owner become the victim. Thus, changes in land use is creating impact on enjoyment and benefit from agriculture and land right is warned from the effects of climate change. Ultimately, these ill effects are further opening the door for insecurity of land tenure. The above findings for impacts of land use change due to climate change affecting access to land, migration, and security of land tenure are also similar to the study findings of Quan & Dyer (2008).

The findings of this study are based on core information collected directly from the local level and are also in line with the findings of other researchers as we discussed above. Thus, study supports land use change especially in agriculture is decreasing the crop yield, promoting conflicts in the context of climate change and is also creating socio-economic effects on the livelihood of the people, which is directly challenging land tenure and ultimately affecting the arrangement and security of tenure.

5.5. Concluding remarks

Synthesis discussions of this chapter show that major driving forces for land use change is urbanization. Climate change is also playing an important role for land use change in agriculture. Although, CF management is playing role for preserving the forest, land use is changing in the area. Combination of meteorological data analysis from four different stations also indicates the climate is changing in the recent years in the area. Ownership right, lease right, and sharing of crops are the major tenure system in the study area.

Though climate change has no clear and direct effect on land use in one, two or three years but in decades or more than decades of time it affects in livelihood of the people by decreasing the productivity and then forces for changing land use by modification. Furthermore, land use change caused by climate change is decreasing the agriculture production and creating various socio-economic effects on tenure in the study area such as conflicts between tenant and land owner, changes in land tenure from tenancy to ownership, increase in informal land holding, unclear forest use right, termination of the lease, increase in land transaction, high effects in ownership right. These effects are challenging and warning the enjoyment from the land tenure and ultimately affecting the formal arrangement and security of tenure. Based on the discussions of this chapter, the next chapter contains conclusions and recommendations of the study.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Introduction

This chapter includes the conclusions and recommendations based on the overall findings of the study and discussions from the previous chapters. The main aim of the study is to assess the changes in land use by using temporal satellite images for the last 26 years. The study also assesses the indication of climate change in the study area. Further, the study explores the socio-economic impacts of changes in land use on tenure in the context of climate change. This chapter concludes the principal findings for 3 sub-objectives of the study: i) To review the impacts of climate change on land and livelihood, ii) To identify changes in land use and iii) To identify the conflicts and impacts of land use change on tenure. This chapter includes 3 sections. Section 6.2 includes conclusions based on objectives of the study and the research hypothesis. Finally section 6.3 includes recommendations of the study.

6.2. Conclusions

Main objective of the study is to identify the changes in land use and its socio-economic impact on land tenure in the context of climate change. The study indicates that land use and climate are changing which are also affecting agriculture and people's livelihood in the area. Agriculture land use is changing by modification or cropping pattern due to the effect of climate change. The changes in land use are ultimately creating conflicts and socio-economic impacts on tenure in the area. Conclusions of the study based on discussions from the previous chapters on the sub-objectives and hypothesis of the study are presented as follows:

Sub- objective i. To review the impacts of climate change on land and livelihood

Desk study and literature review showed that climate change has impact on weather which ultimately changes temperature and rainfall pattern. Every crop grows properly in normal pattern of temperature and rainfall. The changes in temperature and rainfall from the normal pattern and scarcity of water degrades the productivity which further decreases the production. These effects forces for changing land use especially in agriculture by modification and changing cropping pattern. Scarcity of water acts as catalyst for shifting agriculture from irrigated to rain-fed and changing farming to grazing as well. In the extreme events of climate change such as flooding, landslides, erosion, tropical cyclone, droughts, thunderstorms etc. decrease and damage the crops. Thus, climate change affects agriculture by decreasing crops and encouraging land use change.

Climate change affect the people livelihood by decreasing the natural resources such as forest, water, etc. and also by increasing conflict for using the limited resources. It also affect people livelihood by decreasing and damaging agriculture production. The decrease in production affects the socio-economic aspects of life such as decreased community participation, decreased employment, which further affect the access and security to land. These effects may also encourage migration of the people from agriculture affecting the people's livelihood. It also affects people's livelihood by increasing epidemic diseases. Further, extreme events of climate change as discussed above could affect household assets, infrastructure and loss of life. Thus, climate change affect people's livelihood not only by decreasing the earnings but also by decreasing the quality of life.

Sub-objective ii. To identify changes in land use

Analysis of interview data identifies urbanization as the major driving force for the land use change in the study area. Furthermore, climate change is also a major driver for land use change in the agriculture land use which is changing agriculture by modification and cropping pattern.

Spatial analysis of multi-temporal satellite images shows that land use pattern are changing from past to recent years. Forest was increased from 1989 to 2006, while from 2006 to 2015 it was decreased. Agriculture land use was also increased from 1989 to 1996 while it was decreased from 1996-2006, and from 2006-2015 it was slightly increased. Residential land use was gradually increased from 1989 to 2006 while from 2006-2015 it was increased drastically. Barren land was decreased drastically from 1989 to 1996 and then further decreases from 1996-2006 but from 2006 to 2015 it was slightly increased. Thus, forest land use is decreasing, agriculture land use is more or less intact, residential land use is increasing and barren land in decreasing over the period 1989-2015.

Sub-objective iii. To identify the conflicts and impacts of land use change on tenure

Analysis of interview data and meteorological data support the indication of the climate change in the study area. All the household reported that temperature is increasing and rainfall is decreasing in the recent years which is supported by meteorological data analysis indicating maximum temperature is increasing at the rate 0.043 ^{0}c per year with reference to long term average temperature and rainfall is decreasing at rate 10mm per year with reference to long term average rainfall. Further, this change in temperature and rainfall is decreasing the agriculture production in decades or more period of time in the area.

