

**LAND USE INTENSITY DYNAMIC IN THE ANDHIKHOLA  
WATERSHED, NEPAL**

**A Dissertation**

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**in**

**GEOGRAPHY**

**By**

**Chhabi Lal Chidi**

**T.U. Regd. No.: 2049-84**

**Ph.D Reg. No.: 33/2070**

**Tribhuvan University**

**Kathmandu, Nepal**

**February 2020**

## LETTER OF RECOMMENDATION

We certify that this dissertation entitled “**Land Use Intensity Dynamic in the Andhikhola Watershed, Nepal**” was prepared by Chhabi Lal Chidi under our guidance. We, hereby, recommend this dissertation for final examinations by the Research Committee of the Faculty of Humanities and Social Sciences, Tribhuvan University, in fulfillment of the requirements for the Degree of DOCTOR OF PHILOSOPHY in GEOGRAPHY.

### Dissertation Committee



-----  
Prof. Pushkar Kumar Pradhan (Ph.D)  
Supervisor



-----  
Prof. Pashupati Nepal (Ph.D)  
Co Supervisor

Date: 22nd July, 2020



**TRIBHUVAN UNIVERSITY**  
**FACULTY OF HUMANITIES & SOCIAL SCIENCES**

**Office of the Dean**  
**Kirtipur, Kathmandu**



C. No.:.....

**APPROVAL LETTER**

This dissertation entitled **Land Use Intensity Dynamic in the Andhikhola Watershed, Nepal** was submitted by **Mr. Chhabi Lal Chidi** for final examination to the Research Committee of the Faculty of Humanities and Social Sciences, Tribhuvan University, in fulfillment of the requirements for the **Degree of Doctor of Philosophy in Geography**. I hereby certify that the Research Committee of the Faculty has found this dissertation satisfactory in scope and quality and has therefore been accepted it for the degree.

.....  
Dr. Bhim Raj Suwal  
Act. Dean and Chairman  
Research Committee

Date: *July 23, 2020*

## DECLARATION

I, hereby, declare that this dissertation is my own work and that it contains no materials previously published. I have not used its materials for the award of any kind and any other degree. Where other author's sources of information have been used, they have been acknowledged.



Chhabi Lal Chidi

Date: 22nd July, 2020

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## ABSTRACT

Land use/land cover science has so far mainly focused on broad land cover conversions while the spatial patterns of the intensity systems remain highly unclear. Land use intensity refers to the function of energy use per unit area of land that can be measured on the basis of input and output of a land. Traditional approaches often only examine one or a few aspects of land use intensity disregarding the multidimensionality of the intensification process in the complex land system. This situation hampers the development of a sound understanding of the mechanisms, determinants and constraints underlying changes in land use intensity. Thus, analysis and monitoring of land use intensity should follow an integrative conceptual framework of land use intensification. Mountainous regions like Nepal have long practice of intensive subsistence farming in practice integrating all land use/land cover units, which requires integrative approach to fully understand. However, literatures concerning on integrated concept of understanding of this intensive subsistence farming in the hills of Nepal is still lacking. Thus, this study is concerned on 1) land use/land cover change, 2) land use intensity change, and 3) to identify major determining factors of land use intensity change. This study consists of very valuable information to understand dynamics of land use intensity in the integrated agriculture system. Even in the incompatible spatial scale of various data sources, this study included maximum number of variable in order to identify major determining factors of land use intensity dynamics.

This study is mainly based on secondary data source. However, primary information was used for update and verification of data in order to identify the ground reality. Various maps and other secondary information were collected from available sources. Land use/land cover data were derived from aerial photo and high resolution satellite image. Object based image analysis technique was used so as to derive land use/land cover data. Several raster and vector based processes were executed in GIS to derive explanatory variables. Quantified values of land use intensity makes possible to address the complex spatial relationship of land use intensity dynamics with its driving factors through multivariate geo-statistical analysis. Twenty four quantitative explanatory variables were selected to test the strength of defining the dynamics of land use intensity. Thus, the land use intensity change was response variable and 24 variables were explanatory variables. Finally, land use intensity method is very

valuable concept to understand complex land use/land cover change and landscape ecological system. The following findings have been derived in order to fulfill the objectives of the study:

This study was conducted in the northeast part of Andhikhola watershed area located in the middle Hill region of Nepal having altitude range from 800 m to 1600 m from average mean sea level, which is located in subtropical and warm temperate climatic regions. The annual rainfall is around 3500 mm in the study area, which is quite high than national average 1600 mm. Only 13% of land has less than 5° and more than 50% land is 5° to 30° slope. This area is more accessible than most of the other Hill regions of Nepal due to its connectivity with Siddhartha highway, which was constructed in 1960s. Siddhartha highway crosses the study area and connected by several branch roads to other parts of the study area. The district headquarter including other market centers provide services with several service centers located in urban areas and other rural areas. Traditional intensive subsistence farming practice is dominant economic activities with limited commercial agriculture practice at accessible areas. Recent outmigration of rural farmers from the hill, urbanization process towards low land and accessible area are general scenario of the study area. It has resulted increasing agriculture land abandonment in the hill slope area is responsible for increasing greenery and increasing built up area along with the Siddhartha highway.

First, abandonment of agriculture land converts into shrubs and shrubs into forest are major land use/land cover changing pattern in the study area. Increasing built up area in lowland along with highway has developed slowly and gradually into urban area.

Second, average land use intensity is decreasing in the study area. Most of the areas have decreasing land use intensity. Marginal and remote areas has higher rate of decreasing land use intensity than in lowland suitable areas for agriculture. Very limited urban areas along with the highway have increasing rate of land use intensity.

Third, statistical analysis shows that the spatial distribution of land use intensity dynamics is highly controlled by physical, accessibility and natural resource variables. Incompatible spatial scale of socioeconomic data is the major cause of low strength of determining land use intensity dynamic.

Implementing part of land use policies in Nepal has remained weak since many decades. Thus, traditional intensive subsistence farming system remained stagnant over a long period of time with very limited commercialization in the accessible areas. The income opportunities outside this area were the attracting attributes of rural farmer to move them from their original places not only resulted agriculture land abandonment, but also pressure release in forest, grass land and shrubs. These types of heavy land use/land cover change has multifaceted implications on food security issue due to shrinking agriculture land, loss of biodiversity due to the increasing invasive plant, interspecies competition between human and wildlife, biomass intensity due to increasing vegetation and ground water recharge due to vegetation cover. These fields need for further investigation.

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## ACRONYMS AND ABBREVIATIONS

ABM	Agent Based Model
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CBS	Central Bureau of Statistics
CNES	National Centre for Space Studies
DADO	District Agriculture Development Office
DDC	District Development Office
DEM	Digital Elevation Model
DFO	District Forest Office
DHM	Department of Hydrology and Meteorology
DLDO	District Livestock Development Office
DN	Digital Number
DPHO	District Public Health Office
DSCO	District Soil Conservation Office
DVO	District Veterinary Office
ERDAS	Earth Resources Data Analysis System
ESRI	Environmental Systems Research Institute
ETM	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization
GCP	Ground Control Point
GIS	Geographical Information System
GPS	Global Positioning System
GWR	Geographically Weighted Regression
IKONOS	Greek word eikōn, for image
KESL	Kenting Earth Science Limited
LRMP	Land Resource Mapping Project
LST	Land Surface Temperature
NAS	National Academy of Science
NDVI	Normalized Difference Vegetation Index
NIR	Near Infra -Red
OBIA	Object Based Image Analysis
OLI	Operational Land Imager
OLS	Ordinary Least Square

OUP	Oxford University Press
PCA	Principal Component Analysis
RAP	Rural Access Program
RCA	Reality Check Approach
RS	Remote Sensing
SPOT	Satellite Pour Observation de la Terre
SPSS	Statistical Package for the Social Science
TIRS	Thermal Infrared Sensor
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VDC	Village Development Committee
VIF	Variance Inflation Factor
WGS	World Geodetic System

# CHAPTER I

## INTRODUCTION

### 1.1 Background

Land cover is the biophysical cover of the earth's surface and the immediate sub-surface, embracing soil materials, vegetation and water (Munch, Gibson & Palmer, 2019). Originally, land cover has narrow meaning referring only to the type of vegetation cover of land surface, but its meaning was extended including soil and biodiversity (Verheye, 2009). Furthermore, land cover is observed biophysical cover of the earth surface, which describes vegetation and manmade features omitting bare rocks and water, but in practice these elements are also included in this term (Mayhew, 2006). The term "land use" is referred to land cover, but here it is used in terms of socioeconomic and intentional purposes. Thus, land use is interference of human with intention to derive beneficial output from natural land resources. Land use is generally describes as areas for residential, agriculture or industrials purposes. Land use varies in nature and intensity with the purpose of serve and biophysical characteristics (Verheye, 2009). Land use is quite different than land cover because of the intentional use of natural cover to their benefits. Thus, here land use refers how people are using the land and land cover is the physical land surface type. Land use and land cover are sometimes interchangeable because land cover determines how certain types of land cover are used by human for certain benefits and certain types of land use reflect certain types of land cover. Therefore, in general land use and land cover is written as land use/land cover to define both together for better understanding of physical cover of land surface and its use.

Intensity refers to the state or quality of being intense (Hornby, 2001; Dorling Kindersley Limited & Oxford University Press, 2006). Land use intensity can be referred how intensely human use particular land surface. Land use intensity is a function of the energy use per unit area of land use/land cover (Brown & Vivas, 2005). Efficient assessment of land use intensity is looked as a composite system and its performance depends on the input, output level of land use/land cover and land use intensity, land use structure and other factors (Gong, Chen, Liu & Wang, 2014). Single metrics are easy to compute and interpret, but cannot provide coherent picture

of intensity, whereas system metrics, by aggregating multiple processes, hamper the understanding of the relation between different system components (Kuemmerle, Erb, Meyfroidt, Muller, Verburg, Estel, et al. 2013). Therefore, ample opportunities exist so as to make advance of both types of metrics in parallel to arrive at a second generation of land use intensity metrics. However, several scientist realize that a large knowledge gaps currently exist that limit our ability to understand and characterize pattern and dynamism of land use intensity particularly a comprehensive conceptual framework and a system of measurement is lacking (Erb, Haberl, Jepsen, Kuemmerle, Lindper, Muller, et al. 2013). They have proposed four dimensions and indicators of land use intensity such as input to land, output from land, combined indices of input and output, and finally changes in system properties. Therefore, the conceptual framework of measuring land use intensity is the land based production system embedded within a territory and the analysis and monitoring of land use intensity should follow and integrate conceptual framework that focuses on input on the land, output from the land, and the human induced, but unintended outcomes of land use intensification. Thus, land use intensity is the hierarchical order of numerical values of different land use types that can be measured based on input and output of different land use/land cover types (Erb, 2012, Kuemmerle, Erb, Meyfroidt, Muller, Verburg, Estel, et al., 2013).

Land use/land cover change is the modification of piece of land from one state to another one (Verburg, Chen, Soepboar, and Veldkamp, 2000) and dynamics of land use/land cover are fundamental elements to monitor physical and human processes (Shreenivasulu, Jayaraju, Kishore, & Prasad, 2014; Lausch, Blaschke, Hasse, Harzog, Syrbe, Tischendorf, et al., 2015; Dikshit, 1999). Land use/land cover science has so far mainly focused on broad land cover conversions while the spatial patterns in the intensity systems remain highly unclear (Kuemmerle, Erb, Meyfroidt, Muller, Verburg, Estel, et al., 2013). Traditional approaches often only examine one or a few aspects of and use intensity disregarding the multidimensionality of the intensification process in the complex land system (Turner, Lambin & Reenberg, 2007; Lambin & Meyfroidt, 2011). This situation hampers the development of a sound understanding of the mechanisms, determinants and constraints underlying changes in land use intensity (Erb, 2012). Thus, analysis and monitoring of land use intensity should follow an integrative conceptual framework of land use intensification (Erb, Haberl,

Jepsen, Kuemmerle, Lindner, Muller, et al., 2013) that is able to address the system level analysis of land use/land cover change. Intensive subsistence farming practice integrates all land use/land cover types as a single entity, integrating each other interdependently (Malla & Chidi, 1997) in the Hills of Nepal in which concept of land use intensity is being inevitable for proper understanding to it.

## **1.2 Statement of the Problem**

The quality and quantity of land use/land cover is related with many challenges of sustainable science (Vitousek, 1997). Land use/land cover change plays a central role in global carbon cycle and significantly contributes to climate change (Brovkin, Sitch, Boh, Claussen, Bauer & Cramer, 2004). Moreover, human socioeconomic system relies on land use/land cover and intrinsically linking to food security (Aryes, 2007). Land use intensity change is highly important in terms of its socioeconomic and ecological effects (Tilman, 1999). Clear understanding of land use intensity is the basic requirement in order to achieve harmony among ecological, economic and social system, which provides baseline reference to evaluate future change and sustainability (Huimin, Fang, Jiyuan, Xiangming & Yuanwei, 2017). Empirical studies revealed that the past concept of inverse relationship between intensification of land use and expansion of spare land for production is trivial because it has not straightforward interpretation having complexity on it (Rudel, Schneider, Uriarte, Turner, DeFries, Lawrence, et al., 2009). It needs an innovative method and new perspective for better understanding of casual chains between various factors, mechanisms, determinants and constraints of land use intensification process (Erb, 2012). Availability of remote sensing data for research has brought land use/land cover change into focus and it also diverted the attention to intensification because of most changes associated with intensification are not related to land use/land cover changes and not detectable by remote sensing (Verburg, Neumann & Nol, 2011). Conceptualizing, quantifying and understanding land use intensity and its change are highly influenced by socioeconomic processes, options and capabilities (Liverman & Cuesta., 2008). Land use intensity is the degree of the human interference due to their activities on land (Ma, Cheng, Bo, Li & Gu 2017) and it can be understand that human influence plays vital role in intensifying land use. Different approaches are adopted on land use intensity research among which economic approach is more popular (Mezosi, Burghard, Meyer, Bata, Kovács, Czúcz, et al., 2019). Spatial and

temporal dynamic of land use/land cover is influenced by multiple factors. The influencing factors have nonlinear relationship with land use/land cover (Li, Wang, Li & Lei, 2016) and its intensity as well which need non stationary dependency analysis to identify the spatial relationship of land use intensity dynamic with its determining factors.

Traditional intensive subsistence farming practices of Nepal is still dominant in the Hills and the Mountains of Nepal. High population pressure during last fifty years became major environmental degradation and loss of productivity (Shrestha, 1999; Eckholm, 1976) because of the extension of cultivated cropland to marginal hill slopes where the land carrying capacity was very low and removal of vegetation cover, but in the last two decades, the land use/land cover is being highly dynamics (Chidi, 2016a; Chidi, 2016b) because of the labor shortage due to the outmigration of rural farmers from hill to plain; and rural to urban; and foreign countries. Sharp decrease of involvement in agriculture of economically active population (Satyal, 2010) has further accelerated this situation. As a result, agriculture land abandonment, successful implementation of community forestry (Gurung, Karki & Bista, 2011) in the Hills and urbanization in lowland area is being major process of land use/land cover change. Land use/land cover change has multiple implications. Therefore, it should be fully understood for environmental management, livelihood and sustainable development. Traditional intensive subsistence farming practice in the Hills and Mountains of Nepal integrates cultivated land, livestock, forest, grassland, built up areas. It requires integrative approach of study to fully understand its direction of dynamism and interrelationship with its determining factors. However, neither government nor other concerned agencies are fully aware about recent land use/land cover dynamics in Nepal, which has multiple implications at present and in the future. Land use intensity is useful concept to understand integrated traditional agriculture system. Thus, this study aims to assess land use/land cover and their intensity dynamic in northeast part of Andhikhola watershed. Selected study area is the combination of several sub-watersheds of Andhikhola. From the preliminary study, it was found to be most dynamic and representative area of the watershed in the context of topography, accessibility, resource availability and combination of several land use/land cover and its dynamic character.

### **1.3 Research Questions**

The present research attempts to answer the following research questions:

- How land use/land cover is changing in the study area?
- What is the situation of land use intensity dynamics in the study area?
- What are the major determining factors of land use intensity dynamics?

### **1.4 Objectives of the Study**

The general objective of this study is to assess the status of land use/land cover change, land use intensity change and to identify the determining factors of land use intensity change. The specific objectives are as follows:

- To assess the pattern of land use/land cover change.
- To assess the land use intensity change in the study area.
- To identify the major determining factors of land use intensity change.

### **1.5 Significance of the Study**

The present study has focused on the land use/land cover change in such a diverse geographical area which could be a good example for other studies that how land use intensity change is determined by various factors. The significance of the study can be identified as follows:

The concept of land use/land cover study and quantification of its intensity will be very useful for further research in which large knowledge gap exists. Furthermore, more accurate measurement and analysis will provide valuable insight to complex land system.

So far no studies are available on land use/land cover change measurement, which is a key element, but it is not only adequate, intensity analysis based on various determining factors would provide compliment to the existing body of literature.

A better characterization of the spatial patterns of land use intensity is crucial to monitor the various environmental and societal impacts of land use and to understand the diversity of changing land use intensity as well.

Recently available technique such as object based image processing on high resolution imageries of Remote Sensing (RS) and GIS would add added value of understanding the land use intensity in broad sense.

Multivariate spatial analysis technique using Geographically Weighted Regression (GWR) model is very good example for the further spatial ecological research for geographers and other spatial analysts.

This research reveals that how relationship among variables differs spatially, which is very useful in spatial analysis of relationship among multiple variables.

### **1.6 Limitations of the Study**

None of the research remains without any limitation. Thus, this study has also few limitations related to the study area and spatial scale of data source, which are as follows:

Watershed level analysis would be the best for this study, but high resolution image is very costly. Therefore, this study was limited only on northeastern part of the study to make cost effective. However, the study area was selected for the best representative area of the watershed as much as possible.

Watershed level analysis shows that there is higher dependency of shrinking of cultivated land on ward level population change (Chidi, 2016a). Similarly, this study shows the higher relationship of land use intensity dynamics with built up kernel density. However, this study shows weaker dependency of land use intensity dynamics on demographic, caste/ethnicity and food sufficiency variables. Demographic, caste/ethnicity and food sufficiency data are available only on ward level, which is more generalized for grid level analysis for this study and it was not possible to collect detail data in this study. If these data would be micro level, the strength of explanatory variables might be higher than present findings.