Analysis of the household interview identifies ownership right, lease right, tenancy right, and sharing of crops as the major land tenure system in the study area. Further, analysis of the household interview data also identifies the impacts of the land use changes. The major impacts of land use change identified are conflicts between land owner and tenant, changes in tenure from tenancy right to ownership right, termination of lease right, conflicts for clear using the forest product due to decrease and deforestation of forest, development of informal tenure arrangement due to forest encroachment. Decrease in production due to land use changes within the agriculture land use is also creating various socio-economic effects such as decrease in employment in agriculture, migration from agriculture. Land use change is also decreasing the income from farming and encouraging credit and sale of land for running the livelihood. These socio-economic effects are decreasing the enjoyment from land production, challenging and warning land right and are also affecting the security of land tenure.

Hypothesis: From the analysis of chi-square test for independency of attributes of land use change and land tenure with three interview questions related to land use change caused by climate change in the previous chapter identifies, asymptotic significance value of likelihood ratio and chi-square are less than 0.05, which indicates null hypothesis is rejected and research hypothesis (alternative hypothesis) is selected at 95% level of confidence, and level of significance, α=0.05,. Thus, this statistical analysis conforms land tenure depends on land use change caused by climate change.

The study indicates that though the effect of climate change on land use and tenure security is not seen in one two or three years but is decreasing the production and encouraging for changing land use which is affecting tenure security in decades or longer period. Statistical testing of hypothesis also supports changes in land use have significant impact on tenure in the context of climate change. So, we have to prepare for

future sustainable land administration, with strengthening the function of land administration by incorporating the information of climate change with land administration as the new role of land administration for secure tenure in the context of climate change.

6.3. Recommendations

The study shows that land use pattern are changing from past to recent years. Land use is a cross cutting issue and its proper management in the context of climate change plays an important role for security tenure. Respondent from households reported that they are changing agriculture land use by modification. Thus, further study for assessing the modifications in the agriculture land use caused by climate change with the spatial analysis of high resolution temporal satellite image is recommended.

The finding of the study indicates that land use and climate are changing in the area. Further, changes in land use are also creating socio-economic impact on tenure in the context of climate change. These findings are location specific for a small area which cannot represent the entire country. Thus, further study for identifying the impacts of land use change on tenure in the context of climate change in different location is also recommended.

Analysis of meteorological data supports the indication of climate change in the area. Meteorological stations are dispersed with low spatial coverage. Thus, satellite based technique can be used to get temperature and rainfall as an alternate source of meteorological data with high spatial coverage for which further study is suggested.

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APPENDICES

Appendix 1: Questionnaire for Household interview, interview with local governmental officials and interview with central governmental officials.

i) Questionnaire for Household interview in the study area

Interview No.: ..... VDC :.....

Ward no:.....

Introduction and livelihood condition of the respondent's household

1. Name: .....
2. Age:..... Sex:.....
3. How many members are in your household?

.....

4. What is the main occupation of your household?

Business	Farming	Remittance	Others
.....	.....	.....	.....

5. What is the main source of your income?

☐Sale of crops ☐Nonfarm activities ☐Remittance ☐ Others.....

6. What is the yearly income of your household?

Business	Farming	Remittance	Others	Total
.....	.....	.....	.....	.....

7. Do you possess any land for farming?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please follow next questions

8. How are you holding the land?

☐ Ownership right ☐Lease right ☐Sharing of crops ☐ Tenancy right ☐ Others ....

9. What is the size of your farming land?

.....

10. Do you possess any livestock?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please follow next immediate question

11. Does your livestock supporting income for the household?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

Please specify...

12. What variety of annual crops are you growing in your land?

.....

13. What is the source of water for household and agriculture?

.....

14. Is the crop production is decreasing in recent years?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify which crop is decreasing and what coping strategy are you using....

15. Are you changing cropping pattern in your farming? (In the context of climate change)

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify.....

16. How many months the agriculture production from your farm is sufficient for your livelihood?

☐ 12 months ☐ 6 months ☐ 3 months ☐ Others.....

If less than 12 months please specify how you cope..

17. How are you coping with the decreased crop yield in the extreme events?

☐ Credit ☐ Borrowing ☐ Selling land ☐ Others.....

18. Does any member of your household migrate in search of employment due to decreased agriculture production?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify

19. Are you member of community forest group of this area?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please follow next questions

20. Do you get forest product such as wood from community forest?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify

21. Is the fuel wood sufficient for your household?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

Please specify

22. Is there any other community participation in this area?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify

Land use change

23. Which of the following land use is commonly changing in this area?

☐ Agriculture to Forest ☐ Agriculture to Urban ☐ Forest to Agriculture

☐ Forest to Urban ☐ Cereal crops to vegetables ☐ Others.....

If yes please specify.....

24. Do you have to pay any tax for changing land use?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify

25. Have you ever modified the agriculture land use by changing annual cereal crops (Rice, wheat, maize etc.) to vegetable crops (potato, tomato, cauliflowers, etc.)? (In the context of climate change)

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify.....

26. Which of the following is main cause for land use change in this area?

☐ Demography ☐ Urbanization ☐ Economy ☐ Changes in policy ☐ Owner change

☐ Climate change ☐ Ecosystem services (food production, wood production etc.) ☐ Others...

27. Is there any deforestation in this area?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify

Land tenure

28. Which of the following land tenure is highly affected by land use changes in this area?

☐ Ownership right ☐ Lease right ☐ Sharing of crops ☐ Tenancy right ☐ Others .....

If yes please specify why.....

29. Is there any type of conflict between land owner and tenant?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify

30. Do you think changes in land use is decreasing employment in farming ?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

31. Do you think land transaction is also changing the land use in this area?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

Climate change

32. Do you think there is an increase in temperature in recent years in this area?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

33. Do you think there decrease in rain fall pattern in recent years in this area?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

34. Is there any change in agriculture production due to change in temperature and rainfall within 10 years period?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

35. Do you get any subsidy for farming in support of climate change?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify

36. Do you think changes in land use can effect land tenure in context of climate change ?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

37. Are you member of any climate related project working in this area?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

38. Are you prepared for the climate change?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify your strategies.....

39. If you have anything to share or add?

.....

ii) Questionnaire for interview with the local governmental officials

Interview No.: ..... Name: .....

Organization: ..... level: .....

1. Are you conducting any community participation programme for supporting the house hold in regards to climate change at local level?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

2. Which of the following land holding is mostly affected by land use change in this area?

☐ Ownership right ☐ Lease right ☐ Sharing of crops ☐ Tenancy right ☐ Others .....

If yes please specify.....

3. Do you think land transaction is increasing in this area?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify

4. Which of the following are the major cause of land use change in this area?

☐ Demography ☐ Urbanization ☐ Economy ☐ Changes in policy ☐ Owner change
☐ Climate change ☐ Ecosystem services (food production, wood production etc.) ☐ Others...

5. Is there any evidence of conflict between land owner and tenant for changing land use?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify.....

6. Is REDD+ collaborating with local government for preserving the forest land use?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

7. Is there any coordination among different government organizations and NGO, INGO, for addressing land use change issues?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify .....

8. Do you think changes in agriculture land use is decreasing the employment in this area?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

9. Is there any migration in search of new employment from agriculture in this area?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify if there is any record.....

10. Is there any effect of land use change on climate in this area?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify

11. Is there any evidence of climate change in this area?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify

12. Is there any local land use planning for adapting climate change?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

if yes please specify

13. Is there any mechanism of officially recording changes in land use ?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

if yes please specify

14. Is the local government running any agriculture extension programme and subsidy for supporting the farming system in context of climate change?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify

15. Do you think changes in land use can effect land tenure in context of climate change ?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

16. Is the local government prepared for the climate change?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify

17. Do you have any other information or document to share?

iii) Questionnaire for interview with the central governmental officials

Interview No.: ..... Name: .....
Organization: ..... level: .....

1. Is central level government planning for proper management of the land use issues?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

2. Which of the following are the major cause of land use change in this area?

☐ Demography ☐ Urbanization ☐ Economy ☐ Changes in policy ☐ Owner change

☐ Climate change ☐ Ecosystem services (food production, wood production etc.) ☐ Others

3. Is there any policy for restricting changing land use haphazardly?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

4. Is there any policy for supporting agriculture farming in extreme events of climate change?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify.....

5. Do you think Forest deforestation is effecting climate?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes specify and follow next question..

6. Is there any policy for preserving forest land use and combating the adverse effects of climate change?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

7. Are you planning for the climate change adaptation at local level?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

8. Is there any climate change adaptation policy?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

9. Is there any mechanism for coordination among different government organization and NGO, INGO for the implementation of climate change adaptation policies ?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify how.....

10. Do you think changes in land use can effect land tenure in context of climate change ?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

11. Do you think center level is well prepared with sufficient planning and policies for adapting the people in extreme events of climate change?

☐ More Yes ☐ Yes ☐ More No ☐ No ☐ Not sure

If yes please specify

12. Do you have any other information or document to share?

Appendix 2: List of organizations visited for data collection

a) List of Local and district level offices (Local level)

1. Village Development Committee
2. District Land Revenue Office
3. District survey Offices

b) List of Central level offices (Central Level)

1. Ministry of Land Reform and Management
2. Ministry of Forest and Soil Conservation
3. Ministry of Agriculture Development
4. Ministry of Federal Affairs and Local Development
5. Ministry of Science, Technology and Environment
6. Ministry of Irrigation
7. National Land Use Project
8. Department of Hydrology and Meteorology

Appendix 3: Detail activity during the field work

(30 September, 2015 - 30 October 2015)

No. of Day	Date	Activities performed	Remarks
1	Wednesday, 30-9-2015	Departure from Netherlands	
2	Thursday, 01-10-2015	Arrived at Kathmandu airport at the evening	
3	Friday, 02-10-2015	Communication with senior surveyor Rajan Giri of Lalitpur Survey Office, Tilak Raj Joshi, and Survey officer Janak raj Bhatt of Survey department for the data collection. Topographical map was collected and GPS was also collected from the Survey officer Habendra Prasad Dev of survey Department, Nepal.	Garmin GPS 2 sets. Planning for field data collection was done.
4	Saturday, 03-10-2015	Field was visited for collection of ground truth with Janak raj Bhatt, Rajan Giri and one assistant local people Rajan Bist of Chapagaun	(10 control points of Chapagaun VDC were collected Points)
5	Sunday, 04-10-2015	Ground truth collection was done	(15 control points of Chapagaun VDC were collected Points)
6	Monday, 05-10-2015	Ground truth collection was done	(16 control points of Chapagaun and Lele VDC were collected Points)
7	Tuesday, 06-10-2015	Ground truth collection was done	(14 control points of Lele VDC were collected)
8	Wednesday, 07-10-2015	Ground truth collection was done	(10 control points of Lele VDC were collected Points)
9	Thursday, 08-10-2015	Meteorological data collection and interview with DDG of DHM	Interview with Saraju Kumar Bhaidhya(DDG of DHM) about climate change issues.
10	Friday, 09-10-2015	Household interview and training to senior surveyor Rajan Giri for the household interview	Chapagaun VDC ward no. 8 (4 interview), ward no.7 (3 interview) and ward no.6 (3 interview)
11	Saturday, 10-10-2015	Household interview	Chapagaun VDC ward no. 4 (3 interview), ward no.9 (4 interview) and ward no.5 (3 interview)
12	Sunday, 11-10-2015	Household interview	Chapagaun VDC ward no. 1 (4 interview), ward no.2 (4 interview) and ward no.3 (4 interview)
13	Monday, 12-10-	Local level officials interview in	Shant bd. Desar (Office Assistant,