Land use/land cover change has multifaceted issues such as food security, soil erosion, extension of invasive plant, interspecies competition between human and wildlife, changing biomass intensity and ground water recharge or drying up of water resources. This study has also found those issues in the study area, but could not address because of the study limitation.

## CHAPTER II

### REVIEW OF THE LITERATURE

Literature review has been divided into four categories; first one is related to concept, approach theories and models, second is review of empirical studies, third is land use policies of Nepal and fourth is research gaps.

#### **2.1 Approach, Theories and Model**

Different approaches, theories and models related to this study published in different literatures have been reviewed into the following sub-headings:

##### **2.1.1 Approach**

This part includes these literatures related to data acquisition technique, quantification of land use intensity, controlling factors of land use/land cover change and land use intensity analysis.

##### ***A. Data acquisition techniques***

Satellite sensor has become an important tool for studying land use/land cover change which offers the advantage of rapid data acquisition of land use/land cover information at a lower cost than ground survey method and analysis. Remote sensing data can provide critical insight into the involving human environment relationship (Szuster, Chen & Borger, 2011). Large variety of remote sensing imagery from sensors provides a large amount of multispectral data about our earth surface for global and detailed analysis of change detection and monitoring. Multispectral satellite image is being valuable source of land surface information (Bakula, Kupidura & Jelowicki, 2016) whereas historical aerial photo is for historical record of land surface (Molg, and Bolch, 2017; Tayyebi, Delavar, Saeedi, Amini & Alinia, 2008; Mandal, 2011) to derive historical land use/land cover data. Pixel based supervised classification using maximum likelihood is a popular technique of multispectral image classification for land use/land cover (Ramachandra, Kumar & Joshi, 2012) data acquire. Traditional image analysis methods are mostly pixel based and the use of the spectral differences of landscape elements. During the last two decades, considerable attention of image analyst has been taken by object based image analysis for

analyzing and interpreting remote sensing image (Addink, Coillie & Jong, 2012). Several studies have proven that object based image analysis gives higher accuracy than pixel based classification for high and medium resolution imageries (Duro, Franklin, & Dube, 2012; Wang, Wang & Zhou, 2012) for land use/land cover study. Additionally, the object based classification offered a more generalized visual appearance and more continuous depiction of land cover, which perhaps better represent how land cover interpreters and analyzes actually perceive the landscape.

### ***B. Quantification of land use intensity***

Intensity can be measured by considering several factors which requires quantitative method. There are different ways to quantify the intensity, weighted technique, is one of them, which is often used in order to assign value to the variables in a rational or realistic way. In this system, each land category is given certain weight as per their hierarchical order of use intensity (Wang, Liu & Ma 2010) on the basis of input, output and the human induced, but unintended outcome of land use intensification. This technique has been used in Yellow river basin in China. They have given weight 1 for unused land, 2 for forest and water body, 3 for agriculture land and 4 for industrial lands. Similar types of technique have been used in many studies (Bluthgen, Dormann, Prati, Klaus, Kleinebecker, Holz, et al. 2012; Zhang, Zhao & Liu, 2013; Armengot, Maria, Moreno, Bassa, Chamorro, & Sans, 2011). Several studies related to land use intensity calculation and quantification technique are mostly concerned on single or few themes.

### ***C. Controlling factors of land use/land cover change***

Land use/land cover change is the leading edge and hot topics of global change research in which the mutual influence between land use/land cover and human society acts on the human survival environment and food security (Chang, Hou, Li, Zhang & Chen 2018). Continuous monitoring of land use/land cover changes is important to understand the dynamics and predicting the patterns and trend of changes in landscape and associated interaction at different spatial scale, which support evidence based improvement of land management policies and practices (Yohannes, Cotter, Kelboro & Dessalegn, 2018). Understanding the mechanisms of land use/land cover change caused by a variety of driving forces is one of the major goals of global

change research. Economic and rational individual person attempts to discern and choose the system arrangement that is favorable for him (Hengzhau, 2011). In traditional rural society, people land ratio become change due to natural change of population and farmers agreement to adjust land because they may encounter these circumstances. The relationship between land use/land cover change and its driving factors is a complex, dynamic and non-linear progress that is usually accomplish by comparing land use/land cover and the location specific characteristics (Olaniyi, Abdullah, Ramli & Sood, 2012). In recent decades, outmigration of farmers from rural areas is a key transformative process in agriculture regions of the developing world (Gray & Bilsborrow, 2014). Land use/land cover pattern analysis provides evidence of the heterogeneity of the region, both in terms of agrarian structure and land use/land cover trajectories in different localities (Aguiar, Camara & Escada, 2007) and it is dynamic and frequently changes, often because of human interventions. Current land use/land cover patterns are the result of centuries of human activities in specific areas and are strongly influenced by natural conditions. Today's heterogeneous landscapes with their mosaic of arable land, patches of natural vegetation, grassland, agro-biodiversity, built-ups and others reflect the diverse land use/land cover in an area. Studies have shown that external factors such as agricultural policy and forest conservation policy are frequently driving forces behind changes in the use of land in rural areas (Lourenco, Correia, Jorge & Machado, 1997). Similarly, social, economic and demographic changes affect land use/land cover patterns over time (Axinn & Ghimire 2011). Therefore, land use/land cover represents an insightful reflection of human interaction with its environment in an area (Gautam, Webb, & Eiumnoh 2002; Virgo & Subba 1994; Thapa 1996; Jackson, Tamrakar, Hunt & Shepherd 1998). These studies can provide useful insights into changes to local and external pressures of various kinds and how these translate into changes in land use/land cover patterns over time. Development interventions in the form of, for example, infrastructure, the introduction of new technologies (change of traditional "phaali" or plough by improved wider one for tilling), changes to policies, urbanization (demand food – change in intensity of agricultural land use/land cover and cropping patterns in surrounding areas of huge cities such as Kathmandu, Lalitpur and Pokhara) are likely to translate into changes in land use/land cover and socio-economic development in response to these drivers of change. Land use/land cover studies also deal with explaining the economic process, viz. human behavioral

component that underlies land use/land cover change, i.e. causal relationships between individual choices and land use/land cover change outcomes (Axinn & Ghimire 2011). As human systems of production change, by shifting cultivation, subsistence agriculture, or commercial production, patterns of consuming land change and these changes alter the use of the land and the nature of the resulting land cover. Provisions of schools, health services, markets and transportation services may all change social life in consumption patterns of land. These changes in patterns of consuming land are likely to have important consequences for local land use/land cover (Gulhan & Ceylan 2016; Braimoh & Onishi, 2007). The peoples of Nepal are diverse caste/ethnicity groups having various culture, religion and tradition including diverse socioeconomic conditions and their settlements are locating at certain geographic condition (Gurung, Khanal, Pradhan & Ghimire, 2006, Gurung, Gurung & Chidi 2006, Gurung, Suwal, Pradhan & Tamang 2014; Dahal, 2014). Ethnic diversities have an effect on micro level land use intensity change due to their behavioral and socioeconomic characters in some Asian countries (Weber, Faust, Schippers, Mamar, Sutarto & Kreisel, 2007; Trincsi, Pham & Turner, 2014). Thus, land use/land cover is a fundamental measure of how the environment is organized in a setting. Changes in land use/land cover are reflected in the relative magnitude of the land area devoted to agricultural and non-agriculture activities. Over time, as the population changes, as economy grows, and as government infrastructure spreads, land use/land cover is likely to be transformed in many ways, for instance, in the conversion of agricultural land to land for housing and other non-agricultural enterprises, the reduction of public forest and grazing lands, and the intensification of farm land.

#### ***D. Land use intensity analysis***

Land use/land cover change analysis rarely identifies the processes behind the change in land patterns whether the observed transitions are due to systematic or random processes instead, land use intensity analysis can quantify, detect and differentiate between systematic and random processes of landscape transitions, and analyze how the land transitions have shifted over time which can analyze maps to identify landscape transitions over a number of time points at once (Mwangi, Lariu, Julich, Patil, McDonald & Feger, 2017). Land use intensity is able to quantify the impacts of

human activities on natural resources, which are the major driver of environmental change. Therefore, land use intensity analysis is an essential measurement for assessing land use/land cover sustainability (Huimin, Fang, Jiyuan, Xiangming & Yuanwei, 2017). Land use intensity is a quantitative indicator of the intensity of the impact by human activities and thus is often used to describe the intensity of human activities (Felipe-Lucia, Comin & Bennett, 2014; Kindu, Schneider, Teketay & Knoke, 2016) that can be quantified on the basis of intensity of human occupancy on land. Quantification of the land use/land cover on the basis of relative importance of land use/land cover composition can provide valuable insights for understanding in human dominated landscapes (Pellissier, Mimet, Fontaine, Svenning & Couvet, 2017) because it is the indication of the degree of the inference of human activities on land. Spatiotemporal analysis of land use/land cover research has gone one step ahead on the basis of intensity concept (Ma, Cheng, Bo, Li & Gu, 2018) which is very valuable to use various quantitative models and analysis. Quantitative dependency analysis requires standardization of the values of the variables in order to compare the relative contribution of explanatory variables (Letourneau, Verburg & Stehfest, 2012). Multivariate models of the proximate causes of land use/land cover changes allow to account for the interactions between independent variables and to rank explanatory variables according to their degree of importance in explaining the spatial variation of land use/land cover change (Mertens & Lambin, 2000) and its intensity. The relationship between land use/land cover and its driving factors is a complex, dynamic and non-linear process that is usually accomplished by comparing land use/land cover and the location specific characteristics (Olaniyi, Abdullah, Ramli & Sood, 2012). Cellular Automata has capabilities in simulating the spatiotemporal characteristics of complex system and can be used to simulate unexpected behavior of complex system that cannot be represented by normal equations (Yang, Zhang & Chen, 2014; Chen & Nuo, 2013). Tobler's first law of geography (Tobler, 1970) results spatial autocorrelation problems in geographical data and it constrains the application of general linear models. Therefore, geographers have developed local statistics for spatial analysis like GWR technique (Fotheringham, Charlton & Brunson, 2002) which tests whether there is spatial variation in the strength, intensity and direction of a relationship inductively through analyzing separate subsets of character, defined by their proximity to a randomly selected core at different scales. GWR presents a platform for exploring the relationships that exist between explanatory variables and

the response variable across space and such analysis is conducted within a single framework (Nkeki & Osirike, 2013) but yields multiple results and explanations. Several studies in the past proved (Oshan & Fotheringham, 2018; Gwarda, 2018) that GWR is a very effective instrument of spatial dependency analysis. The model is considerably better with local empirical data than global model and it enabled the drawing of detailed conclusions concerning the local variation determinants.

### **2.1.2 Theories**

Theories related to this study have been described under the category of agriculture land rent, human ecological, functional behavior and structural functional.

#### ***A. Agriculture land rent theory***

Johann Heinrich von Thünen conceptualizes from the Isolated State (1826) developing the first serious treatment; economic geography, relating with rent theory. He has developed the theory of marginal productivity in a quantitative way (Okelly & Bryan, 1996; Pinto, 1975). The use of land is based on the cost of transport to market and the land rent a farmer can afford to pay, which is determined by constant yield. The model generates concentric rings pattern of agricultural activity. Dairying and intensive farming lies around the city, which is occupied by perishable products such as vegetables, fruit, milk and other dairy products must get to market quickly. Timber and firewood would be produced into second ring because it was very important and difficult to transport to city. Third ring is for food grain production and the last ring is for animals that can transport themselves to the city. The cultivation of a crop is only within certain distances from the city. After a certain distance from the market, the production of a crop becomes unprofitable, either because its profits drop to zero or the profits earned by other crops are higher. The conclusion of this theory is that products having low yields with high price and high transport costs relative to its weight or distance due to its weight will have higher location rent close to the market than a product having lower transport costs. This theory is criticized (Peet, 1969; Chisholm, 1961) ignoring other characteristics and explaining only the use of zones controlled solely by economically rational perception. However, its universality nevertheless a high value within geographical questions and methodology. This

theory is helpful for this study to understand how proximity to market or service center effects on pattern of land use/land cover and its intensity change.

### ***B. Human ecological theory***

Ecology is not just biological, but a human science as well (Young, 1974). Thus, human ecology is the study of relationship between humans and their natural, social, and the surrounding environments they built up. In the initial period, the history of human ecology has strong roots in geography and sociology. A major historical landmark was stimulated in the study of ecological relations between humans and their urban environments. Main focus of research was human-nature interactions in frequent reference to the economy of nature (Jelinski, 2005; Stallin, 2007; Liu, Dietz, Carpenter, Alberti, Folke, Moran, et al. 2007). Human ecology has a fragmented academic history with developments spread throughout a range of disciplines, including geography and some authors have argued that geography is human ecology (Gross, 2004; Barrows, 1923; Bruhn, 1972). Human ecology has a history of focusing attention on human impact on the biotic world (McDonnell 1997; Young, 1974). Paul was the early contributor of applying human ecology, addressing human population explosion, resource limits, pollution, and published a comprehensive account on human ecology (Sears, 1954). Human ecology is an analysis applied to the relations in human beings (Park 1936; Borden, 2008) integrating diverse perspectives from a broad spectrum of disciplines covering wider points of view. This theory helps to look for interrelationship and interaction of different aspects of land use/land cover and its intensity with its controlling factors.

### ***C. Functionalist and behaviorist theory***

Functionalism is a theory of mind which states that mental states such as beliefs, desires, being in pain, etc. are constituted solely by their functional role. They have causal relations to other mental states such as numerous sensory inputs and behavioral outputs (Block, 1996). Thus, functionalism is a theoretical level between the physical implementation and behavioral output (Marr, 1982). Behaviorism is an approach to understanding the behavior of humans and other animals, which assumes that behaviors are either reflexes produced by a response to certain stimuli in the environment. Behaviorists generally accept the important role of inheritance in

determining behavior. However, they focus primarily on environmental factors also. Behaviouralist examines the behavior, actions and acts of individuals rather than the characteristics of groups in different social settings (Walton, 1985). Functionalists want to individuate mental states causally, and since mental states have mental causes and effects as well as sensory causes and behavioral effects. Functionalists individuate mental states partly in terms of causal relations to other mental states. One consequence of this difference between functionalism and behaviorism is that there are possible organisms that according to behaviorism have mental states, but according to functionalism, do not have mental states. This theory helped to understand how individual behaves and acts on a new changing situation. Furthermore, it helped to understand land use/land cover and its intensity change is controlled by function of the people which have been controlled by individual behaviors.

#### ***D. Structuralist-functional theory***

Structural functionalism is a framework for building theory that sees society as a complex system whose parts work together so as to promote solidarity and stability, which looks at society through a macro-level orientation broadly focusing on the social structures that shape society as a whole (Macionis & Gerber, 2011). This theory believes that society has evolved like organisms. A common analogy presents these parts of society as organs that work toward the proper functioning of the body as a whole (Urry 2004). In the most basic terms, it simply emphasizes the effort to impute, as rigorously as possible, to each feature, custom, or practice, its effect on the functioning of a supposedly stable and cohesive system. Structural-functionalism came to describe a particular stage in the methodological development of social science, rather than a specific school of thought. The concept of this theory is inevitable to understand land use/land cover and its intensity changes. Land use/land cover and its intensity changes are multifaceted and complex interaction of nature and human interaction.

### **2.1.3 Models**

Several models were identified and employed as important models for this study, among them some selected models; agent based, statistical, spatial interaction, optimized and integrated are incorporated in this study.

#### ***A. Agent based model***

An agent-based is a computational model for simulating the actions and interactions of autonomous agents with a view to assessing their effects on the system as a whole. Particularly within ecology, it is also called individual-based models (Grimm & Railsback, 2005). It is used on non-computing related scientific domains in both physical and social science (Niazi & Hussain, 2011). This model is related to, but distinct from, the concept of multi-agent systems or multi-agent simulation in that the goal of Agent Based Model (ABM) is to search for explanatory insight into the collective behavior of agents obeying simple rules, typically in natural systems, rather than in designing agents or solving specific practical problems (Niazi & Hussain, 2011). This model simulates the simultaneous operations and interactions of multiple agents in an attempt to re-create and predict the appearance of complex phenomena (Gustafsson & Sternad, 2010). This model is a kind of micro scale model that simulates the simultaneous operations and interactions of multiple agents in an attempt to re-create and predict the appearance of complex phenomena. This model is was very helpful for this study to conceptualize the role of individual controlling factors on land use intensity dynamics and how single variable can play different roles at different locations. Additionally, it was helpful to understand the role of individual variables in individual and combined state of analysis.

#### ***A. Statistical model***

A statistical model is a mathematical model, which embodies a set of statistical assumptions concerning the generation of some sample data and similar data from a larger population. A statistical model represents, often in considerably idealized form, the data-generating process. The assumption of a statistical model describes a set of probability distributions, some are assumed to adequately approximate the distribution from which a particular data set is sampled. The probability distributions inherent in statistical models are what distinguish statistical models from other non-statistical

mathematical models. This model is usually specified by mathematical equations that relate one or more random variables and possibly other non-random variables. As such, a statistical model is a formal representation of a theory (Ader, 2008). This model is a special class of mathematical model. A statistical model can be distinguished with other mathematical models which is non-deterministic statistical model. Thus, in a statistical model specified through mathematical equations, some of the variables do not have specific values, but instead have probability distributions. Statistical models are often used even when the physical process being modeled is deterministic. The three purposes of statistical modeling (Konishi & Kitagawa, 2008) are extraction of information, prediction and description of stochastic structure. Applied statistician has ability to formulate appropriate statistical models and then apply them to data in order to answer the questions of interest. This model is inevitable to understand requirements of data for statistical analysis. This theory was helpful on data generation, data standardization, selection of statistical model and validation of result.

### ***B. Spatial interaction model***

Spatial interaction model predicts the volume of people, goods, services and information moving between two locations of space. This model predicts the interchange of goods, peoples and services between all the members of a discrete set of locations or zones resulting in a square matrix of flows from each zone to another individual zone. Spatial interaction model was formerly known as trip distribution models continue to play a critical role in advanced models. Spatial distribution models are the largest source of error in travel forecasting (Zhao & Kockelman, 2002). Despite the development of more advanced alternatives, the most common spatial interaction model in travel forecasting remains the gravity model (NAS, 2007). Most spatial interaction models attempt to predict the flow of people and goods in terms of two basic factors, although some models incorporate additional explanatory variables such as accessibility, psychological boundary, demographic attributes, destination qualities, k factors and other spatial bias factors. This study concerns with spatial interaction of human and nature. Land use/land cover and its intensity is the spatial result of this interaction. Without any concept of interaction, none of the variables can be explained as a response and explanatory variables. That's why spatial interaction

model is very useful to understand the relationship among different variables in this study.

### ***C. Optimization model***

Optimization model is a type of mathematical model that attempts to optimize an objective function without violating resource constraints. An optimization problem consists of maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of the function. The generalization of optimizing theory and techniques to other formulations constitute a large area of applied mathematics. Optimization includes finding the best available values of some objective function given a defined domain, including a variety of different types of objective functions and different types of domains. Optimizing model requires three set of variables in decision making process such as decision variables, result variables and uncontrolled variables (Zhang, Lu & Gao, 2015). Decision variables are determined by related decision makers and describe alternative courses of action. Result variables are outputs and are often described by objective functions. Uncontrollable variables are the factors that affect the result variables, but are not under control of decision makers. Difficulties in solving multi-agent optimization problems are to construct an optimization algorithm describing the properties of a multi-agent system that is unknown to a centralized decision maker. This study was very valuable to understand how to optimize the prediction strength of explanatory variables in GWR model. From this concept of optimization, frequent filtering processes of variables were executed to optimize the prediction strength and result validation.

### ***D. Integrated model***

Integrated model is a type of scientific modeling often used by the environmental analysis. Integrated model integrates knowledge from more domains into a single framework (Bruckner, 2016). Integrated modeling is referred to as assessment because the activity aims to generate useful information for policy making, rather than to advance knowledge for knowledge's sake. This assessment model is that part of integrated assessment which relies on the use of numerical models. Integrated assessment model has a long history, but scholars disagree on the first precedent.

However, it became recognizable as an interdiscipline in the late 1980s with a focus on understanding and regulating acidification. Integrated assessment mode was further developed in the area of climate change (Pindyak, 2017). Generally, integrated model helps decision makers to understand very complex environmental problems because it brings together and summarize information from diverse fields of study. Integrated assessment models are mathematical computer models based on explicit assumptions about how the modeled system behaves. The strength of this model is its ability to calculate the consequences of different assumptions and to interrelate many factors simultaneously, but it is constrained by the quality and character of the assumptions and data that underlie the model. As this study is concerned with the integration of different determining variables of the land use intensity dynamics in integrated agriculture system, this concept was highly valuable for conceptualizing and methodological development for this study.

## **2.2 Review of Empirical Studies**

Different empirical studies propounded by different scholars around the world including Nepal in different time and venue have been incorporated under this topic. Additionally, it has reviewed historical document of database and national policy related to land related policies, planning and management in Nepal.

### **2.2.1 Empirical Studies in the World**

This section incorporates empirical studies in the world related to land use/land cover change and land use intensity analysis.

#### ***A. Land use/land cover change***

Among several empirical researches, a study on land use/land cover in Andhra Pradesh, India based on the topographic maps and satellite image. The study concluded that satellite image is vital tool for continuous observation and quantification of environmental phenomena across various spatial and temporal scales, which are otherwise not possible to attempt through conventional mapping technique (Shreenivasulu, Jayaraju, Kishore & Prasad, 2014). Several researches were conducted on agriculture land abandonment and its causal relationship in Europe and post-Soviet European Russia (Gellrich & Zimmermann, 2006; Weissteiner, Boschetti, Bottcher, Carrara, Bordogna & Brivio, 2011; Prishchepov, Mullaer, Dubinin,

Baumann, and Radeloff, 2013; Sanz, Fernandez, Mouillot, Ferrat & Istria, 2013) and concluded that agricultural land abandonment in this region is as a result of depopulation due to outmigration. Major areas of land abandonment are at the marginal less productive land than suitable area for cultivation. Several land use/land cover and its dynamic studies have been conducted in the past. This field of research has flourished due to the recent advanced technology like Geographical Information System and Remote sensing technology. It is not only advanced into the number of research, but also in accuracy and efficiency.

Object based image analysis technique on high resolution satellite image has been used in several empirical studies in the world. In some empirical studies, object based image analysis techniques have been used for high and medium resolution multispectral satellite images such as SPOT-5, IKONOS, ASTER, QuickBird, Landsat and other images of different part of the world (Whiteside, Boggs & Maier, 2011; Addink, Coillie & Jong, 2012; Duro, Franklin & Dube, 2012; Wang, Wang & Zhou, 2012; Gutierrez, Seijmonsbergen & Duivenvoorden, 2012; Liu & Elrahman, 2018). The common finding of these empirical study is object based image analysis technique improves accuracy of image analysis due to the use of various characteristics of landscape features rather than only the spectral value in pixel level analysis.

### ***B. Land use intensity***

Related to land use intensity, studies in different parts of the world were conducted especially on single theme. Novel index of land use intensity for organic and conventional farming (Armengot, Maria, Moreno, Bassa, Chamorro & Sans, 2011) research was conducted in Mediterranean cereal fields and by using Principal Component Analysis (PCA) and concluded that land use intensity index supports the discrete categorization of land use intensity. A study on the relationship between land use intensity and biodiversity at regional scale concluded that an understanding of the relationship among human activities and ecosystem functioning at multiple scales is critical for the development of future land use/land cover scenario that seeks to enhance ecological integrity (Diggelen, Sijtsma, Strijker & Burg, 2005) and the key threat for biodiversity is because of the economic development resulting land reclamation for urban built up on agriculture land. Land use intensity comprehensive

index model was used for the study on dynamic and change of spatial pattern of land use/land cover in Yellow river basin in China (Wang, Liu & Ma, 2010). This study has given hierarchical weight for different land use/land cover classes on the basis of input and output for particular land use/land cover types. Erb (2012) has discussed about the socio-ecological metabolic approach so as to understand land use intensity analysis. Land use change science requires innovative methods and new perspectives which allow the construction of sound casual chains among different factors, mechanisms, determinants and constraints. It was helpful in order to develop an analytical framework for conceptualizing complex, and semantic interaction related to land use intensification including feedback of production and consumption which will be able to give guidance for data collection and analysis and enhance to understand the interaction between land expansion and intensification. Socio-ecological metabolic concept is related to socio-ecological systems in which society as a hybrid of the cultural system of recursive communication and biophysical structure such as human population, artifacts and livestock. A study on status of land use intensity in China and its impact on land carrying capacity in which hierarchical intensity classification was conducted on the basis of intensity of human impacts integrating remote sensing and socioeconomic data. This study has concluded that land use intensity is the most important factor effecting land use efficiency and land carrying capacity. This study further concluded that quantitative analysis of relationship is crucial and theoretical importance for better explore, understand, and discover land use change and sustainable land management options (Huimin, Fang, Jiyuan, Xiangming & Yuanwei, 2017). A study on impact of land use intensity on ecosystem services in agro-pastoral ecotone of Central Inner Mongolia of China which is a transitional zone between arid and semi-arid agriculture area, and pasture land. This study has quantified land use intensity and five ecosystem services to evaluate the relationship among them. There was synergetic relationship between land use intensity and ecosystem services because of crop production and net primary production relatively high with developed agriculture in the study region. Furthermore, soil degradation has increased with increasing land use intensity (Li, Zhang, Liu, Liu, Ding & Zhang, 2017). Middle and lower reaches of Shule river basin of China was selected for spatio-temporal variation analysis of land use intensity. The degree of human interference of human activities on land is taken as a land use intensity which describes land use degree and human activity intensity. This study has

concluded that spatio-temporal variation of land use intensity is determined by socioeconomic situation, policies and technological factors having multi-dimensional interaction between human and land at different levels of spatial and temporal scale (Ma, Cheng, Bo, Li & Gu, 2018). An integrated approach to estimate land use intensity in Hungary was conducted. Study was adopted an integrated approach of land use intensity analysis. Finding of this study was to higher relationship between human activity and land use intensity in higher human activity area and lower in lower activity areas ((Mezosi, Burghard, Meyer, Bata, Kovács, Czúcz, et al., 2019). In recent period, some studies have been conducted, most of them are recent under four year period and most of them are related to natural science rather than human activities. However, most of the reviewed literatures are related human activities which are valuable for conceptualizing and methodological development for land use intensity analysis and its determining factors.

### **2.2.2 Studies in Nepal**

Review of the 100 years land use/land cover change information of Nepal revealed that crop land was increased by 13 percent in the last 50 years period (1960- 2010), but during the period of 1978 to 2010, the increased area was 2.64 percent only. The forest land was nearly 44 percent in 1960, but it was reduced to 29 percent in 1990 of the total area. It was recovered again in 2010 having 39 percent. Urban area had rapidly increased during last 32 years (Paudel, Yili, Shi-cheng, Lin-shan, Xue & Khanal, 2016). Spatio-temporal analysis of land use/land cover in Nepal in the last century (1910-2010) also revealed the increasing trend of agriculture land, but the rate of increment is highly variable at different physiographic and altitudinal regions. It is because of the population change and policies (Paudel, Yili, Shicheng & Linshan, 2018). Khanal and Watanabe (2006) had examined the processes, causes and consequences of abandonment of agricultural land near the villages of Sikles and Parche of Kaski district of Nepal. This study concluded that abandonment of agricultural land observed in the Nepal Himalaya is common in many mountain areas of the world. However, this has recently resulted in pronounced socioeconomic and environmental problems in Nepal. Recent study in Chiti area of Lamjung also revealed the extensive farmland abandonment in the rural areas of Lamjung and expected to be further increased in the future. Complex topography and various socioeconomic factors have played significant role on promoting present farm land

abandonment. Present socio-economic change and physical constraints are the major cause of rural land abandonment in the study area (Chaudhary, Wang, Khanal, Xu, Fu, Dixit, et al., 2018). A study analyzed about land use/land cover change in relation to physical, economic and institutional constraints in Madi Khola watershed and revealed that overall land change patterns in the region are largely explained by both elevation and the socioeconomic conditions. Land use/land cover change is a complex process of both physical and socioeconomic condition. Decisions are made at different levels from the individual to their respective households, community and government institutions at different scales from plot to landscape and watershed (Khanal, 2002). Depopulation from hill slope agriculture land has caused labor shortage in rural areas resulting agriculture land abandonment and loss of agriculture productivity in Andhikhola watershed (Chidi, 2015). Land use intensity research (Chidi, 2014) had conducted in the same study area using ordinary least square method and found weak relationships of local values of the variables. Two empirical studies on watershed level concerning on depopulation, agriculture land abandonment, and land use/land cover change had been conducted and general findings of these studies were depopulation is major driver of agriculture land abandonment and spatial pattern of land use/land cover change have been controlled by heterogeneous physical as well as cultural factors (Chidi, 2016a; Chidi, 2016b) in which GWR model was used and find very suitable for identification of local level relationship among variables. Land use change study during 1978 to 2004 in Galaudi Khola and Pokhare Khola in the Middle Hill regions of Nepal was conducted based on aerial photo and remote sensing image. There was decreasing rate of rain-fed cultivated land and forest area, and inversely irrigated cultivated land and shrubs had increased during 1978 to 2004. Decreasing rain-fed cultivated land after 1992 was because of the conversion of rain-fed cultivated land into irrigated paddy field (Awasthi, Singh, Sitaula & Pradhan 2007). A study on linking physical, economic and institutional constraints of land use change and forest conservation in the Mid Hills of Nepal during 1976 to 2000 has indicated that conversion of forest land into cultivated land was increasing with increasing elevation. This study revealed that conversion rate of higher elevation is highly critical as compared to lower elevation. Remote area with lower income and far from the agriculture service center had more conversion of forest land into agriculture land due to low agriculture productivity and low institutional support (K. C., 2011). In the land use/land cover change modeling of

Phewa lake watershed of Pokhara during 1995 to 2010 shows that increasing trend of forest, waste land and built up area and inversely terrace agriculture was in decreasing trend during the study period. Fairly dense to open forest was increased during this period rather than dense forest. Different biophysical and socioeconomic factors were the drivers of watershed level land use/land cover dynamic in the study area (Regmi, Saha & Subedi, 2018). A study on land use and land cover dynamics and assessing the ecosystem service values in the trans-boundary Koshi River Basin, Central Himalayas during 1990 to 2015 revealed that there was increasing trend of cultivated land, forest, water body, wet land, barren land and grassland. Snow and glacial coverage decreased due to climate change. The increasing population was major driver of increasing agricultural land across the country. It was mostly because of the conversion of forest land into cultivation. Increased forest land is because of the conversion of chiefly cropland and small patches cropland and other different land covers into forest. Built up area had increased significantly across the basin due to urbanization including Nepal. Ecosystem services value had increased during the study period due to land use/land cover change which indicates the improving ecosystem services (Rai, Yili, Paudel, Acharya & Basnet, 2018). Land use/land cover change study in the Eastern Hill of Nepal revealed that major changes of land use/land cover were forest and agricultural land during 1994 to 2014. Conversion of forest land into agriculture and forest into shrubs were major conversion during 1994 to 2004 and conversion of agriculture land into forest during 2004 to 2014. In developing community forest, labor shortage due to outmigration of rural farmers was the major driving factor of land use/land cover change (Chapagain, Rai & Paudel 2018). Socioeconomic factor was found as a dominant factor of land use/land cover change in the study area on the basis of the farmer's perception of agriculture land use change. Population growth was the major socioeconomic variable as perceived by local farmers followed by migration variable. Climatic and topographic factors were perceived as third important factors in land use and land cover change. Access on transport network for technology and market access were also traced important variables for agriculture land use change (Paudel, Yili, Yan, Rai & Li, 2019). An empirical research based on object based image analysis technique using high resolution multispectral image has conducted in Nawalparasi and Chitwan district of Nepal and this method has provided satisfactory accuracy of land use/land cover classification. A study on land use/land cover change of Shivapuri Nagarjun National

Park of Kathmandu had conducted using Landsat image. This study identified that deforestation had increased travel distance for fuel and water collection for the villagers and negative impact on ecosystem services (Joshi, Joshi, Shrestha, Shrestha, and Gautam, 2013).

A study on urban agriculture structure and dynamic of urban landscape in Kathmandu valley revealed that farming practices of the valley is independent of change in spatial structure of urban land use/land cover caused by urbanization process (K. C., 2011; Shrestha, 2014). Spatio-temporal dynamics of land use pattern in response to urbanization of Biratnagar during 1976 to 2009 revealed the drastic changes of land use/land cover due to urbanization. Urban area had considerably increased and cultivated land decreased during the study period (Rimal, 2012). Urban land use change in Butwal and Charikot had also found increasing urban area and decreasing cultivated land, but the rate of urbanization was higher in Butwal as compared to Charikot and decreasing rate of cultivated land was slower in Charikot as compared to Butwal during 1999 to 2006 (Mandal, 2013; Mandal, 2011). Unpredictable increased in urban built up area in Pokhara during the study period 1952 to 2001 because of population increment by nearly 42 percent, it is mostly because of the rural to urban migration (Rimal, 2011). Land use/land cover change study in Kathmandu valley had revealed that urban built up area was decreasing slowly during the decade of 1960 to 1970 and it increased rapidly after 1980. Urbanization in Kathmandu valley developed heterogeneous and fragmented combination of land use/land cover. Refill type of urban development process in the city core and its neighboring fringe areas had decreasing trend of distances between land use patches, which indicates a higher probability of homogenous landscape development in future (Thapa & Murayama 2010). There were rapid increases of urban built up area in the Hill and Tarai cities of Nepal, which were three times increase in Pokhara and five times increase in Bharatpur during last 28 years (1990 to 2018) because of rapid population growth in urban area. It is due to migration of rural people from surrounding areas (Rai, Yili, Paudel, Khanal & Acharya, 2020).

The land use/land cover literatures indicate that there was the expansion of cultivated land before 1990 due to the population growth. During last 30 years period, agriculture land abandonment is increasing in rural area of Hill and Mountain regions

of Nepal, and inversely urban built up area is rapidly increasing during this period. It is because of the rapid rate of urbanization process due to rural to urban migration. Biophysical constraints in the Hill slope and socioeconomic changes are due responsible major drivers of land use/land cover change in Nepal.

### **2.3 Land Use Policy in Nepal**

Land use policy refers to the methods of using and managing land and natural resources. The practical meaning of land use policy is intensions, programs, and operations of public authority in order to control land use/land cover in desirable direction (Mwagore, 2002). Land use policy is the part of the long-term development strategy of a country integrating with country's broader development strategy. Land and agriculture have played a very important factor in Nepal's social, economic, and political life for the centuries. Historically, land related policies in Nepal are characterized by a various factors like political interest, cultivation practices, population growth, interregional migration and economic transition of the country from feudalism to open liberal economy. Similarly, caste/ethnicity and class had characterized the land holding pattern in the country also played some role in the land related policies in Nepal (Pokhrel, 2011). In 1960, the traditional system of land administration, which is related in the change with the introduction of Birta Abolition Act 1959 A.D., and was followed by the promulgation of the Civil Code 1963 A.D, and the Land Administration Act 1967 A.D. The Land Act and Rules 1964 of Nepal authorized the government to implement a program for control of land fragmentation and consolidation of land. The aim of this Act was to divert inactive capital and labor from land to other economic sectors to bring about an equitable distribution of cultivated land to improve the living standard of tiller in maximizing agriculture production (Sharma & Khanal, 2010). However, the Ministry of Land Reform and Management had not yet developed program within stipulated time frame and policies and program formulated by Government of Nepal rarely implemented (Basnet, 2016). During 1964 to 1974, Nepal government mainly addressed agriculture development and next decades 1974 to 1984, government emphasized reform in land management system to increase agriculture production and conserve natural resources in order to reduce economic inequality. From 1984 to 1996, the main policy was to increase productivity, first in the agriculture sector and then in the forestry and other land uses.

During 1996 to 2001, land use/land cover was recognized as a major means for socioeconomic development and pieces of land were pinpointed for specific uses agriculture, forestry, pasture, settlement, urban development and industrialization. In the tenth five year plan (2001-2006), major concern was an effective land administrative system based on modern technology and also addressing historical and religious heritage and *guthi* land through community participation. The focus of plan 2007 to 2010 mainly focused on land ownership, productivity and management and preparation of land use zoning regulations. Similarly, plan of 2010-2013 was for proper land management for social and economic transformation (GoN, 2013). As in the past, numbers of legislation on land rights and land use were formulated and many organizations were set up for implementation, but most of these efforts remained only in paper rather than implementation and because of lack of an efficient and meaningful land use management framework. Most of the government efforts to regulate land use through environmental policies have been largely ineffective (Paudel, Pandit, and Reed 2014). Realizing these problems, government adopted the Land Use Policy 2012. This policy stresses on the sustainable use of agriculture land based on land capability and to control land fragmentation which were failed in previous effort. Again Land Use Policy 2015 was also introduced in order to address all contemporary issues on a long term basis reviewing Land Use Policy 2012 (GoN, 2012). Adopted three principles of this policy are to promote the complimentary land use principle for encouragement, maintain competitive land use principle for maintaining balance and avoid conflicting land use principles. The policy has emphasized the strategy line of optimum and sustainable use in unused and under used land.