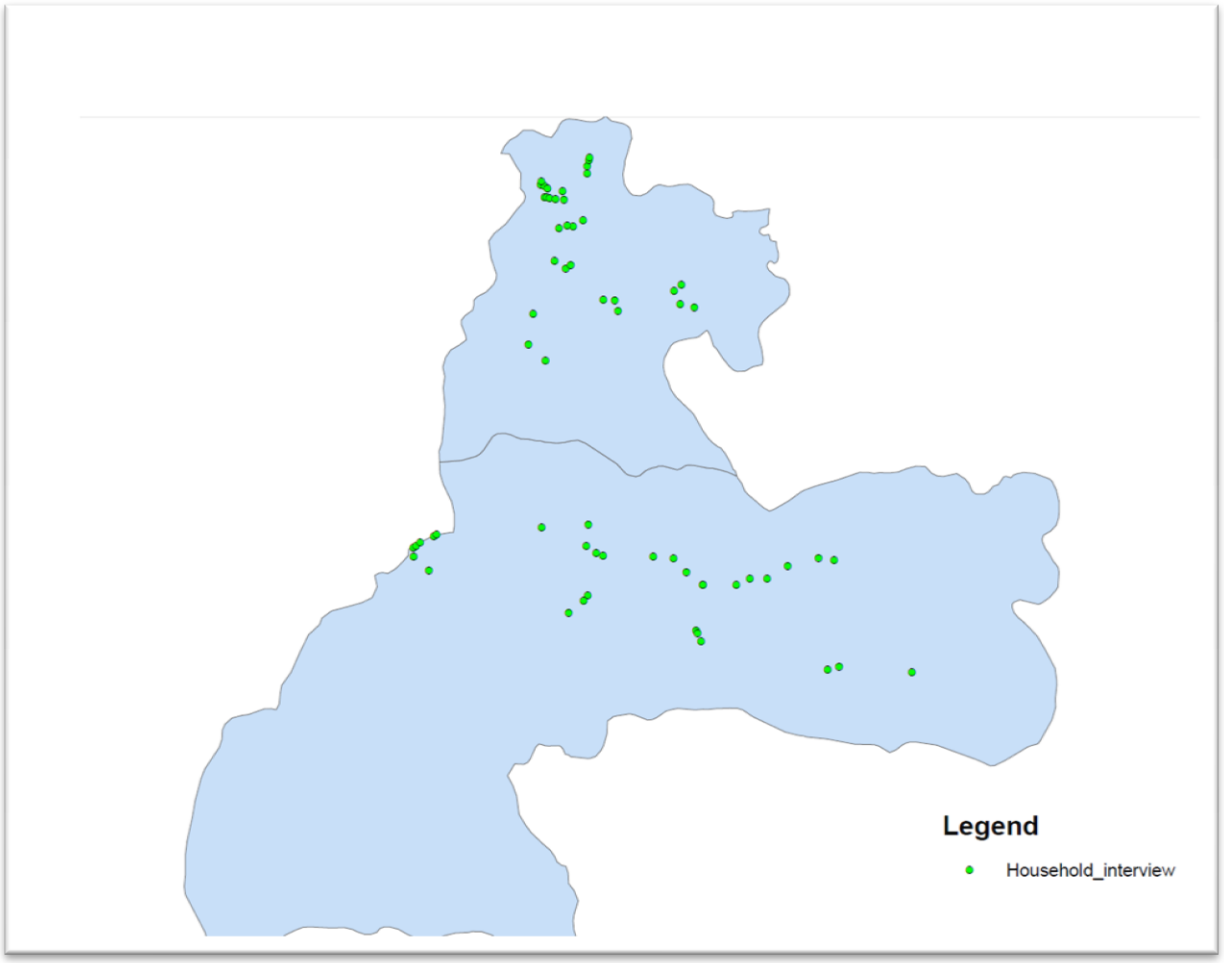
	2015	Chapagaun	Chapagaun VDC) and Sidhhi Maharjan (Technical Assistant, Chapagaun VDC)
14	Tuesday, 13-10-2015	Interview with central level governmental officials	Laxmi Gautam Pandey (Under Secretary, MOFA & LD), Sagar Rimal (Under Secretary, MOF & SC), and Gopal Giri (Under Secretary, MOLRM)
15	Wednesday, 14-10-2015	Interview with central level governmental officials	Chakra Mani Sharma under secretary, MOFA & LD), Siv Nandan shah (Under Secretary, MOAD), Dr. Narendra bd. Chand (Under Secretary, MOF & SC, REDD implementation center),
16	Thursday, 15-10-2015	Interview with central level governmental officials	Binita Bhattarai (Section Officer, MOST & E), Akhanda Sharma (Under Secretary, MOST & E)
17	Friday, 16-10-2015	Interview with central level governmental officials	Nab Raj Subedi (Chief Survey Officer, NLUP), Nagendra Jha(Joint Secretary, NLUP) and Kalanidhi Paudel (Under Secretary, MOI)
18	Saturday, 17-10-2015	Household interview and training to survey officer Janak raj Bhatt for house hold survey	Lele VDC ward no. 4 (3 interview), ward no.5 (3 interview) and ward no.3 (4 interview)
19	Sunday, 18-10-2015	Local level officials interview in Lele	Puskar Mahat (Lele VDC council member), Bal Krishna Lamsal (VDC Secretary) and Jagat bd. Mahat, Office Assistant)
20	Monday, 19-10-2015	Household interview	Lele VDC ward no. 1 (4 interview), ward no.2 (4 interview) and ward no.6 (3 interview)
21	Tuesday, 20-10-2015	*Data checking and Preliminary data processing*	
22	Wednesday, 21-10-2015		
23	Thursday, 22-10-2015		
24	Friday, 23-10-2015		
25	Saturday, 24-10-2015		
26	Sunday, 25-10-2015	Local level officials interview	Buddhi Maan Jaisi (Chief Survey Officer, District survey office) and Narayan Prasad Acharya (Chief Revenue Officer, District land revenue office)