Review of policy provisions for agricultural development in Nepal revealed that those policies and legislations formulated by government were not implementable at community level which led to failure. Weakness and ineffectiveness of implementing agencies is also another most important factor of failure. Policies and legislative provisions were is top-down and supply driven mechanisms with focus on the relationship between technological inputs and outputs rather than a bottom-up approach with active participation from local communities and other key stakeholder. As a result, although some improvement is observable, the growth rate remained very low as compared to neighboring countries due to several causes and consequences

(Khanal, Nepal, Zhang, Nepal & Paudel, 2020). This review has also proves the ineffectiveness of land related agriculture policies of Nepal.

## **2.4 Research Gaps**

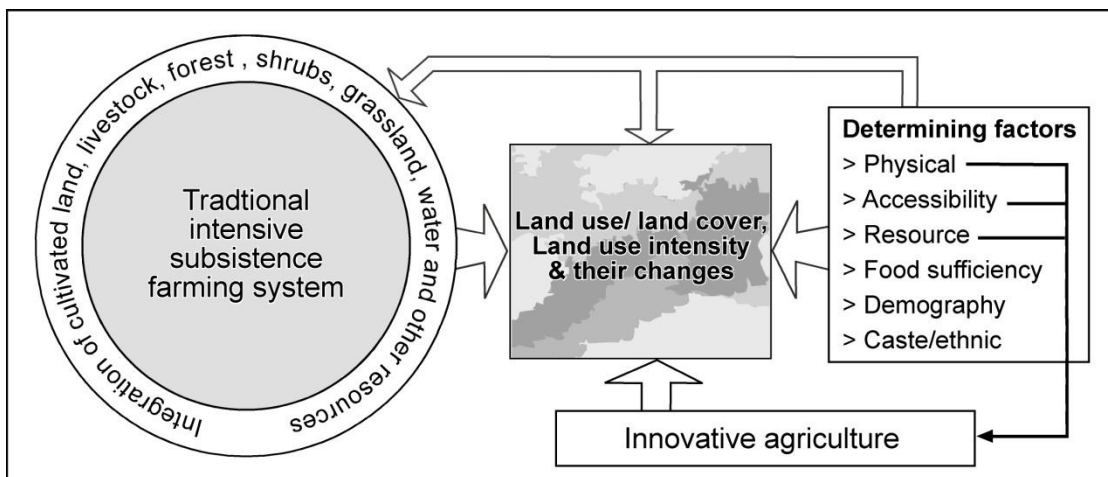
Literatures were very helpful in order to derive required useful knowledge of the study. However, they were equally important to identify the weaknesses and knowledge gaps. The gaps identified during the review of literatures were related to concept, methods and empirical researches which have been described into the followings.

- Integrated land use intensity analysis is emerging in last four years period although there was some attempt in the past. Land use intensity dynamics is very helpful to understand the integrated traditional subsistence farming area like Nepal. But none of the literature was found concerning on integrated land use intensity analysis of Nepal till date.
- Very few literatures are available in the study of land use/land cover change analysis using high resolution image and data derived by object based image classification technique in Nepal. Object based image analysis technique is highly accurate than data derived from traditional pixel level image classification technique.
- GWR model is very useful for multivariate dependency analysis of geographical data and it is highly useful to understand the spatial variation of relationship among variables. Furthermore, most geographical data violate assumptions of parametric statistical technique in which this model is very useful. But very few studies have used this model in the world and none of the literature is available in the context of Nepal.

Thus, this study is concerned on land use intensity dynamics and its detrainning factors on the basis of high resolution image deriving data using object based image analysis. Furthermore, this study will adopt non-stationary spatial statistical analysis to identify the dependency of land use intensity dynamic on its determining factors.

## 2.5 Conceptual Framework

Traditional insensitive subsistence farming system of Nepal is integration of cultivated land, livestock, forest resources, grazing land, grassland and water resources whether they are public or private it doesn't matter, all are equally integrated (Malla & Chidi 1997). Being a traditional practice of agriculture, its temporal and spatial dynamism is highly controlled by several determining factors. Those factors are physical, accessibility, availability of usable natural resources, food sufficiency for household from their own agriculture product, demography and different caste/ethnic groups of population. Then, their reflection can be visible on land use/land cover and land use intensity. The linkage of traditional intensive subsistence farming system, innovative agriculture, land use/land cover and land use intensity, and their determining factors have been given in the Figure 3.1



**Figure 2.1: Conceptual Framework**

Recently developed innovative agriculture is at limited area because it is highly dependent on topography, road access and soil capability and irrigation facility. It has also played role on land use/land cover dynamics in the study area, but its impact is very limited.

## CHAPTER III

### METHODOLOGY

#### 3.1 Philosophical Base of the Study

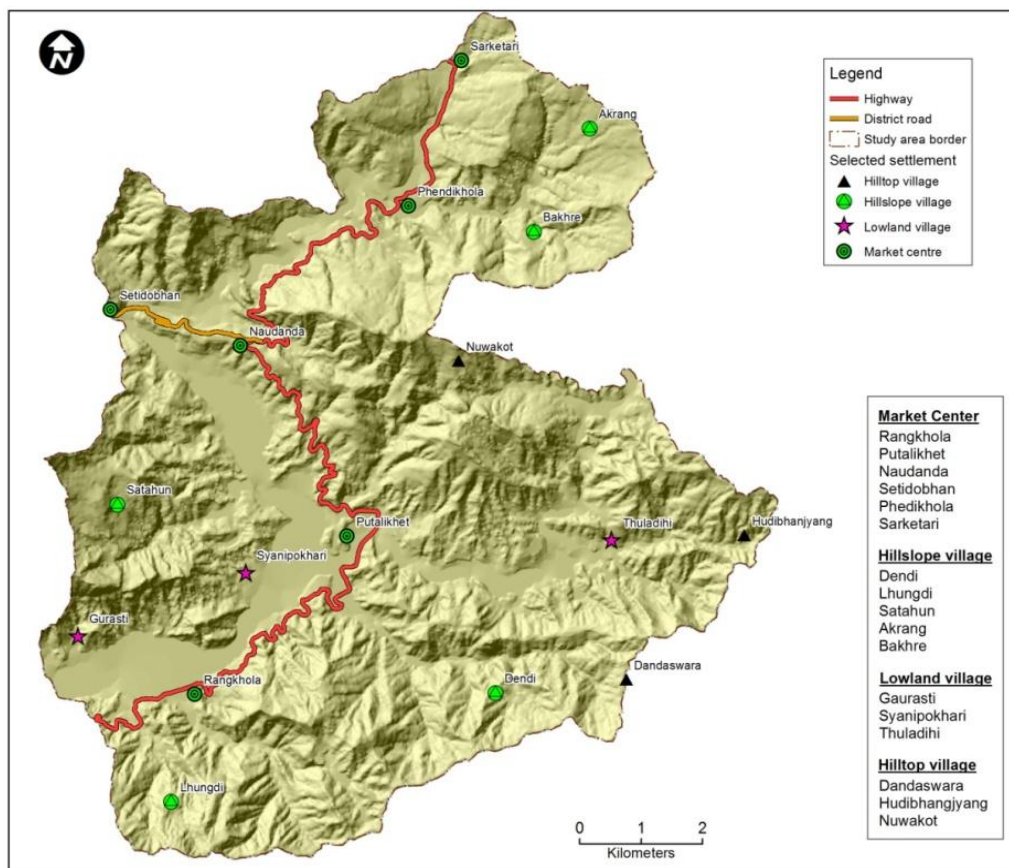
This study is based on positivism philosophy. Positivism philosophy describes that knowledge can be scientifically verified which is capable of logical and mathematical proof (OUP, 2005). This approach makes empirical generalizations, statements of law like character relating with phenomena that can be empirically recognized. Positivists believe that only factual knowledge gained through observation and measurement and that should be trustworthy (Oyerinde, 2016). They depend on quantifiable observations that lead to statistical analyses. Researchers are independent because there is no provision of human interest within the study (Crowther & Lancaster, 2008), but relates to the viewpoint that researcher needs to concentrate on facts. Science underlying ground of positivism is deterministic and mechanistic. Deterministic is in the sense to discover specific nature of cause and effect relationship, which mechanical nature can be explained in a way that researchers develop hypotheses to be proved or disproved. Then, chosen methods are applied mechanically in order to operate the hypothesis.

#### 3.2 Selection of the Study Area

Selected study area is northeast part of the Andhikhola watershed of Syangja district of Gandaki province of Nepal. The study area covers an area of 97.8 square kilometer (Figure 4.1). From the previous studies (Chidi, 2015; Chidi, 2016a; Chidi, 2016b; Chidi, 2017) and preliminary observation, it was found that this study area is topographically and climatically diverse and more land use/land cover dynamic. Thus, this area was selected as representative area of the watershed to make cost effective for high resolution image. This area occupies highland and lowland, subtropical and warm temperate, and rural and urban as well as accessibility factors. This study area is the collection of sub-watersheds of Andhikhola watershed. Major tributaries to the east of Andhikhola are Seti khola, Phendi khola, Bhadh khola, Aroundi khola and Rang khola. Some other small tributaries between them have also included. Some other small tributaries to the east are Kukhure khola, Chore khola, Gumi khola and Sumre khola. There are four small tributaries to the west of Andhikhola. Those are

Gol khola, Baidi khola, Chisyar khola and Aru khola. Watersheds of these tributaries have been included in the study area including some other watershed of minor tributaries between them.

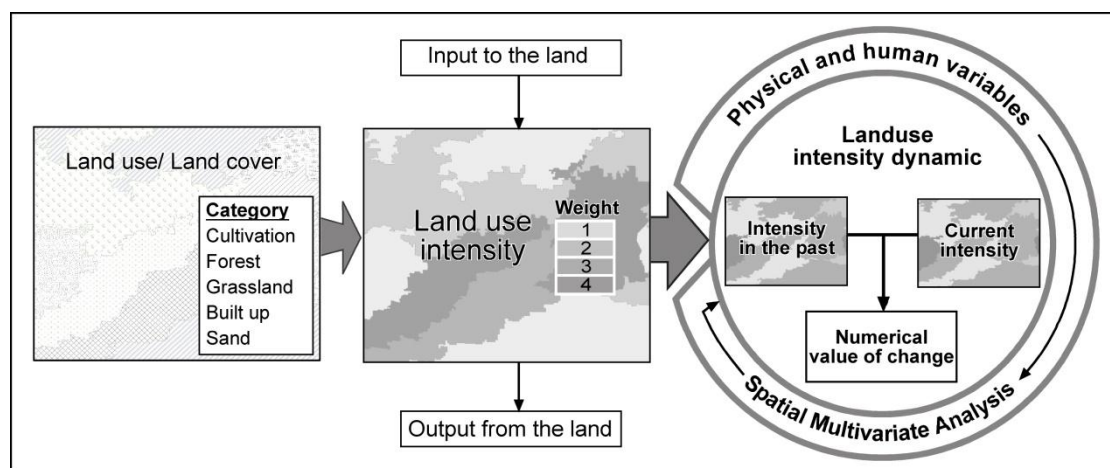
Seventeen location of settlement were selected to verify the ground reality using Reality Check Approach (RCA) (Jupp, Dogbe & Korboe, 2016) on the basis of different altitude & accessibility. Among them, six selected market centers were Rangkhola, Putalikheth, Naudanda, Phedikhola, Sarketari, and Setidobhan, which are located along with the highway and major branch road. Three settlements were taken from rural area locating along the fertile land of river basin. Those were Gaurasti, Syanipokhari and Thuladidhi. Dendi, Lhungdi, Satahu, Akrang and Bakhre were selected from the settlement locating at hill slope. Dandaswara, Hudibhangyang and Nuwakot were taken from hill top settlements. These settlements were selected on the basis of researcher's own judgment in order to to derive reliable information (Figure 3.1). Three households were selected from each selected settlements for RCA. Households were selected on the basis of rich, poor and medium income in order to dig out representative information.



**Figure 3.1: Location of Selected Settlements for Ground Reality Check**

### 3.3 Conceptual Methods

Traditional approaches on land use/land cover study often examine one or a few aspects of land use intensity, disregarding the multidimensionality of the intensification process in the complex land system (Lambin & Meyfroidt, 2011). Thus, analysis and monitoring of land use intensity requires an integrative conceptual framework that focuses on inputs to the land, outputs from the land and the human induced, but unintended, outcomes of land use intensification (Erb, Haberl, Jepsen, Kuemmerle, Lindner, Muller, et al. 2013). Traditional insensitive subsistence farming system of Nepal is integration of cultivated land, livestock, forest resources, grazing land, grassland and water resources whether they are public or private, it doesn't matter, all are equally integrated (Malla & Chidi 1997). Thus, the analysis is based on land use intensity data derived from categorical land use/land cover information and complex geo-statistical analysis in order to identify the major drivers of land use intensity dynamism in the study area. The conceptual framework is presented in the diagram (Figure 3.2)

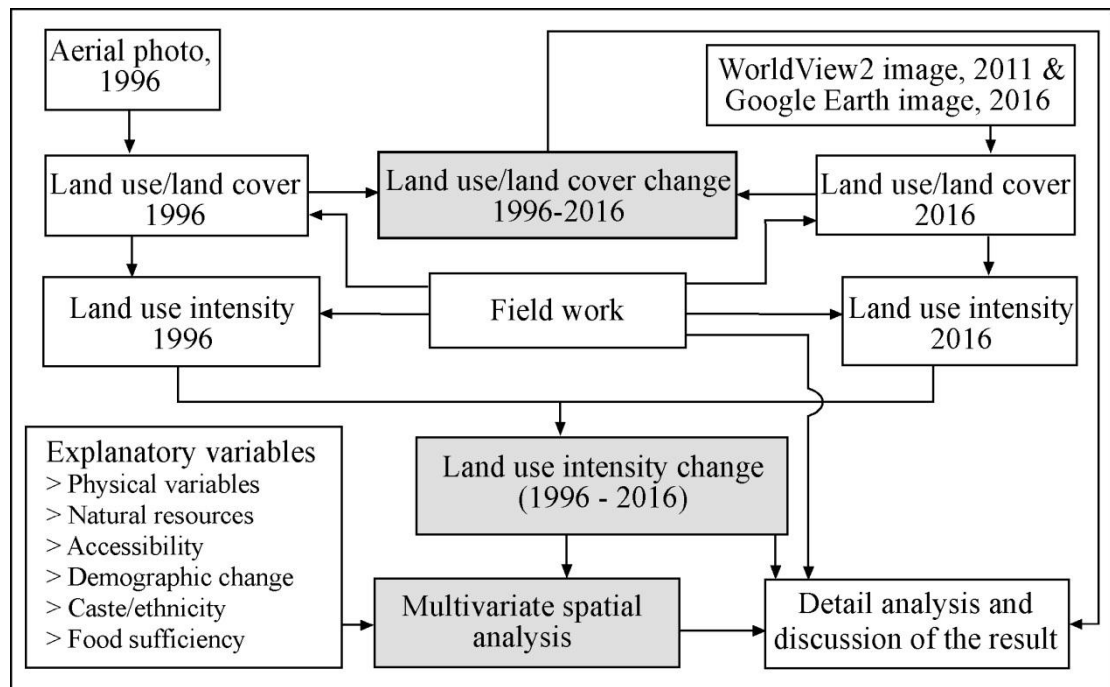


**Figure 3.2: Methodological Framework**

### 3.4 Process

The works of this study starts from the collection of secondary information sources such as maps and other required data. Land use/land cover information was derived from aerial photo, which was taken in 1996 and worldView2 image (2011). Land use/land cover data were corrected and verified by field survey. Land use intensity maps were derived based on land use/land cover maps. Quantitative variables of

explanatory variables were derived from available maps and other information. Multivariate geo-statistical analysis was used so as to identify the strengths of the explanatory variables defining land use intensity dynamism. Step by step process flow of the study has been given in Figure 3.3.



**Figure 3.3: Process Flow**

### 3.5 Data Sources

Particularly, secondary data such as aerial photo and satellite image are major data of this study. However, field survey data is equally important for this study, which is inevitable for data verification, updating, correcting and casual analysis of the result from secondary data.

#### 3.5.1 Primary Data

Primary information of this study was the ground truth for image classification and update of land use/land cover for 2016 from WorldView2 image 2011 and Google Earth image 2016. Qualitative information were collected through observation where RCA methods were employed in order to collect the information about agriculture system, integration of different land use/land covers, input and outputs from the different land use/land cover types including private and public land resources. Changing situation of human life and activities, migration, land abandonment, presence of local people in the village, development activities, overall landscape change information were also collected from the field.

### **3.5.2 Secondary Source**

Different types of secondary data were collected from various sources. Major data are mostly related to maps, satellite images, population, food sufficiency report and profiles. The detail description of secondary sources of data is presented in the following Table 3.1.

**Table 3.1: Secondary Data, Sources and Derived Information**

Data components	Sources	Publishers	Data extracted
Population, household and sex	Population Census 2001 and 2011	Central Bureau of Statistics of Nepal(CBS)	Ward level population, household size and sex ratio change
Caste/ethnicity population and food sufficiency	VDC Profiles	Concerned VDC Offices	Ward level caste/ethnic population and food sufficiency of households
District profile, agricultural, livestock, education, forestry, communication and other related services.	District level information	DDC, DADO, DLDO, DSCO DFO, DVO, DPHO	District level general information about location of service centers such as collage, school, hospital, health post, post office etc.
Rainfall, temperature and humidity data	Department of Hydrology and Meteorology (DHM)	Department of Hydrology and Meteorology (DHM)	Rainfall and temperature data
Large scale 1:25000 base maps which includes physical and cultural features of the study area	Survey Department of Nepal	Survey Department of Nepal	Topographic features such as contour, drainage, land use/ land cover, transport network, settlement, built up area.
Vertical aerial photo acquired in 1996	Aerial Photo 1996 Survey Department, Government of Nepal	Survey Department of Nepal	Photo map for land use/land cover data 1996 (Appendix V)
Land capability map 62 P/16	Kenting Earth Science Limited	Kenting Earth Science Limited	Land capability class map.
Thermal band 10 and band 11 (30m spatial resolution)	Landsat8 (30 <sup>th</sup> December 2014 and 8 <sup>th</sup> June 2015) OLI	USGS	Land surface temperature
Multispectral image with spatial resolution of 2m and panchromatic image with spatial resolution of 0.5 m	WorldView2 image of 2011 Digital Globe	Digital Globe	Land use/land cover data of 2016 after rigorous field verification in 2016 (Appendix V)
High resolution Google Earth image 2016	Google, CNES/airbus, and Digital Globe	Google Earth	Correction, checking and verification of ground feature and ground truthing for image classification

In addition, sources of data were various research articles retained from several websites, libraries and other available sources. Major web sites used in order to obtain data were Google Earth, Science Direct, Springer and so on. Several supportive documents were collected from central library of Tribhuvan University, library of the Central Department of Geography, Tribhuvan University, Kathmandu. Similarly, some documents were collected from the library of the University of Graz, Austria. Several relevant research articles from various websites were also downloaded.