27	Monday, 26-10-2015	Household interview	Lele VDC ward no. 8 (4 interview), ward no.7 (3 interview) and ward no.9 (4 interview)
28	Tuesday, 27-10-2015	Interview with central level governmental officials	Janak raj Joshi (Chief Survey Officer, MOLRM) and Kesav Prasad Khanal , Coordinator Hariyo Ban Program, WWF)
29	Wednesday, 28-10-2015	Local level officials interview in Chapagaun	Phone interview with Mohan pd. Chapagain (Chapagaun VDC Secretary) and Mahesh Shrestha (VDC Council Member of Chapagaun)
30	Thursday, 29-10-2015	Finalizing the field work	
31	Friday, 30-10-2015	Departure to Netherlands from Kathmandu	

Note:

DHM : Department of Hydrology and Meteorology
MOFA & LD : Ministry of Federal Affairs and Local Development
MOF & SC : Ministry of Forest and Soil conservation
MOLRM : Ministry of Land Reform and Management
MOI : Ministry of Irrigation
MOAD : Ministry of Agriculture Development
REDD : Reducing Emission from Deforestation and forest Degradation
MOST & E : Ministry of Science, Technology and Environment
NLUP : National Land Use Project
WWF : World Wide Fund for nature
VDC : Village Development Committee
DDG : Deputy Director General

Appendix 4: Spatial pattern of household interview



Appendix 5: Statistics for the endmember spectrum

i) Statistics of endmember spectrum for agriculture

ROI Summary	Pixel Count			
Agriculture	228			
Agriculture				
Basic Stats	Min	Max	Mean	StdDev
Band 1	736	1235	929.293860	93.637066
Band 2	837	1372	1096.991228	103.113256
Band 3	834	1579	1229.587719	155.458413
Band 4	1652	3201	2554.802632	281.239799
Band 5	1428	3521	2662.289474	386.703423
Band 6	861	2588	1854.442982	336.229077

ii) Statistics of endmember spectrum for residential

Residential				
Basic Stats	Min	Max	Mean	StdDev
Band 1	711	2583	1292.941176	500.927995
Band 2	881	2740	1420.823529	545.563038
Band 3	871	2849	1483.156863	587.711983
Band 4	1315	4306	2587.745098	845.139180
Band 5	786	4367	2427.176471	963.844546
Band 6	498	3477	1904.274510	760.056710

iii) Statistics of endmember spectrum for forest

ROI Summary	Pixel Count			
Forest	1476			
Forest				
Basic Stats	Min	Max	Mean	StdDev
Band 1	198	1419	464.758130	111.504621
Band 2	199	1451	447.612466	126.633394
Band 3	100	1473	332.464770	125.006514
Band 4	610	3104	1376.680217	449.758149
Band 5	87	2060	553.678184	304.492182
Band 6	-15	1642	242.210705	161.351616

iv) Statistics of endmember spectrum for barren

ROI Summary	Pixel Count			
Barren	77			
Barren				
Basic Stats	Min	Max	Mean	StdDev
Band 1	844	1109	959.831169	52.739529
Band 2	1007	1366	1197.233766	87.278878
Band 3	1051	1679	1323.662338	141.411178
Band 4	1513	2575	2010.220779	209.262906
Band 5	1481	3419	2390.220779	406.839475
Band 6	1191	3057	2095.805195	396.580484

Appendix 6: Land use change statistics

i) Land use change statistics (for land use change map 1989-1996)

Table

Land use change statistics 1989-1996

Rowid	VALUE	COUNT	CLASSIFIED_89_VA	CLASSIFIED_96_VA	RED	GREEN	BLUE	OPACITY
0	1	1993	1	1	0	1	0	1
1	2	607	1	2	0	1	1	1
2	3	907	1	3	0.627	0.322	0.176	1
3	4	553	1	4	0.753	0.753	0.753	1
4	5	346	2	1	0.498	1	0	1
5	6	132	2	2	0.627	0.125	0.941	1
6	7	303	2	3	0.647	0.165	0.165	1
7	8	190	2	4	1	0.753	0.796	1
8	9	2257	3	1	1	0.647	0	1
9	10	389	3	2	0.69	0.188	0.376	1
10	11	17105	3	3	0	0.392	0	1
11	12	152	3	4	1	0.714	0.757	1
12	13	4924	4	1	0.824	0.706	0.549	1
13	14	1649	4	2	1	1	1	1
14	15	2786	4	3	0.647	0	0	1
15	16	526	4	4	0	1	1	1

ii) Land use change statistics (for land use change map 1996-2006)

Table

Land use change statistics 1996-2006

Rowid	VALUE	COUNT	CLASSIFIED_96_VA	CLASSIFIED_2006	RED	GREEN	BLUE	OPACITY
0	1	3523	1	1	0	1	0	1
1	2	1448	1	2	0.933333	0.509804	0.933333	1
2	3	4378	1	3	0.627451	0.321569	0.176471	1
3	4	171	1	4	1	0.752941	0.796078	1
4	5	1291	2	1	1	1	0	1
5	6	803	2	2	0.627451	0.12549	0.941176	1
6	7	570	2	3	0.647059	0.164706	0.164706	1
7	8	113	2	4	0	0.619608	0.878431	1
8	9	1147	3	1	1	0.647059	0	1
9	10	583	3	2	0	0.619608	0.878431	1
10	11	19322	3	3	0	0.392157	0	1
11	12	49	3	4	1	0.752941	0.796078	1
12	13	531	4	1	1	0.647059	0	1
13	14	367	4	2	1	1	1	1
14	15	154	4	3	0.647059	0.164706	0.164706	1
15	16	369	4	4	0.752941	0.752941	0.752941	1

iii) Land use change statistics (for land use change map 2006-2015)