### **3.6 Field Methods**

Secondary information was updated on the basis of primary information. General qualitative information such as changing situation of various aspects of human life, migration, land abandonment, presence of local people in the village, development activities, agriculture system, overall landscape change were collected from primary sources. Therefore, the primary source of information was mainly for updating of secondary data sources; and to know the ground reality for analysis and discussion. Primary data were collected using various methods which is described into the followings sub headings.

#### **3.6.1 Observation, Ground Truth and Field Notes**

Observation is the one of the important data collection methods in the study. The following tasks were completed during field observation. Observation was done with topographic map, color printed false color image and classified image, Global Positioning System (GPS), check list and note books. Required notes, sketches, indication and correction of some features differ than before were recorded and corrected on maps and images. GPS data were recorded in checklist (Appendix VII) and saved into device also.

- This ground truth of land use/land cover was conducted in 50 different locations of each land use/land cover categories such as forest, cultivated land, shrubs, grassland, abandoned land, horticulture farm, GPS, aerial photo, false color printed hard copy of WorldView2 image (2011), Google Earth image (2016) and classified image, and topographic map were taken in the field. During the field survey, high resolution image of 2011 and classified image were verified

according to actual land use/land cover in 2016 and made possible to make actual land use/land cover during the field survey.

- Land use/land cover pattern and its dynamism were carefully observed at different locations with various geographical characteristics such as slope gradient, altitude, slope aspect, urban, rural etc. Most of the study area were visited and observed through transact walk. Road, service centers, and other required information were verified and corrected on large scale map.
- Cropping pattern at different geographical locations, traditional and recently initiated commercial crops in the rural areas and business activities in urban and other parts of the study area were observed. Spatiotemporal pattern of crops were observed visiting both in winter and summer season in the study area.

### **3.6.2 Discussion with Family Members**

RCA was also used to know the ground reality which has been taken as the best approach in order to acquire quickly informal, relaxed and insightful conversations with the informants of the households' family members of the study area (RAP3, 2015; Pain, Nycander, and Islam, 2014; Lewis, Jupp, Arvidson, Rukanuddin, Huda & Jahan et al. 2012; Jupp, Dogbe & Korboe, 2016). Seventeen locations were selected for intensive study (Figure 3.2). These locations were selected from various topographic and social characteristics. Total 51 households were involved in order to collect data which has been already discussed in the selection of the study area. Information related to migration of family members and its impact on their households, their land and daily activities including some other related information were collected. A questionnaire (Appendix IV) was also used for the discussion with family members.

### **3.6.3 Informal Discussion**

A total of 32 informal discussions were done with local people, teachers, civil service workers, politicians and social workers during field survey. Informal discussion was also conducted in order to obtain general information and some short and informative discussion as per requirement. These types of discussion were non-structured and non-preparatory work. However, it was very informative and useful for this study.

### **3.7 Data Processing**

Data processing includes several techniques of data generation; generating variables, compilation and standardization of the variables, statistical technique and modeling. These processes include several sub-processes, which have been described in detail below.

#### **3.7.1 Analog to Digital Mapping**

Analog maps were converted into digital form in order to conduct this study. Those maps were topographic map, land system map, land capability map, Putalibazar municipality map of Syangja district and aerial photo. Analog maps and aerial photo were scanned in high resolution scanner and converted into raster format data. Scanned maps were registered into Modified Universal Transverse Mercator projection with Spheroid base is Everest 1830. Then, those maps were converted into WGS\_84\_UTM\_Zone\_44N projection system. Required features such as contour, road, river, settlement, service centers of topographic map were digitized in ArcGIS software. Similarly, land system, land capability and land utilization maps were also digitized. Scanned aerial photo was used to make orthophoto in digital photogrammetric processing which has been described in making orthophoto.

#### **3.7.2 Generating DEM**

Digital Elevation Model (DEM) consists of an array of uniformly spaced elevation data (Chang, 2008). DEM was developed by interpolation method on the basis of known values of sampled points. It was required to derive elevation, slope angle, slope aspect map and to make orthophoto for this study. It was generated on the basis of 20 meter contour interval data of topographic map scale 1: 25000. Natural neighbor interpolation finds the closest subset of input samples to a query point and applies weights to them based on proportionate areas to interpolate a value (Sibson, 1981). Among the scattered data interpolation method based on natural neighbors possess the best adaption to inhomogeneous sample distributions while only building on a highly local support (Bencina, 2005). Therefore, this research was also adopted this method for interpolation of 10 meter spatial resolution using all vertices of vector data of contour line because vertices of the contour line was scattered without uniform

distribution in the watershed area. Slope angle and slope aspect map were also developed from this DEM image.

### **3.7.3 Developing Orthophoto**

Aerial photography is one of the most common and historical form of remote sensing which gives a bird's eye view of large area, enabling to see earth surface features in their spatial context. Black and white panchromatic aerial photo is being used from the beginning of the aerial photography to identify the historical record of land surface features (Lillesand, Kiefer & Chipman, 2011). Photogrammetry is the science which obtains spatial measurement and other geometrically reliable derived products from photographs. Digital photography is changing rapidly and forms the basis for most current photogrammetric operations (Lawali & Dauda, 2014). Seven overlapping vertical aerial photographs captured in 1996 at the scale of 1:50000 were collected from Survey Department of Nepal as a data source of land use/land cover in 1996. The accuracy of photogrammetric measurements depends on the use of Ground Control Points which are accurately located on the photograph and they must be clearly identifiable both on the ground and on the photograph (Lillesand, Kiefer & Chipman, 2011). Required coordinates of  $x$  and  $y$  of identified 38 Ground Control Point (GCP) on the pair of aerial photo were derived from already geo-referenced map and  $z$  value was derived from the DEM instead of using GPS on the ground. It is because of only the requirement of matching orthophoto, other maps and image together. Coordinates of GCPs are used as a geometric ground truth to calibrate photo measurements. This information is critical in a host of photogrammetric operation. Orthophoto is like map with certain scale and showing terrain in actual detail which is excellent base map for compiling data to be input to a GIS or overlaying and editing data. Therefore, orthophoto production is the elimination of sensor tilt and terrain relief effect from captured perspective imagery (Habib, Kim & Kim, 2007). Modern orthophotos are now produced digitally, using digital photo and a DEM as the primary input to the orthophoto production process. All seven collected analog aerial photos of the study area were scanned and converted into digital photo and was used for digital orthophoto making process. Among the several softwares, Erdas Imagine software was used for this study (ERDAS, 2010). Leica Photogrammetry Suite is the extension of Erdas Imagine (Leica Geosystem Spatial Imaging, 2006). Project Manager was

followed for orthophoto generation. Basic elements (Schenk, 2005) of photogrammetric principles were completed in the digital processes.

### **3.7.4 Image Classification**

Land use/land cover map of 2016 was derived from the WorldView2 image of 2011. Traditional pixel level classification system of high resolution image for land use/land cover analysis is being problem, which is purely descriptive categorization of the spectral characteristics of pixel. Object Based Image Analysis (OBIA) supports to overcome this problem, which paves the way for a combined use of spectral and spatial (contextual) information toward the developing indicator of land use/land cover (Blaschke, 2010). WorldView2 image of 8 band multispectral (11bit) image having 2 meter spatial resolution. Additionally, panchromatic image of 0.5 meter spatial resolution image was available. Multispectral image was re-sampled with panchromatic image. Then, final multispectral image was also developed 0.5 meter spatial resolution. Available OBIA software eCognition Developers (Trimble, 2016) was used for this study (Myint, Gober, Brazel, Clarke & Weng, 2011) which is mostly used software in the world. Several processes required for OBIA in eCognition software are as follows. Threshold classification methods were used developing different algorithms to classify land use/ land cover for rule set for OBIA technique. Semi-automatic technique was also applied in order to derive actual result from the image. Classification accuracy was ranged from 75 percent to 90 percent. Accuracy of forest was the highest and built up area was the lowest.

### **3.7.5 Land Use/Land Cover**

Land use/land cover data were derived from the aerial photo and satellite image such as Google Earth image and classified WorldView2 image. Furthermore, land use map were updated from the field verification.

#### **a) Land use/land cover 1996**

Vector data of land use/land cover categories of 1996 was extracted from the topographic map and aerial photo of 1996. Detail correction of vector polygon of land use/land cover of topographic map scale 1:25000 was done on the basis of orthorectified aerial photo overlaying in ArcGIS software. Land use/land cover was

categorized into cultivated land, forest, shrubs, grassland, built up, sand and water body. Cultivated land was categorized into perennial irrigated, seasonal irrigated and rain fed. This area was identified on the basis of field observation, topographic map and Google Earth image. Perennial irrigated area is that area which lies lowland having all time availability of irrigation facility, seasonal irrigated area is that area which lies along the small tributaries generally remains dry in winter and sloppy area where only summer spring water is available for irrigation. Other cultivated land was categorized into rain fed which completely depends upon rainfall to its irrigation. Except larger compact settlement of urban area, all other disperse rural built up points of topographic map were converted into circle polygon having 100 square meter area because average area of single built up and its premises was nearly 100 square meter area. Then, these circle polygons were merged with land use/land cover polygon. Compact settlements of urban area and merged built up polygon were categorized into built up area of 1996. Then, land use/land cover categories of 1996 were perennial irrigated cultivated land, seasonal irrigated cultivated land, rain fed cultivated land, shrubs, grassland, built up, sand & gravel, and water body. Sand, gravel and water body was removed for land use intensity calculation because its change is mostly due to natural causes rather than human because this study is mostly concerned with the change by human intervention. Forest, shrubs and grassland was grouped into single category (vegetative area) because of the complexity to quantify the intensity of human intervention into different categories of land use/ land covers.

#### b) Land use/land cover 2016

Land use/land cover data for 2016 was derived from WorldView2 image of November 2011. Derived land use/land cover of 2011 was updated on the basis of Google earth image of 2016 in each grid which has been defined in generating square grid of the methodology chapter. Field verification in 2016 was also conducted and around the selected area for RCA. Land use/ land covers were categorized into forest, shrubs, grassland, cultivated land, built-up, sand or gravel and water body. Cultivated land was further categorized into perennial irrigated cultivated land, seasonal irrigated cultivated land and rain fed cultivated land on the basis of Google Earth image and field survey. Criteria of categorization were the same as described in land use/land cover in 1996. Built up area was derived by same way as defined in land use/land

cover 1996, but built up points of highland area was taken only half of the total built up of 1996 because more than half of the existing built up point in the highland remote area, there had not household members and some of them had totally abandoned their houses. These settlements were identified on the basis of field observation and discussion with local people. This built up polygons were merged with land use/land cover data. Water body and sand area was removed as in 1996. Final land use/land cover category was same as land use/land cover in 1996.

c) Land use/land cover change

Land use/land cover maps of 1996 and 2016 were intersected in order to identify the changes and transfer one category to another. Different slope gradients, slope aspects, elevation maps were created from already developed DEM. Those maps were intersected with land use/land cover maps of 1996 and 2016 to identify the spatial-temporal variation of land use/land cover change. Maps and numerical data were derived from these intersected maps.

### **3.7.6 Land Use Intensity**

This part deals with the technique of generating grid, weighting land use/land cover categories to derive land use intensity and their changes as follows:

a) Generating square grid:

Square grid is the unit of observation of land use intensity analysis. Thus, frequent tests of grid size revealed that 500m x 500m is the best for quantitative analysis of available data sources of land use intensity. Smaller grid size was unnecessary detail of the grid and larger than this size revealed dilution of intensity value. Thus, square grid of 500x500 meter was generated based on already developed DEM. Total square grids were 426 in order to cover the study area.

b) Land use intensity:

Land use intensity is based on intensity of human occupancy of land which is based on subjective judgment. There is distinct hierarchical intensity of land use in the study area. Built up area was highest intensity of human occupancy. It was used for full time protection of their life and property. Commercial and industrial buildings were

for income generating purpose which was the greater intensity of income than other agriculture field based income. Therefore, the greatest weight 5 was given to built-up area. Perennial irrigated field is mostly low land area with all season irrigation and three crop production in a single year. These agriculture fields are used throughout the year for agricultural works. However, for some short period of time, it may be fallow. Therefore, it is in the second position of intensity which has been given weight 4. Seasonal irrigated cultivated land has no irrigation facility in winter dry season. Mostly two crops are cultivated in this field. Therefore, the occupancy intensity of this land is in third position and it has been given weight 3. Rain fed cultivated land is mostly in hill slope area, which is only one season cultivation with mixed crop and it is the least occupied land of cultivation and it is given weight 2. Tree crops are mostly orange farming in this category of land. Vegetated area are used for grass, fodder, grazing and timber. Both input and output rate of this area is the lowest than above defined other land use/land cover categories and it was given lowest weight of intensity 1 (Table 3.2).

**Table 3.2: Weight Given for Different Land Use/ Land Cover**

Land use/land cover 1996 & 2016		
Types	Uses	Weight
Built up area	All time protection of life and property including commercial activities.	5
Perennial irrigated cultivation	Three crops and most of the time under cultivation	4
Seasonal irrigated cultivation	Two crops and fallow in winter dry season	3
Rain fed cultivation	One season crop with mixed cropping	2
Vegetated area	Sometime used for grass, fodder, grazing, timber, fuel wood, litter.	1

Grid value of land use intensity of 1996 and land use intensity 2016 were generated through this process from the given formula of intensity with weight given into different land use/land cover categories.

Grid score for variable was calculated using the given equation 1 (Bracken 2008).

$$Intensity = \sum A_i . W_i \dots\dots\dots 1$$

Where,

$A_i$  is an area proportion of particular category of land use/land cover in the square grid.

$W_i$  is the given weight for particular category of land use/ land cover.

Certain weight has been given to certain land use/land cover category which is widely used to analyze spatial and inter-temporal characteristics of land use/land cover change (Liu, Liu, Zhuang, Zhang & Deng, 2003; Deng, Huang, Scott & Emi, 2006; and Wang, Liu & Ma, 2010) in the world. The weight given for certain land character has been given in the Table 3.2.

c) Land use intensity change

Land use intensity change was calculated subtracting land use intensity score of each grid in 2016 to land use intensity score in 1999. Separate maps and numerical data of land use intensity in 1996, land use intensity in 2006 and their changes were derived by these processes.

**3.7.7 Data for determining variables**

This section describes processes of generating different explanatory variables using image, map and socio-demographic information collected from different sources.

a) Land surface temperature:

Land surface temperature (LST) is a key parameter in the physics of the earth surface through the process of energy and water exchange with the atmosphere, which plays an important role in a wide variety of scientific studies, such as ecology, hydrology, and global change studies (Liang, Li & Wang, 2012; Zhang & He, 2013). In the present day, advancement of satellite data has widely used in environmental related studies and climate change. Landsat8 Thermal Infrared Sensor (TIRS) is the newest for the Landsat project, providing two adjacent thermal bands (Yu, Guo, & Wu, 2014) that is a significant one in LST calculation (S., V. & K., 2016). Required images and other information are freely available in website [www.usgs.glovis.org](http://www.usgs.glovis.org).

Landsat8 TIRS and OLI images with meta data file (Path/Row – 142 / 41) were downloaded. The images were already rectified to WGS-1984-UTM-Zone\_44N. Downloaded image information of Landsat8 is given into the following table 3.3.