Table

Land use change statistics 2006-2015

Rowid	VALUE	COUNT	CLASSIFIED_2006	CLASSIFIED_2015	RED	GREEN	BLUE	OPACITY
0	1	3551	1	1	0	1	0	1
1	2	2238	1	2	0	1	1	1
2	3	400	1	3	1	0	0	1
3	4	303	1	4	1	0.713725	0.756863	1
4	5	1104	2	1	1	1	0	1
5	6	1532	2	2	0.627451	0.12549	0.941176	1
6	7	283	2	3	0.647059	0.164706	0.164706	1
7	8	282	2	4	1	0.752941	0.796078	1
8	9	2147	3	1	1	0.647059	0	1
9	10	2805	3	2	0.690196	0.188235	0.376471	1
10	11	18721	3	3	0	0.392157	0	1
11	12	751	3	4	0	0.619608	0.878431	1
12	13	151	4	1	0.823529	0.705882	0.54902	1
13	14	233	4	2	1	1	0.878431	1
14	15	7	4	3	0.647059	0	0	1
15	16	311	4	4	0.827451	0.827451	0.827451	1

Note:

Value	Land use change
1	Agriculture - Agriculture
2	Agriculture - Residential
3	Agriculture - Forest
4	Agriculture - Barren
5	Residential - Agriculture
6	Residential - Residential
7	Residential - Forest
8	Residential - Barren
9	Forest - Agriculture
10	Forest - Residential
11	Forest - Forest
12	Forest - Barren
13	Barren - Agriculture
14	Barren - Residential
15	Barren - Forest
16	Barren - Barren

Appendix 7 : Statistics for average temperature and rainfall in land use change map

1 a) Statistics for temperature in land use change map 1989-1996

Table

Statistics for temperature in land use change 1989-1996

Rowid	VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	1	1968	177120	22.56909	22.83631	0.26722	22.65288	0.04452	44580.879129
2	2	602	541800	22.55262	22.83631	0.28369	22.62652	0.03033	13621.16815
3	3	895	805500	22.51981	22.83631	0.31650	22.78878	0.08916	20395.961788
4	4	549	494100	22.55262	22.83631	0.28369	22.68205	0.02998	12452.447582
5	5	342	307800	22.51981	22.83631	0.31650	22.66393	0.05601	7751.06629
6	6	130	117000	22.55262	22.78081	0.22819	22.66510	0.04290	2946.463066
7	7	298	268200	22.51981	22.83631	0.31650	22.73233	0.09952	6774.236788
8	8	190	171000	22.55262	22.69453	0.14191	22.69175	0.01627	4311.432594
9	9	2227	200430	22.51636	22.78081	0.26444	22.59198	0.03262	50312.339115
10	10	386	347400	22.51636	22.83631	0.31995	22.58374	0.02116	8717.326122
11	11	16974	152766	22.51981	22.83631	0.31650	22.52456	0.02287	382331.88067
12	12	152	136800	22.51636	22.60718	0.09082	22.52891	0.02799	3424.394779
13	13	4852	436680	22.51981	22.83631	0.31650	22.58133	0.02804	109564.65504
14	14	1637	147330	22.51636	22.78081	0.26444	22.57389	0.01961	36953.464495
15	15	2741	246690	22.51981	22.83631	0.31650	22.58750	0.04650	61912.346367
16	16	526	473400	22.51636	22.69453	0.17816	22.55741	0.02127	11865.200684

1 b) Statistics for rainfall in land use change map 1989-1996

Table

Statistics for rainfall in land use change 1989-1996

Rowid	VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	1	1968	177120	1551.01220	1595.63867	44.62646	1577.84450	7.024286	3105197.985596
2	2	602	541800	1551.01220	1595.63867	44.62646	1580.88417	5.005041	951692.275024
3	3	895	805500	1551.01220	1610.09252	59.08032	1558.63313	14.67549	1394976.653687
4	4	549	494100	1551.01220	1593.07458	42.06237	1572.06516	4.812738	863063.773438
5	5	342	307800	1551.01220	1610.09252	59.08032	1577.86376	9.583099	539629.406738
6	6	130	117000	1559.31787	1593.07458	33.75671	1574.29489	7.88438	204658.335815
7	7	298	268200	1551.01220	1610.09252	59.08032	1568.26712	17.96375	467343.604004
8	8	190	171000	1566.27160	1590.85546	24.58386	1567.00283	3.232232	297730.538696
9	9	2227	200430	1559.31787	1610.09252	50.77465	1590.93190	8.031756	3543005.35022
10	10	386	347400	1551.01220	1610.09252	59.08032	1589.96458	3.720485	613726.328247
11	11	16974	152766	1551.01220	1610.09252	59.08032	1608.99377	5.043824	27311060.37414
12	12	152	136800	1587.24023	1598.15014	10.90991	1596.56343	3.492248	242677.641602
13	13	4852	436680	1551.01220	1610.09252	59.08032	1592.64251	5.707965	7727501.492798
14	14	1637	147330	1559.31787	1610.09252	50.77465	1590.28472	3.399575	2603296.100586
15	15	2741	246690	1551.01220	1610.09252	59.08032	1595.65586	9.064343	4373692.716553
16	16	526	473400	1566.27160	1598.15014	31.87854	1590.40701	3.201239	836554.090576