**Table 3.3: Landsat Image Acquire Data, Time and Season**

Image acquired date	Scene centre time	Season
2014-12-30	4:54	Cold
2015-06-08	4:53	Hot

Two seasons images were downloaded in order to identify the differences of surface temperature and calculate the average surface temperature of the study area. An equation (Artis and Carnahan 1982) was used to calculate land surface temperature using information given by thermal sensor of satellite, which is already used by several scientists (Das, 2015 and S., V., and K., 2016) is given equation 2.

$$LST = BT / \{1 + w * (BT/p) * L_n(e)\} \dots\dots\dots 2$$

Where,

LST = Land surface temperature

BT = at satellite temperature

W=Wavelength of emitted radiance (11.5µm)

$p = h * C / S$  (1.438\*10<sup>-2</sup>mk)

$h$  = Planck's constant (6.626\*10<sup>-34</sup>JS)

$s$  = Boltzmann Constant (1.38\*10<sup>-23</sup>J/K)

$C$  = Velocity of light (2.998\*10<sup>8</sup> m/s)

$p = 14380$

In order to find the satellite temperature, TIRS data can also be converted from spectral radiance to brightness temperature, which is effective temperature reviewed by the satellite under an assumption of unity emissivity. The conversion equation 3 is follows (USGS, 2015):

$$T = \frac{K_2}{L_n\left(\frac{K_1}{L_\lambda} + 1\right)} \dots\dots\dots 3$$

Where,

T = Top of atmospheric brightness temperature in Kelvin

$L_\lambda$  = Spectral radiance (watts/m<sup>2</sup> \*sr\* $\mu$ m)

$K_1$  = Thermal conversion constant for the band

$K_2$  = Thermal conversion constant for the band

Here, the output is in Kelvin unit of top of atmospheric brightness temperature can be converted into degree centigrade by subtracting 272.15 (Das, 2015; S., V. & K., 2016) which is satellite temperature. Spectral radiance ( $L_\lambda$ ) is calculated using digital number (DN) of TIRS data using the formula given equation 4 (USGS, 2015).

$$L_\lambda = M_L * Q_{cal} + A_1 \dots\dots\dots 4$$

Where,

$L_\lambda$  = Spectral radiance

$M_L$  = Radiance multiplicative scaling factor for the band

$A_1$  = Radiance additive scaling factor for the band

$Q_{cal}$  = Level 1 pixel value in DN

Additionally, emissivity (e) is calculated using equation 5 (Carlson and Ripley, 1997):

$$e = 0.004 * P_v + 0.986 \dots\dots\dots 5$$

Where,

e = Emissivity and

$P_v$  = Proportion of vegetation

Proportion of vegetation ( $P_v$ ) is calculated using equation 6.

$$P_v = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \dots\dots\dots 6$$

Whereas, NDVI is calculated using equation 7 (Lillesand, Kiefer and Chipman, 2011):

$$NDVI = \frac{NIR - Red}{NIR + Red} \dots\dots\dots 7$$

In this way, land surface temperature of both cold season (Dec, 2014) and hot season (June, 2015) was derived. Image maps of average land surface temperature and range

of temperatures in two different seasons were prepared. All these calculation processes were done in ArcGIS software.

b) Solar radiation:

Incoming solar radiation (insolation) is the determining factor of the earth's physical and biological systems (Ikici & Teke, 2017). As a result, information of the amount of insolation at specific locations is helpful for application in diverse fields like agriculture, resource management, meteorology, civil engineering and ecological research. Solar radiation is the electromagnetic waves emitted by the sun (Mayhew, 2006), which is a key factor for most natural processes and human activities. Variation of solar radiation on the earth surface varies due to the position of the sun, transmittance of the atmosphere and the geographical characteristics of the surface (Mamassis, Efstratiadis & Apostolidou, 2012). DEM based calculation method is widely used to derive area solar radiation of the earth surface (Bencina, 2005; Piedallu & Gegout, 2008; Kausika, Dolla, Folkerts, Siebenga, Hermans & Sark, 2016; Effat, 2016). The solar radiation analysis tool calculates the insolation across a landscape or for specific locations, based on methods from the hemispherical view shed algorithm (Fu & Rich, 2002). The total amount of radiation calculated for a particular location or area is given as global radiation. Solar Radiation is calculated in the unit of watt hours per square meters. The following processes were adopted in order to calculate the area of solar radiation according to ESRI guidelines (ESRI, 2012) in ArcGIS. Ten meter resolution DEM was used deriving from 20 meter contour interval map. Mean latitude 28.12 degree was used with default value sky size 200. Total one year solar radiation starting from 1<sup>st</sup> January 2017 to 31<sup>st</sup> December 2017 was calculated. The value for direction calculation was given maximum value 32 to maximize view shed highly intensive. Diffusion proportion was given 0.3 and typical values of 0.5 were used generally for clear sky condition.

c) Other physical variables:

Separate raster maps of slope gradient, elevation and slope aspect maps were developed from already derived 10 meter resolution DEM.

d) Land capability and irrigation type:

Scores of the grids of land capability and irrigation variables were also derived using given intensity formula. The given weights (Table 3.4) of the different categories of land capability and irrigation facility were used by calculating grid scores.

**Table 3.4: Weight Given for Land Capability and Irrigation Facility**

Land capability		Irrigation facility	
Types	Weight	Types	Weight
Class I	4	Perennial Irrigation	3
Class II	3	Seasonal irrigation	2
Class III	2	Rain fed	1
Class IV	1		

Source: Derived from land capability map, 1986

e) Demographic, caste/ethnic and food sufficiency:

Raster maps were developed for wards level available information to derive grid based variables. Those variables were caste/ethnicity, food sufficiency and demographic information of 2001 and 2011. Caste/ethnicity variables were percentage of *Bahun* and *Chhetri* population, percentage of *Dalit* population, percentage of *Janajati* population, percentage of *Dalit* and *Janajati* population. Food sufficiency variables were percentage of food sufficiency household for less than 6 months, percentage of households up to 9 months and percentage of food sufficient households with more than 9 months with food surplus. Demographic variables were population change, household size change and sex ratio change during 2001 to 2011.

f) Accessibility and other variables:

The kernel density is a well-known nonparametric geospatial estimation of densities (Kim & Scott, 2012), which can be applied to line or point datasets with spatially extensive attributes (DeSmith, Goodchild & Longley, 2007). Output of kernel density is usually a raster dataset (Longley, Goodchild, Maguire & Rhind, 2005) where each cell has a density value that is weighted according to distance from the starting features. The user can choose the cell size of the output raster, the attribute field to be used in the calculation, its units of measure and the search radius or bandwidth. The surface value is highest at the location of the point and diminishes with increasing

distance from the point, reaching zero at the search radius distance from the point. Both line and point kernel density was applied in this study. Line density estimation was used for road network for accessibility and drainage system for water resource. During the kernel density, estimation of different weight was given for certain hierarchical class of the features that has been described below:

- Settlement density: All built up points given in topographic maps scale of 1:25000 in 1996 was input of this raster surface map in order to create settlement intensity in the study area. Fifty meter spatial resolution raster surface was created for intensity surface map of the settlement in the study area.
- Road access: Roads have been classified into four categories such as highway, district road, major road and other road. According to the frequency of vehicles, road condition and means of travel on the road, certain weight for each road categories were given, which indicates the hierarchical importance of the road. Highway is highly important than district road. Therefore, highway was weighted by the value of 6. From the field survey, it was found that highway has double strength of accessibility on the basis of road condition and frequency of the vehicles as compare to district road. Thus, district road, major road and road have been given 3, 2 and 1 weight respectively. Then, 50 meter resolution kernel density raster surface was prepared for transport network intensity of the study area.
- Market facilities: Urban centers are invariably focal point of development, which vary in size depending on their population sizes (Pradhan, 2004). Urban hierarchy was defined on the basis of the size of the urban center. Location of urban centre with its given weight according to the size of the urban was used to develop urban density surface. Urban density surface was developed by kernel density method, which was defined as urban accessibility in the study area.
- Education service: Educational institutions are categorized into college, higher secondary school, secondary school, lower secondary school and primary school. These categories were given hierarchical weight of 5, 4, 3, 2 and 1 respectively. Kernel density raster surface map was prepared for the intensity of educational service in the study area.

- **Water resources:** Irrigation facility is major component for agriculture. River and streams are major water sources of irrigation in dry season. Smaller streams given on topographic map generally gets dry in winter season. Therefore, only major streams were taken as water sources. After selecting major streams and rivers as water sources for irrigation, Horton's law of stream order (Scheidegger, 1968) was used to attribute weight for streams and rivers. Then, kernel density method was used to prepare water resource facility map in the study area.
- **Other services:** Access to infrastructure and facilities in terms of travel time is generally serious problems in rural areas (Choe & Pradhan, 2010). Other services are post office, health institution and administrative services in the study area. Administrative facilities overlap with market facilities, educational institution, health institution and post office. Therefore, administrative service variable was not developed. Weight for hospital was given 3 and 1 for health post because hospital is highly important than health post. Similarly, district post office was given 3 weight and 1 for post office because district post office is highly important than other post offices in the study area. Separate kernel density raster surface maps of health service and postal service were developed. Health services map was developed using location of health institutions and their weight. Accordingly, postal service map was developed using location of post offices and their given weights.

### **3.7.8 Derived Determining Variables**

Total 30 grid based explanatory variables were derived using zonal statistics from raster data and using intensity formula from vector based data. Values of the observation (grid) of variables were according to the calculation and weighted values which have been defined above in data for determining variables. All the values of the observations in the variables are dimensionless. From the total 30 explanatory variables, only 24 suitable variables were filtered for the model estimation of land use intensity change. Those variables were from six different factors such as physical, accessibility, resource, demography, food sufficiency and caste/ethnicity. Those variables and factors have been indicated in Table 7.1. All of these variables were quantified and created the values for each grid. Among them, six variables are physical, six variables are accessibility, three variables are resource, three variables

are food sufficiency, three variables are demography and three variables are caste/ethnicity. The description of the variables has given into the followings:

**Physical:** Physical factor includes geomorphologic, climatic and hydrological variables. Geomorphologic variables are slope gradient and elevation; climatic variables are average temperature, solar radiation, and rainfall; and hydrological variable is flow accumulation.

**Accessibility:** These variables are access or travel distance from settlement, education center, marketing facilities, roads, post office and health facilities. These variables are the intensity of facilities over the spatial surface, which values are determined on the basis of location of service centers and their providing facilities.

**Resource:** Land capability, access to irrigation facility and water resource. Land capability is land suitability for agriculture based on LRMP map of Nepal (KESL 2086b). Availability of irrigation facility is the agriculture land with perennial irrigated, seasonal irrigated and non-irrigated (rain fed) cultivated land. Variable of Water resource variable is the distance from the river available water for irrigation.

**Food sufficiency:** Food sufficiency variables are food sufficiency from their own agriculture product for household, which is the percentage of households with food sufficiency in total number of households in the ward. It indicates that the food sufficiency level for the households by their own product. It is related to their economic dependency on their agriculture products.

**Demography:** It includes population change, sex ratio change and household size change from 2001 to 2011. Higher percentage of male migration than female has changed sex ratio and absence of family member has resulted changing in the household size.

**Caste/ethnicity:** Different caste/ethnic groups have different lifestyles and localities in the study area. The proportion of certain caste/ethnic groups in certain wards has been taken as social variables. Those variables are proportion of *Bahun/Chhetri*, indigenous/nationalities and *Dalits*.

### 3.7.9 Identification of Determining Factors of Land Use Intensity

Geo-statistical and allied techniques were used so as to identify the determining factors of land use intensity analysis. GWR model is the major geo-statistical technique of this study, but some other allied statistical techniques such as ordinary least square and Moran's I technique have been used in this study. Required geo-statistics and allied processing was executed in ArcGIS. These techniques have been described into the following:

a) Ordinary least square regression:

Ordinary Least Squares (OLS) regression is a global linear model based on a single equation to estimate the relationship between a dependent (response) variable and explanatory variables, which assumes a stationary relationship across the study area. A single coefficient is computed and implying as a constant over space (Ryan, 2009). The relationship between a dependent variable  $y$  and explanatory variable  $x$  is presented as a line of best fit. In this equation,  $y$  variable is predicted by  $x$  variables. The mathematical equation is expressed in equation 8.

$$y = \beta_0 + \beta_1x_1 + \beta_2x_2 + \dots + \beta_nx_n \dots\dots\dots 8$$

Where,

$y$  is the response variable

$x$  is the explanatory variable

$\beta_0$  is the  $y$  intercept

$\beta_1, \beta_2$  and  $\beta_n$  are the parameters estimated for variable 1, 2...n respectively.

Ordinary least square regression checks the degree of multi-collinearity among variables in multiple regressions using Variance Inflation Factor (VIF). It identifies any independent variable having VIF is greater than 7.5 means that the variable could be considered as a linear combination of other independent variables (Appendix I, II and III) and should be removed from multiple regression analysis (Chatterjee & Hadi, 2013; Montgomery, Peck & Vining, 2012). Therefore, Ordinary Least Square regression was used at first to identify the multicollinearity of the variables from which variables were selected for prediction validity and maximize the prediction capacity of explanatory variables.

b) Geographically Weighted Regression (GWR):

There is an increasing interest on application and development of local forms of spatial analysis methods that produce local and spatial results instead of single consistent coefficient from traditional global methods. Geographically Weighted Regression (GWR) is a kind of local technique in order to estimate regression models with spatially varying relationships (Lu, Charlton & Fotheringham, 2011). This technique assumes non-stationary relationships between response and explanatory variables. It generates a single equation for each spatial unit and consequently allows regression coefficients to vary across the study area. The model calibrates each spatial unit using the target one and its neighbors. The calibration follows Tobler's first law of geography (Tobler, 1970) where higher weights are assigned to the nearby locations according to their spatial proximity to the target location. The weight indicates the fact that close location has more influence on the calibration than location further away (Fotheringham, Charlton & Brunson, 1998; Brunson, Fotheringham, and Charlton, 2008). The equation is defined as follows:

$$Y_i = \beta_0(\mu_i, v_i) + \sum_k \beta_k(\mu_i, v_i) X_{ik} + \epsilon_i \dots\dots\dots 9$$

Where,

$Y_i$  is the dependent variable at location  $i$

$X_{ik}$  is the value the  $k^{\text{th}}$  explanatory variable at location  $i$

$\beta_0(\mu_i, v_i)$  is the intercept parameter at location  $i$

$\beta_k(\mu_i, v_i)$  is the local regression coefficient for the  $k^{\text{th}}$  explanatory variable at location  $i$

$(\mu_i, v_i)$  is the coordinate of location  $i$

$\epsilon_i$  is the random error at location  $i$

c) Moran's I and autocorrelation:

Regression residual contains the information about the prediction validity of a regression model. If variable is spatially auto correlated, a regression model with these variables will be problematic. In this situation, spatial distribution of the regression residuals serves as a significant indicator for uncertainty of GWR model (Propastin, Kappas & Erasmi, 2007). Random distribution of residuals over the space is the sign for a non-problematic regression model. Spatial patterns of regression

residuals containing positive autocorrelation indicate that the standard errors are underestimated and the correlation coefficient often indicates a significant relationship between variables when in fact there is none (Clifford, Richardson & Hemon, 1989). Moran's I is a commonly used indicator of spatial autocorrelation (Fu, Jiang, Zhou & Zhao, 2014). Local Moran's I measures the degree of spatial autocorrelation at each specific location (Anselin, 1995). Local Moran's I index can be expressed in equation 10.

$$\text{Moran's I} = \frac{(X_i - \bar{X})}{\sigma^2} \sum_{j=1, j \neq i}^n [W_{ij} (X_j - \bar{X})] \dots\dots\dots 10$$

Where,  $\bar{X}$  is mean value of X with the sample number of  $n$ .

$X_i$  is the value of variable at location  $i$

$X_j$  is the value at other locations (where  $j \neq i$ )

$\sigma^2$  is the variance of X.

$W_{ij}$  is a distance weighting  $W_i$  and  $W_j$  which can be defined as the inverse of the distance.

The value of Moran's I can be tested based on an assumption of a normal distribution (Levine, 2004). A high positive value of local Moran's I indicates the target value is similar to its neighborhood and the locations are spatial clusters. A high negative local Moran's I value implies a potential spatial outlier, which is obviously different from the values of its surrounding locations. It means the dispersion of residual distribution or free of autocorrelation.

d) Filtering explanatory variables:

Land use intensity change was dependent (response) variable. Among derived 30 explanatory variables, one was qualitative and cannot be used in GWR model. Thus, remaining 29 variables were filtered into 24 as listed in Table 7.1. Due to the multicollinearity among 29 variables ( $VIF > 7.5$ ) and some variables were rejected by GWR model. Thus, five variables were removed and only 24 variables were selected for GWR model (Appendix I) as explanatory variables. At first, bivariate GWR model of land use intensity with individual explanatory variables were calculated. Secondly, multivariate GWR model of land use intensity were calculated with grouped variables of six different factors separately. GWR model was run with several combinations of

different sets of explanatory variables in order to identify the maximum strength of predicting land use intensity. Finally, 10 variables were found the best, reliable and maximum prediction capacity of land use intensity dynamics. Condition number of individual observations derived by GWR more than or equal to 30. It indicates that there may be unreliability of predicted value of concerned observation. In GWR model, using 10 selected explanatory variables of land use intensity change was not given complete reliability because of the several observations had condition number more than 30. Thus, again only 6 explanatory variables were selected from 10 variables which was resulted 100% reliability of prediction due to all condition number was less than 30. Finally, GWR model of 6 explanatory variables with land use intensity change variable as dependent was executed.

### **3.8 Analysis**

Derived results of the study have been described into three parts. First part is the description of the study area; second part is land use/land cover and its change. Third part includes land use intensity, land use intensity dynamics and identifying major determining factors of land use intensity dynamics. Finally, implication to land use intensity dynamics as well.

#### **3.8.1 Description of the Study Area**

Description of the study area includes information on location; physical features such as relief, drainage, climate, slope gradient, and slope aspect; cultural features such as road network, distribution of settlement and population; distribution pattern and size of health institutions, education institutions and market centers in the study area. Information have been presented on maps and described into the text. Integration of different aspect of traditional agriculture system in the study area has been described with diagram.

#### **3.8.2 Land Use/Land Cover and Change**

In order to fulfill the first objective, land use/land cover patterns of 1996 and 2016 have been analyzed with maps and tables. Land use/land cover patterns have been analyzed in relation to altitude. The proportionate variations of different land use/land cover categories at different elevation ranges in 1996 and 2016 have been analyzed

with tables. Pattern of land use/land cover change has been analyzed by comparing land use/land cover maps of 1996 and 2016. Area and percentage change of different land use/land cover during 1996 and 2016 have been analyzed with tables. Percentage of land use/land cover changes have also been analyzed in relation to different elevation ranges, slope aspects and slope gradients with diagrams.

### **3.8.3 Land Use Intensity and Change**

Distribution patterns of land use intensity of 1996 and 2016 have been analyzed with separate maps and numerical tables. Separate maps of land use intensity and table of descriptive statistical values of land use intensity was used to analyze. Maps and numerical values have been used to analyze the land use intensity change. Map was used for spatial variation of land use intensity change and numerical value for quantity change of land use intensity during 1996 to 2016.

### **3.8.4 Identifying Major Determinants of Land Use Intensity Change**

This technique was used in order to fulfill the objective of this study. This part includes introduction to explanatory variables, derived results from bivariate and multivariate GWR model with different combination of different explanatory variables of land use intensity dynamics. Derived results have been analyzed with the help of several maps and tables. Finally, this part analyzes the identification of major determinants of land use intensity dynamics which was identified through several filtering processes of explanatory variables.

### **3.8.5 Implication to Land Use/Land Cover and Land Use Intensity Change**

After analyzing the result, its implication in different aspects has been analyzed. This part includes causes, consequences, relation to other aspects and indication for field for further research.

## CHAPTER IV

### THE STUDY AREA

#### 4.1 Location

Northeastern part of the Andhikhola watershed was selected for intensive study (Figure 4.1 and Appendix VI: Photo A). Selected study area consists of several sub-watersheds associated with the tributaries (Rangkhola, Badhkhola & Phedikhola) of the Andhikhola river and also includes the district headquarters of Syangja district. Sidhartha highway passes through this study area along east side of Andhikhola river. The geographical extension of the study area is in 28°03'36" N to 28°11'02"N parallels of latitude and from 83°49'34" to 83°56'52" east meridians of longitude. It occupies 97.75 sq. km (20.3% area of Andhikhola watershed) having the elevations range from 779m to 1566m from average mean sea level.

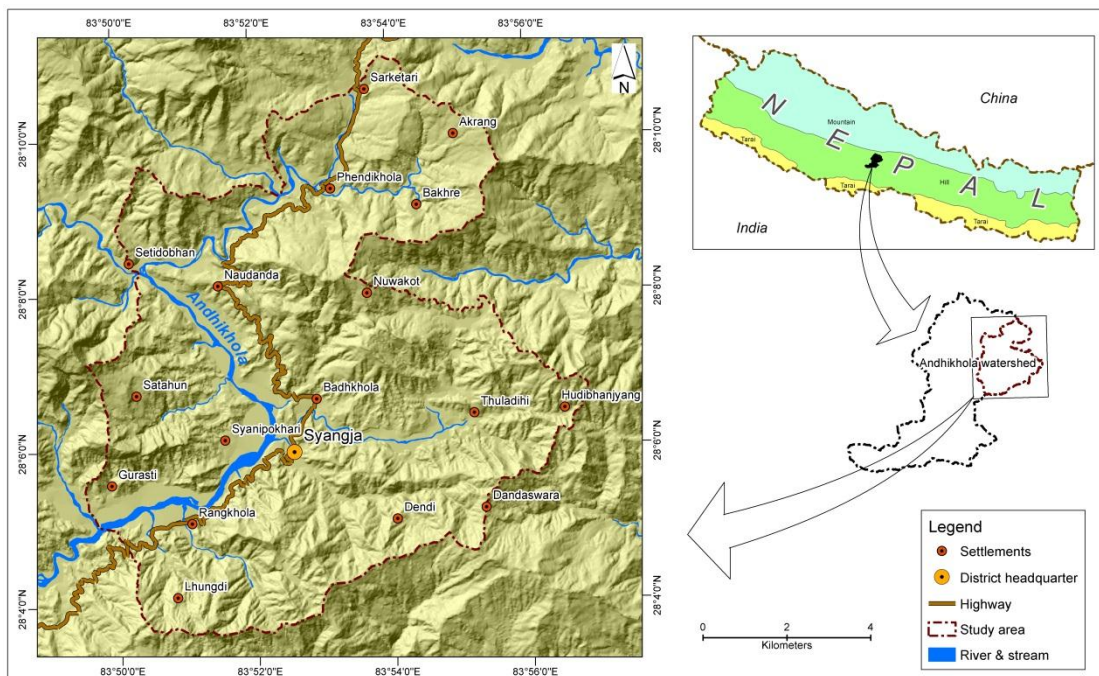
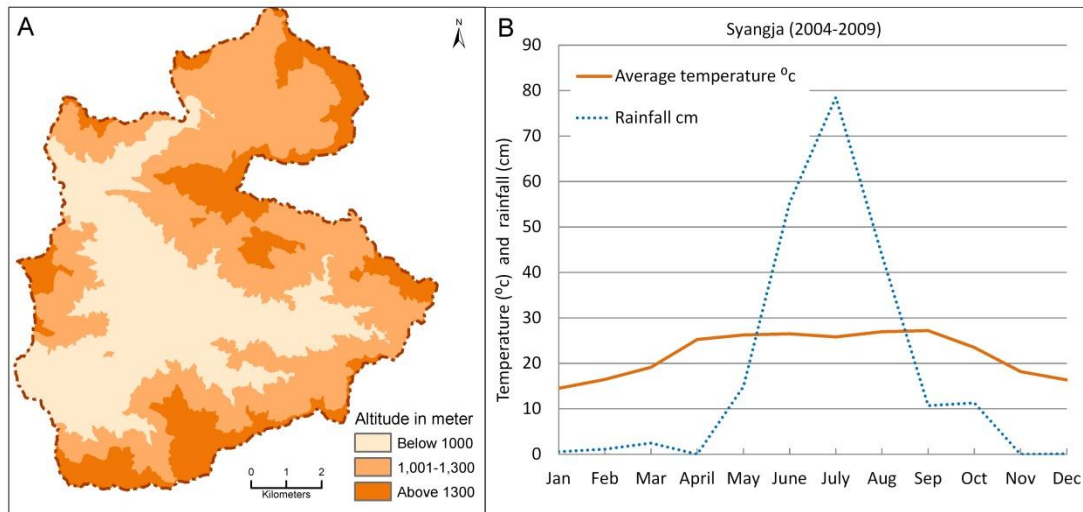


Figure 4.1: Location of the Study Area

#### 4.2 Elevation and Climate

The elevations of the study area ranges from 779m to 1566m from average mean sea level, which is the Middle Mountain of physiographic regions of Nepal (KECL 1986c). More than one third (34.4%) area is below 1000 meter and 47 percent of the

study area is between the elevations of 1000 to 1300 meter. Remaining 18.6 percent area is above 1300 meter (Figure 4.1A). According to the temperature regimes of Nepal, more than one third part of the study area is under subtropical region and remaining area is warm temperate region.



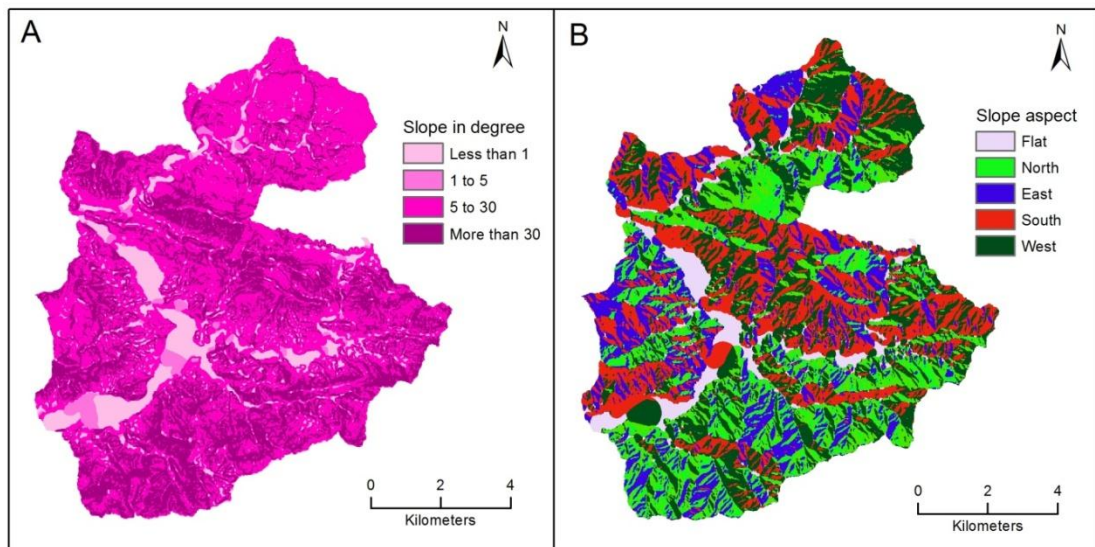
**Figure 4.2: (A) Elevation and (B) Climate**

According to the climatic record of Syangja (DHM, 2004; DHM, 2005; DHM, 2006; DHM, 2007; DHM, 2008 and DHM, 2009) from 2004 to 2009, average temperature in Syangja was 21°C having minimum nearly 12°C in January and maximum nearly 27°C in August (Figure 4.2B). Lower parts of the watershed occurs high temperature up to 35°C in summer hot season and higher part occurs up to 5°C temperature in winter season (DDC, 2007). Annual average rainfall was 2765mm between 2004 to 2009 with minimum 2081mm in 2008 and maximum 3497mm in 2007, which indicates heavy fluctuation in total rainfall. More than 80 percent rainfall falls in summer season i. e. in May to August (Figure 4.2B). Rainfall in the watershed is higher to the north and gradually decreases towards the southern part (DDC, 2007). Land surface temperature was calculated from Landsat8 thermal band 10 and 11 which reveals that June's mean temperature ranges from 24°C to 28°C in the day time and temperature in December is 16°C to 25°C. In June, temperature seems higher in lowland and lower in highland, but inversely in December, day time land surface temperature seems higher at higher altitude than in lower part in the day time. It is because of the sun light is received by higher hill as compared to lower plain area in winter. During the summer season, most of the streams get sufficient water and most of them turns dry in winter season. Heavy rainfall in summer monsoon season causes

frequent flood in the river and rivulets. Higher amount of soil erosion, landslide and flood occur from the hill slopes and sloppy cultivated land. Last heaviest flood in the past was occurred in 1996 in the study area. Heavy sedimentation in the rivers and rivulets caused heavy damage of cultivated land along with the river basin and in the hill sides. Many landslides supply sufficient sediments in the river and streams for heavy flood in lowland areas.

### 4.3 Slope Gradient and Slope Aspects

Being a hilly region, the study area is mostly sloppy land (Appendix VI: Photo A). Limited parts of the lowland are plain. More than 13 percent land is less than 5° slope having nearly 9 percent of the total area is less than 1° slope. More than half (52.53%) areas are under the slope range of 5° to 30°. Remaining are more than 30° slope which covers 34.06 percent of total area (Figure 4.3A). Proportion of east facing slope area (18.75%) is less than other three slopes face north, south and west.

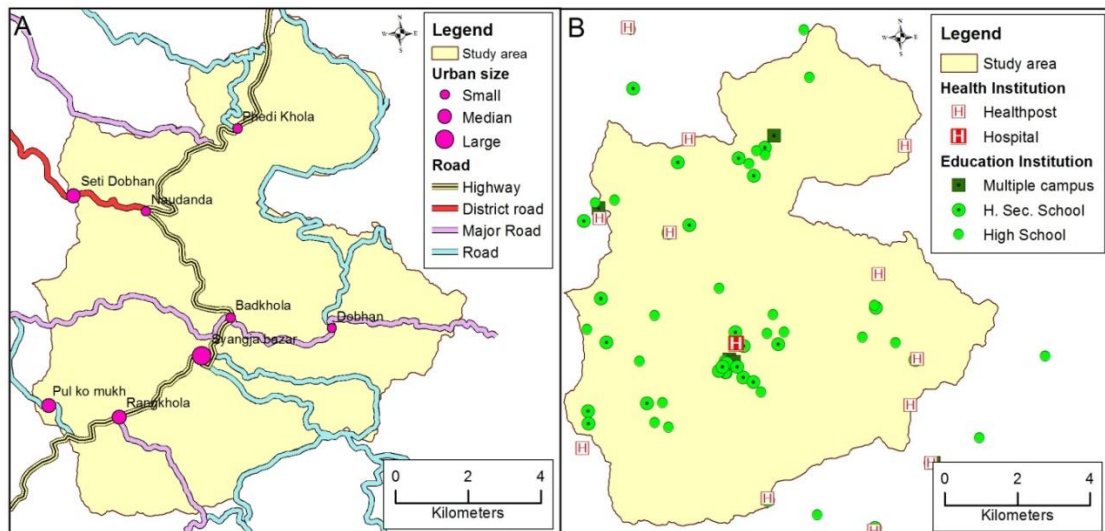


**Figure 4.3: (A) Gradient and (B) Slope Aspect**

The area of north, west and south facing slope is nearly equal proportion having average 25 percent of each slope aspect among which north is the lowest 24.6 percent and west is the highest 25.7 percent. Remaining are 18.8 percent east facing and 6 percent is flat. Most flat land is at lowest place. The higher proportion of the southern part of the study area is north facing slope and the eastern part of the central region is south facing slope. East facing slope is distributed all parts of the study area.

#### 4.4 Infrastructure Service Facilities

Siddhartha highway was constructed around 50 years ago, therefore, the study area was more accessible than other many hilly areas of Nepal in the past. Now, the highway has several connections with district and other roads. Lowland area is more accessible than highland. As a result, most of the urban centers are locating along the highway (Figure 4.4A). Syangja bazaar is the biggest urban centre and district head quarter. Others centers are locating along the highway and other roads. Health and educational institutions are distributing everywhere in the study area, but higher level service infrastructures such as hospitals and colleges are locating in the major urban centers. Therefore, people have to travel towards major urban centers in order to get higher level education, health and postal services (Figure 4.4B).



**Figure 4.4: (A) Road Network and Market Centre, and (B) Location of Services**

#### 4.5 Settlement and Population

In the hill slopes of the study area, the south and east face as well as top of hills have the higher density of settlement and most of them are rural in nature. There are several urban settlements along with the highway of lowland area. However, there are very few settlements at plain area along with the major river. The average population density in Andhikhola watershed is 324 persons per sq. km having minimum 30 persons to maximum 3404 persons per sq. km in the VDCs in 2011. This maximum population density is at very limited parts of the urban area. During 1981 to 2001, the population in the watershed has consistently increasing trend. During 1981 to 1991

annual population growth rate was 0.77 and 1991 to 2001 was 0.78, but population has decreased with the annual rate of -0.93 during 2001 to 2011. Sex ratio in this watershed was consistently decreasing during 1981 to 2011 because of outmigration of male population. Literacy rate of the area is 76.6 percent having male literacy 86.05 and female literacy 69.5 percent, which is much higher than national average literacy rate. Nearly 50 percent of the households have minimum i.e. at least one family member is absent from the household in 2011 in Syangja district in which national figure is only 25 percent. Similarly, the percentage of absentee population from Syangja district is the higher than the national, hill region, development regions and rural areas of Nepal (CBS, 2012). This figure indicates that the higher outmigration rate from the district than other parts of Nepal.

**Table 4.1: Caste/Ethnic Groups of Population in the Study Area**

<b>Caste/ethnic groups</b>	<b>Population, 2011</b>	<b>Percent</b>
Bahun	10207	24.5
Chhetri	9861	23.7
Gurung	7573	18.2
Magar	5634	13.5
Kami	3649	8.8
Damai	2228	5.3
Sarki	755	1.8
Bhujel	709	1.7
Thakuri	354	0.8
Other	707	1.7
Total	41677	100.0

Source: VDC Profile, 2011.

Peoples of Nepal are from different social groups. Some of them are classified into hierarchical level by Hindu caste system those are known as caste group. Many other groups are not under this caste system are known as ethnic groups. Thus, the total stratification of different social groups is known as caste/ethnic groups of Nepal (Bennett, Dahal, and Govindasamy, 2008). Among different caste groups in the Hindu system, higher caste & *Dalit* are broadly classified into two distinct groups. Higher castes are Bahun, Chhetri, Thakuri and some similar hierarchical caste groups and *Dalits* are categorized into untouchable groups. Major higher caste groups in the study

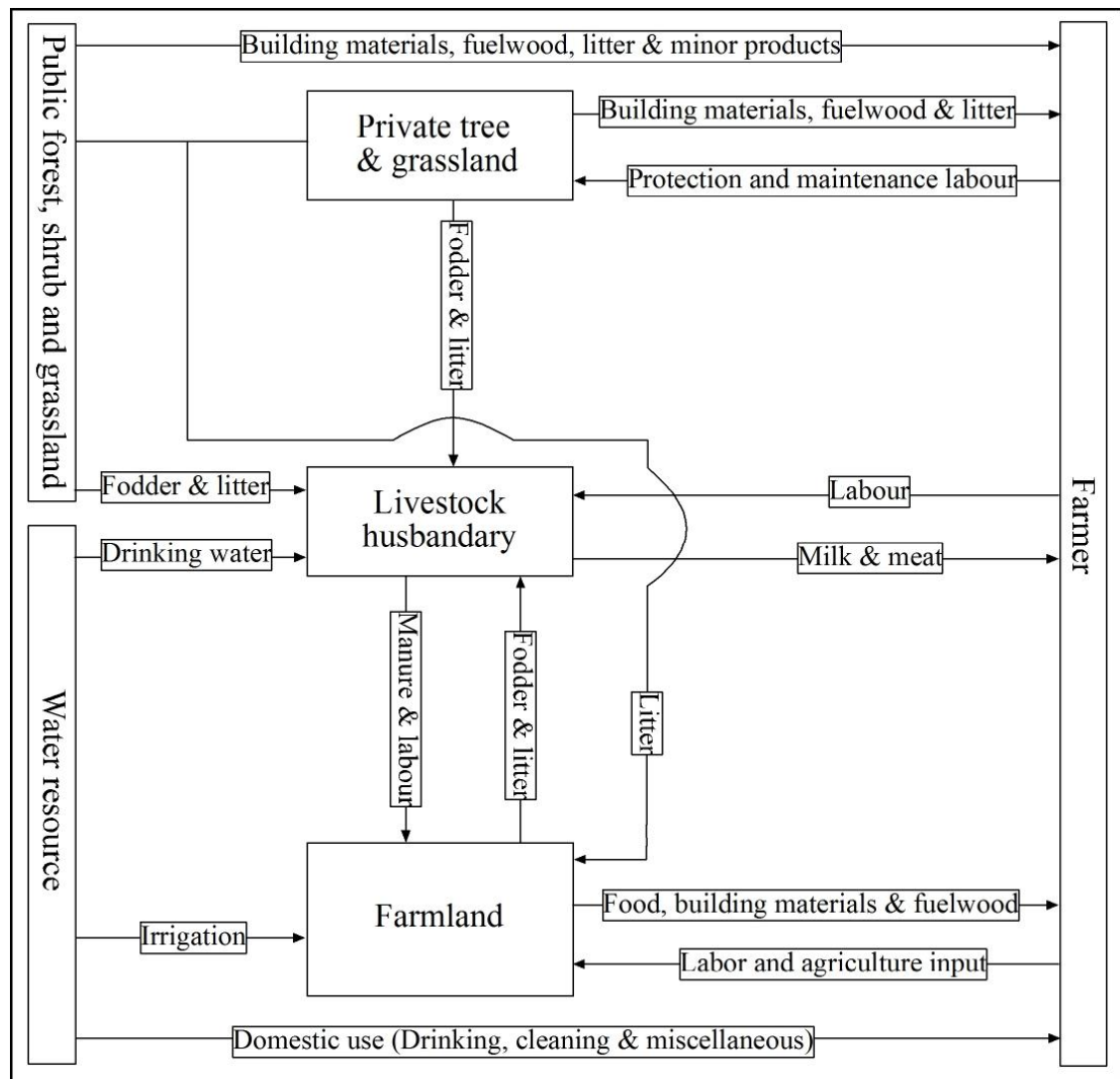
area are Bahun, Chhetri and Thakuri which occupy 49 percent of total population in the study area. *Dalits* are Kami, Damai and Sarki. They occupy 16 percent of total population. Ethnic groups in the study area are Gurung, Magar and Bhujel (NEFIN, 2004). They are also known as Indigenous/Nationalities of Nepal and they are 33 percent of total population. Some other caste/ethnic groups such as Rai, Limbu are also in the study area, but they share less than two percent of total population (Table 4.1). There is significant difference on socio-economic status and access to different basic needs and services among different caste ethnic groups in Nepal (Chhetry, 2006) and in the study area as well. The higher caste groups are significantly higher status on all development and access to the basic needs and services and inversely *dalits'* have the lowest status. Ethnic groups are in between them. Several studies show that socio-economic status and access to basic need and services are also important factors on land use/land cover change analysis.