2 a) Statistics for temperature in land use change map 1996-2006

Table

Statistics for temperature in land use change 1996-2006

Rowid	VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	1	3486	313740	22.52724	22.77554	0.24830	22.61097	0.03621	78821.872103
2	2	1430	128700	22.52724	22.77554	0.24830	22.64623	0.04317	32384.115038
3	3	4305	387450	22.52724	22.77554	0.24830	22.57752	0.03123	97196.235363
4	4	168	151200	22.55595	22.74800	0.19204	22.62824	0.02114	3801.544437
5	5	1281	115290	22.52724	22.77554	0.24830	22.58586	0.02475	28932.492657
6	6	795	715500	22.52724	22.77554	0.24830	22.61913	0.02142	17982.212727
7	7	567	510300	22.52724	22.66461	0.13736	22.57820	0.01660	12801.844469
8	8	112	100800	22.55595	22.66461	0.10865	22.56340	0.02120	2527.101662
9	9	1126	101340	22.52724	22.77554	0.24830	22.70423	0.07881	25564.971378
10	10	576	518400	22.52724	22.77554	0.24830	22.73057	0.07788	13092.809183
11	11	19157	172413	22.52724	22.77554	0.24830	22.53206	0.02622	431646.80038
12	12	49	44100	22.60729	22.77554	0.16825	22.72588	0.02447	1113.568388
13	13	527	474300	22.57456	22.74800	0.17343	22.62786	0.02209	11924.884819
14	14	367	330300	22.55595	22.66461	0.10865	22.63120	0.00994	8305.65073
15	15	154	138600	22.55389	22.66461	0.11071	22.55951	0.0153	3474.16468
16	16	369	332100	22.55595	22.66461	0.10865	22.61866	0.00843	8346.286289

2 b) Statistics for rainfall in land use change map 1996-2006

Table

Statistics for rainfal in land use change 1996-2006

Rowid	VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	1	3486	313740	1559.38171	1608.75622	49.37451	1586.45975	6.669435	5530398.697266
2	2	1430	128700	1559.38171	1608.75622	49.37451	1579.25892	8.855925	2258340.259277
3	3	4305	387450	1559.38171	1608.75622	49.37451	1594.03810	7.408746	6862334.060059
4	4	168	151200	1561.51049	1590.17968	28.66918	1578.56404	3.69242	265198.758789
5	5	1281	115290	1559.38171	1608.75622	49.37451	1588.79663	4.133147	2035248.491455
6	6	795	715500	1559.38171	1608.75622	49.37451	1581.45616	4.778913	1257257.651245
7	7	567	510300	1575.31958	1608.75622	33.43664	1590.69383	3.669468	901923.402344
8	8	112	100800	1575.31958	1590.17968	14.86010	1588.29838	2.85131	177889.419556
9	9	1126	101340	1559.38171	1608.75622	49.37451	1572.81638	14.38815	1770991.250732
10	10	576	518400	1559.38171	1608.75622	49.37451	1567.44654	14.27762	902849.206787
11	11	19157	172413	1559.38171	1608.75622	49.37451	1607.56992	5.784338	30796216.97033
12	12	49	44100	1559.38171	1586.96106	27.57934	1562.50818	4.413369	76562.900879
13	13	527	474300	1565.32263	1593.08654	27.76391	1582.00714	3.620581	833717.763428
14	14	367	330300	1575.31958	1593.08654	17.76696	1576.68780	2.622126	578644.423218
15	15	154	138600	1575.31958	1593.08654	17.76696	1591.54655	1.957086	245098.169556
16	16	369	332100	1575.31958	1590.17968	14.86010	1579.68513	1.493489	582903.813232

2 a) Statistics for temperature in land use change map 2006-2015

Table

Statistics for temperature in land use change 2006-2015

Rowid	VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	1	3511	315990	22.48318	22.73252	0.24934	22.65896	0.03152	79555.614492
2	2	2211	198990	22.48318	22.73252	0.24934	22.59304	0.03916	49953.23081
3	3	398	358200	22.51762	22.73005	0.21243	22.61844	0.04442	9002.142605
4	4	300	270000	22.48318	22.73252	0.24934	22.54101	0.04733	6762.303207
5	5	1092	982800	22.48318	22.73252	0.24934	22.65299	0.03341	24737.064644
6	6	1518	136620	22.48318	22.73252	0.24934	22.68528	0.04417	34436.255423
7	7	278	250200	22.51762	22.70515	0.18753	22.65586	0.03365	6298.328943
8	8	280	252000	22.48318	22.70515	0.22196	22.54059	0.04341	6311.366249
9	9	2126	191340	22.51309	22.70515	0.19205	22.60946	0.03553	48067.729454
10	10	2775	249750	22.51309	22.70515	0.19205	22.61042	0.03746	62743.931059
11	11	18540	166860	22.51309	22.70515	0.19205	22.52142	0.02076	417547.14687
12	12	742	667800	22.51309	22.70515	0.19205	22.52900	0.03916	16716.524071
13	13	148	133200	22.57661	22.73252	0.15591	22.72045	0.02607	3362.627279
14	14	232	208800	22.52207	22.73252	0.21045	22.72311	0.03640	5271.761526
15	15	7	6300	22.50104	22.50104	0	22.50104	0	157.507317
16	16	311	279900	22.48318	22.73005	0.24687	22.48635	0.02267	6993.25621

2 b) Statistics for rainfall in land use change map 2006-2015

Table

Statistics for rainfall in land use change 2006-2015

Rowid	VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	1	3511	315990	1560.10620	1610.07104	49.96484	1578.47823	5.92760	5542037.083984
2	2	2211	198990	1560.10620	1610.07104	49.96484	1588.96230	7.03151	3513195.651978
3	3	398	358200	1562.36572	1610.07104	47.70532	1586.36222	9.63714	631372.165039
4	4	300	270000	1560.10620	1610.07104	49.96484	1596.96110	8.03681	479088.331909
5	5	1092	982800	1560.10620	1610.07104	49.96484	1578.90904	6.83529	1724168.67749
6	6	1518	136620	1560.10620	1610.07104	49.96484	1571.04373	9.44846	2384844.381592
7	7	278	250200	1566.63855	1610.07104	43.43249	1577.44666	7.58413	438530.173706
8	8	280	252000	1566.63855	1610.07104	43.43249	1595.50360	6.96853	446741.010254
9	9	2126	191340	1566.63855	1610.07104	43.43249	1588.72776	7.76391	3377635.219849
10	10	2775	249750	1566.63855	1610.07104	43.43249	1589.72056	7.85877	4411474.576416
11	11	18540	166860	1566.63855	1610.07104	43.43249	1609.17637	4.74230	29834130.03295
12	12	742	667800	1566.63855	1610.07104	43.43249	1602.78888	7.02224	1189269.349854
13	13	148	133200	1560.10620	1591.32287	31.21667	1564.50406	5.66517	231546.602173
14	14	232	208800	1560.10620	1599.78466	39.67846	1562.06301	7.27334	362398.619141
15	15	7	6300	1600.67944	1600.67944	0	1600.67944	0	11204.756104
16	16	311	279900	1562.36572	1601.51257	39.14685	1601.12093	3.33099	497948.610352

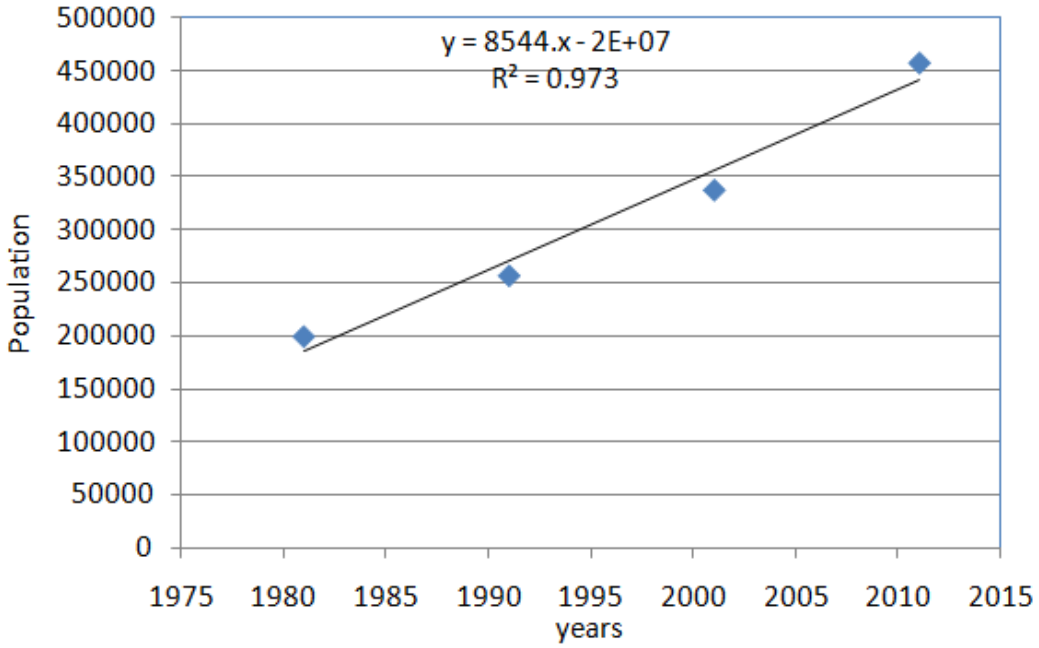
3a) Summary of statistics for mean temperature and rainfall in land use change map

Land use change	Mean temperature			Average	Mean rainfall			Average
	1989-1996	1996-2006	2006-2015		1989-1996	1996-2006	2006-2015	
Agriculture-agriculture	22.652886	22.610979	22.658962	22.6409	1577.84	1586.46	1578.48	1580.93
Agriculture-Residential	22.626525	22.646234	22.593049	22.6219	1580.88	1579.26	1588.96	1583.03
Agriculture - Forest	22.788784	22.577523	22.618449	22.6616	1558.63	1594.04	1586.36	1579.68
Agriculture - Barren	22.682054	22.628241	22.541011	22.6171	1572.06	1578.56	1596.96	1582.53
Residential-agriculture	22.663937	22.585865	22.65299	22.6343	1577.87	1588.8	1578.91	1581.86
Residential-Residential	22.665101	22.619136	22.68528	22.6565	1574.29	1581.46	1571.04	1575.60
Residential - Forest	22.732338	22.578209	22.65586	22.6555	1568.27	1590.69	1577.45	1578.80
Residential - Barren	22.69175	22.563408	22.540594	22.5986	1567.00	1588.30	1595.50	1583.60
Forest - Agriculture	22.59198	22.704237	22.609468	22.6352	1590.93	1572.82	1588.73	1584.16
Forest - Residential	22.583746	22.730571	22.610426	22.6416	1589.96	1567.45	1589.72	1582.38
Forest - Forest	22.52456	22.532067	22.521421	22.5260	1608.99	1607.57	1609.18	1608.58
Forest - Barren	22.528913	22.725885	22.529008	22.5946	1596.56	1562.51	1602.79	1587.29
Barren - Agriculture	22.581339	22.627865	22.720455	22.6432	1592.64	1582.01	1564.50	1579.72
Barren - Residential	22.573894	22.631201	22.72311	22.6427	1590.28	1576.69	1562.06	1576.34
Barren - Forest	22.587503	22.559511	22.501045	22.5493	1595.65	1591.55	1600.68	1595.96
Barren - Barren	22.557416	22.618662	22.486354	22.5541	1590.41	1579.68	1601.12	1590.40

Appendix 8: Population pattern of Lalitpur district from the years 1981-2011

i) The population of Lalitpur district according to census report (Source: Central Bureau of Statistics) is as follows:

Year	Population
1981	199688
1991	257086
2001	337785
2011	457606



Appendix 9: Photographs taken during the fieldwork

i) Photographs during ground truth collection


ii) Photographs during household interview