#### **4.6 Farming Practice**

Like in other districts of Nepal, economically active population engaged in agriculture in Syangja district that constitutes 73.6 percent (CBS, 2014). Cultivable land occupies 62.46 percent of the total watershed area in which only 21.6 percent of them with perennial irrigation facility, 14 percent of them with seasonal irrigated and others are rain fed in Syangja district (DADO, 2013). Because of the low government intervention and lack of effective policy implication, it is still remaining traditional intensive subsistence farming system in most of the part of the Nepal including in the study area. Most parts of the study area are still intensive subsistence farming practice. Subsistence agriculture is self-sufficiency farming in which the farmers focus on growing enough food to feed themselves and their families, which has a range of crop and animals needed by the family to feed and clothe themselves during the year (Waceke & Kimenju, 2007). This farming system in the study area is characterized by extremely small farm size having 0.51 hectare in Syangja district which is quite lower than national figure 0.8 (CBS, 2013).

Planting various crops together with livestock integrating with private and public resources is the general characteristics of the farming system in the study area (Figure 4.5). Due to poor farm management and agriculture practices such as continuous cropping and lack of adequate and appropriate external inputs, the land does not

produce according to its potential and yield are therefore comparatively low and this condition is higher in the hill slope terraces. Lower plain area has irrigation facility, access to highway and fertile plain area has more agriculture productivity and innovative agriculture practices (Appendix VI: Photo B, G & H). Lower hill slope has also more innovation than higher part because of the accessibility. These areas have more commercial crops like fruit, vegetable and some other cash crops production.



**Figure 4.5: Agriculture System in the Study Area (Author's Construct)**

Higher parts of hill slopes still practice primitive types of subsistence farming with inadequate agriculture input and resulting low productivity. High rate of crop failure due to climatic uncertainty, damage by disease and often affected by hails during summer precipitation are usual phenomenon of the Hill agriculture in Nepal. As a result, farmers are compelled to import grains such as maize, millet from other hill

districts and rice from the Tarai districts, as a result of insufficient local production to meet the need or demand.

Subsistence farming practice is to sustain for their livelihood from their agriculture product. Thus, there is meaningful relation of their economic status of farming household and food sufficiency from their agricultural product (Kuwornu, Suleyman & Amegashie, 2013). How much food they produce from their agriculture work and there is sufficient food production for their family members or not from their own agriculture product, which is related to food security for the household. In global context, peoples can buy food from market, but the subsistence farmers produce their food for their own consumption rather than commercial purposes. Thus, if farmers have sufficient food production for the household, they might look little for alternative way of life or additional work in order to sustain their family and they might have less chance of shifting from agriculture work to other. Inversely, if any household has less sufficiency of agricultural product for their livelihood, they have more chance to look after another jobs rather than their traditional farming practice. Thus, food sufficiency for farming household from their agriculture product is related to land use/land cover and agriculture land change as well. Thus, this study has prepared the table of food sufficiency households in the study area which is given in the table below:

**Table 4.2: Households with Food Sufficiency in the Study Area**

<b>Food sufficiency</b>	<b>Number of household</b>	<b>Percent</b>
Less than 3 month	3343	27.8
3 to 6 month	3108	25.8
6 to 9 month	3012	25.0
9 to 12 month	1435	11.9
Surplus	1140	9.5
Total	12038	100.0

Source: VDC Profile, 2011.

Nearly 28 percent households were food sufficiency only for less than 3 months and nearly 54 percent households were food sufficiency for less than 6 months. Food surplus households in the study area were less than 10 percent and nearly 90 percent households were not food sufficiency from their own agriculture product in order to

sustain their family in the whole year from a single year product (Table 4.2). Thus, it can be said that agriculture product is not sufficient in order to sustaining farmers for their livelihood. They have to look after for additional source of income. Food deficiency for households seems in both remote marginal areas and urban areas, which indicates the food deficiency in remote area is due to low agriculture productivity where as in urban areas is due to the people's involvement in non-agriculture activities.

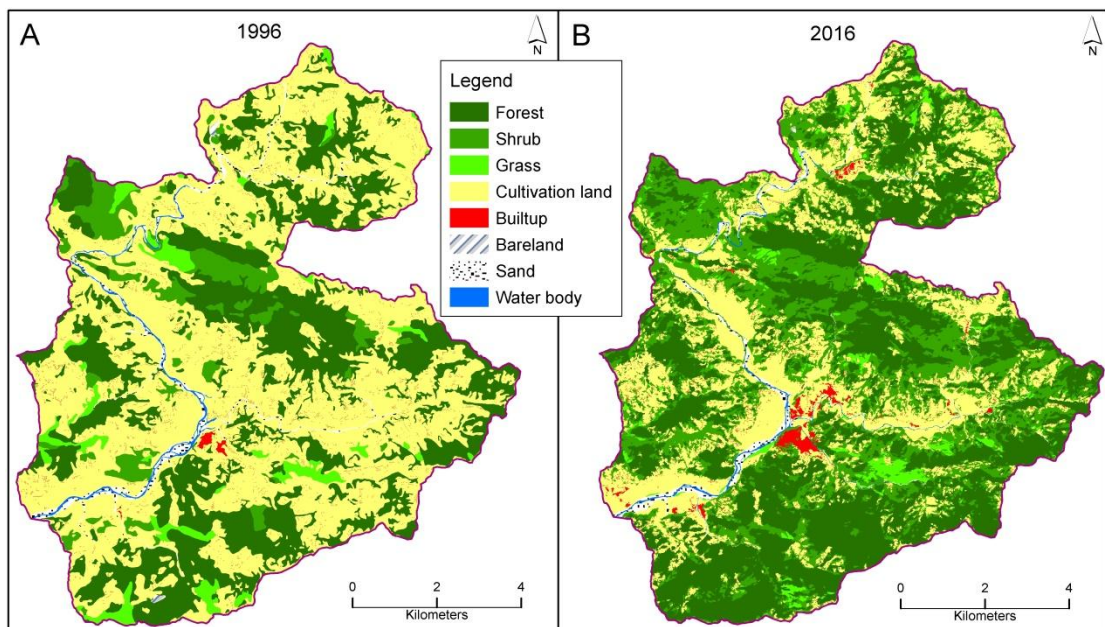
## CHAPTER V

### LAND USE/LAND COVER AND CHANGE

Land use/land cover information of 1996 and 2016 have been used for the study of land use/land cover and its changes in the study area. Land use/land cover and its change have been described in relation to elevation, slope gradient and slope aspects.

#### 5.1 Land Use/Land Cover 1996

Figure 5.1 shows the higher proportion of land is under cultivation in 1996 and most of the remaining parts are forest, shrubs and grassland. Very few areas is covered by built up and river channel.



**Figure 5.1: Land Use/Land Cover in (A) 1996 and (B) 2016**

Table 5.1 shows that nearly 57 percent of the total area was covered by cultivated land followed by forest in 1996. More than 97 percent of the total area was covered by only cultivated and vegetated area (forest, shrubs and grass land). Remaining land was covered other land use/land covers such as sand, built up and degraded area. Degraded land is due to the unscientific road construction in the hill slope. Cultivated land is the highest proportion in each elevation range, but the proportion is decreasing with increasing elevation. Forest area is higher at higher elevation than in the lower

parts. Grassland is increasing from lower to higher elevation. Built up area is higher at lower elevation below 1000 meter and lower proportion at higher altitudes.

**Table 5.1: Percentage of Land Use/ Land Cover in 1996 by Elevation in Meter**

Land use/ land cover	Below 1000	1000 to 1300	Above 1300	Total
Cultivation	71.0	49.9	47.4	56.7
Forest	14.7	39.7	38.1	30.8
Bush	5.9	5.7	7.3	6.1
Grass	1.6	3.8	6.5	3.5
Sand	4.0	0.4	0.0	1.6
Built up	1.2	0.5	0.5	0.7
Water	1.7	0.0	0.0	0.6
Degraded	0.0	0.1	0.2	0.1
Total	100	100	100	100

Source: Derived from land use/land cover maps 1996

## 5.2 Land Use/Land Cover 2016

Figure 5.2 shows that the higher proportion of cultivated land is concentrated at lower elevation and more greenery (forest and shrub) are in the higher elevation area. Large patch of built up area is along with the river valleys in lowland areas.

**Table 5.2: Percentage of Land Use/ Land Cover in 2016 by Elevation in Meter**

Land use/ land cover	Below 1000	1000 to 1300	Above 1300	Total
Forest	21.3	46.4	53.5	39.0
Cultivation	42.6	20.3	17.2	27.4
Shrub	25.4	29.8	25.2	27.4
Grass	2.2	2.4	3.6	2.6
Sand	4.0	0.3	0.0	1.5
Built up	3.0	0.8	0.5	1.5
Water	1.6	0.0	0.0	0.6
Degraded	0.0	0.0	0.0	0.0
Grand Total	100.0	100.0	100.0	100.0

Source: Derived from land use/land cover maps 2016

Forest cover area was the highest in 2016 followed by cultivation and shrub. Proportion of forest area is increasing with the increment in elevation and inversely cultivated land is highly decreasing with increasing elevation. Shrub is similar below 1000 and above 1300 meter, but higher proportion at 1000 to 1300 meter. Grassland is also increasing with elevation, but not much higher proportion than that of cultivated forest and shrubs. The higher proportion of built up area is at lower elevation and its proportion is decreasing with increasing elevation.

### 5.3 Land Use/Land Cover Change

Cultivated land is highly decreasing at the hill slope converting into forest and shrubs. There is no significant change on cultivated land at lowland area. Built-up area has significantly increased along the highway and river valley. Forest and shrub has significantly increased in most of the sloppy land (Figure 5.1 A and B). Maps indicate that lower plain and accessible area has the lowest change of land use/land cover than remote hill slopes.

There is a significant change in land use/land cover in the study area between 1996 and 2016. Shrub area was increased tremendously with over 352 percent during this period. This was followed by the forest coverage and built-up areas (Table 5.3). On the other hand, area of two land use/land cover types such as agriculture land and grassland were decreased remarkably during this period. It was observed that most of the grassland was converted into shrub. Degraded area was increased remarkably due to the unscientific road construction in the hill slope.

**Table 5.3: Land Use/Land Cover in 1996 and 2016**

Land use/ land cover	Land use/land cover 1996		Land use/land cover 2016		Change (%)
	Area sq. km	Area %	Area Sq. km	Area %	
Cultivation	55.47	56.75	26.79	27.41	-51.71
Forest	30.10	30.80	38.12	39.00	26.63
Shrub	5.92	6.06	26.77	27.39	352.32
Grass	3.44	3.52	2.50	2.56	-27.31
Sand	1.54	1.57	1.50	1.53	-2.54
Built up	0.70	0.72	1.45	1.48	105.40
Water	0.56	0.58	0.54	0.55	-4.49
Degraded	0.01	0.02	0.09	0.09	494.43
Total	97.75	100.0	97.75	100.00	0.00

Source: Derived from land use/land cover maps 1996 and 2016.

The land abandonment situation is more critical in the study area (Khanal, 2002) in which nearly 20 percent of total cultivated land was abandoned during 15 years period of 1999 to 2014 in Andhikhola watershed area (Chidi 2017). Thus, the land use/land cover change in the study area is quite higher than other Hill areas of Nepal (Paudel, Yili, Shi-cheng, Lin-shan, Xue & Khanal, 2016; Rai, Yili, Paudel, Acharya & Basnet, 2018).

#### 5.4 Land Use/Land Cover Transformation (1996-2016)

The highest proportion of the transformed cultivated land is into the shrubs followed by forest and grass. More than 51 percent of the total cultivated land of 1996 was converted to vegetated area (forest, shrub and grassland) with some portion was into built-up and others. Conversion of forest area to other land use/land cover is the lowest with higher proportion of shrub was transformed into forest, and grass land into forest and shrubs. Built-up area transformed into cultivated land and shrub due to the abandonment of several villages in the hill slope areas. During filed survey, it was found that several numbers of houses were abandoned, damaged and converted into shrubs, grassland and cultivated land. Some settlements were completely abandoned in the hill side areas including schools. Due to its small change proportion of the total area, it has no significant impact on percentage change. However, 2.18 percent transform of cultivated land into built-up area has significantly increased total built-up area during 1996 to 2016 (Table 5.4).

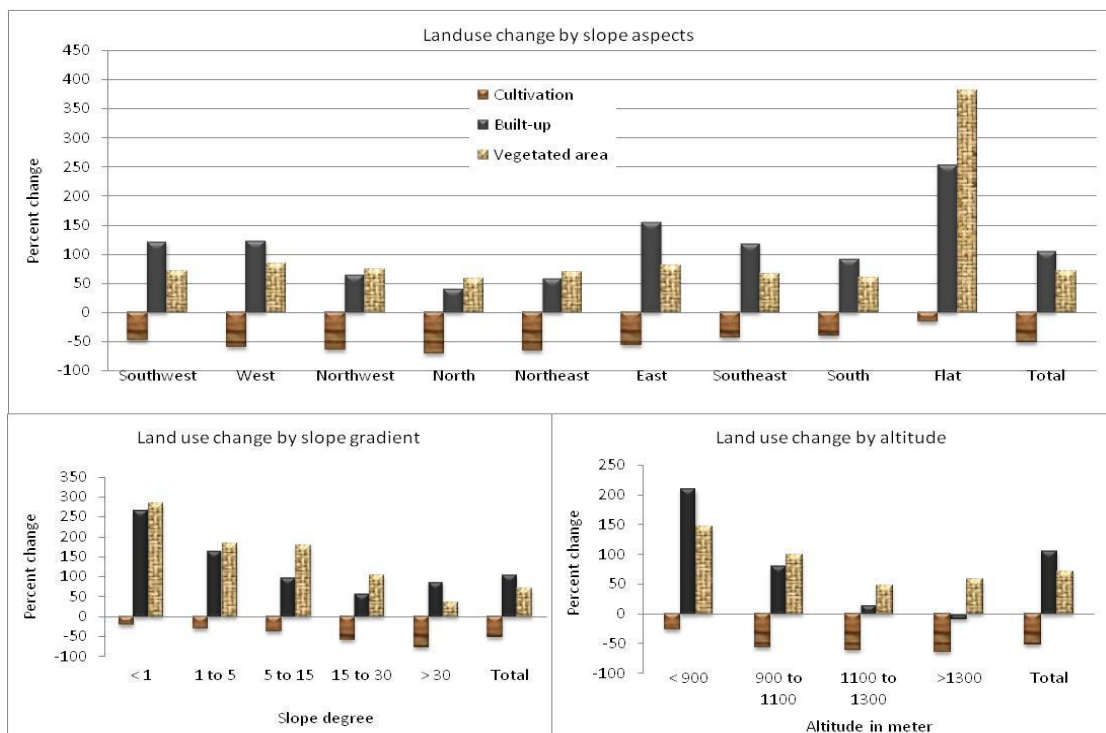
**Table 5.4: Percentage of Land Use/Land Cover Transformation (1996-2016)**

2016 \ 1996	Cultivation	Built up	Forest	Shrub	Grass	Sand	Water
Cultivation	<b>45.45</b>	2.18	19.95	29.06	2.20	0.90	0.26
Built up	45.78	<b>29.14</b>	8.01	16.43	0.57	0.06	0.01
Forest	2.11	0.08	<b>80.06</b>	17.30	0.38	0.05	0.02
Shrub	2.07	0.05	<b>34.61</b>	<b>60.84</b>	2.13	0.14	0.17
Grass	2.04	0.07	26.86	43.15	<b>27.71</b>	0.08	0.09
Sand	24.13	0.37	2.80	11.32	4.04	<b>42.86</b>	14.46
Water	16.43	0.44	0.34	15.06	3.18	<b>42.46</b>	<b>22.08</b>

Source: Derived from land use/land cover maps 1996 and 2016

## 5.5 Land Use/Land Cover Change and Topography

Cultivated land has decreased in all slope aspects, slope gradient and elevation in the study area. However, the proportion of change is highly different at different elevation, slope gradient and slope aspects. The highest proportion of cultivated land has decreased in the north facing slope (more than 70%) followed by the northeast and the northwest because of the lower solar radiation which is less suitable for crop cultivation. It is inevitable to know that most of the human settlements in the hill sides are located at sunny slope face i.e. south and east facing and naturally north and west facing slope are far from the settlement. There is four times higher land abandonment rate in north facing than average land abandonment in Andhikhola watershed (Chidi 2017). Least change is in the flatland followed by south and southeast. The proportion of vegetated area is highly increased at flatland followed by east and west facing slopes. Built-up area is highly increased in the flatland followed by west (Appendix VI: D). Decrease in the cultivated land is highest in the area above 1300 meters and the lowest below 900 meters. Built-up area is increased more than double below 900 meters. Similarly, increasing vegetated area is the highest below 900 meters (Figure 5.2).



**Figure 5.2: Land Use/Land Cover Change by Altitude, Slope Gradient and Slope Aspect**

Decreasing grassland coverage was due to the conversion of grassland into shrub. Built-up area was increased remarkably mainly at the lowland areas, because of the spatial shift of people from traditional settlements of the hill slopes to the lowland and along the roads and the highways. As a result, rapidly growing urbanization process in these areas can be detected (Figure 5.2). In 2016, land use/land cover map shows a more complex pattern compared to the 1996 map as a result of the abandonment of agriculture land which was converted into green areas such as forest, shrubs, and grassland. Land use/land cover change analysis shows that higher parts consists of more land abandonments of cultivated land converting into vegetated area (Appendix VI: Photo F). Increasing built-up area can be detected in lowlands (Appendix VI: Photo D). Most cultivated land has been converted into forest, shrub and grassland. Some parts of the land which was cultivated in 1996 turned into forest coverage in 2016 because those parts within the cultivated land had already some upcoming trees in the old image.

Conversion of cultivated land into a vegetated area is highly correlated with depopulation in the watershed during 1999 to 2014 (Chidi, 2016a). The land use/land cover change during this period shows that the significant decrease of cultivated land and increase of vegetated area due to the agriculture land abandonment in the study area can be compared with many highlands having similar phenomena in the world (Shengfa & Xiubin 2017; Gellrich, Baur, Koch & Zimmermann, 2007; Prishchepov, Mullaer, Dubinin, Baumann & Radeloff, 2013). Thus, this study result is not also different than many other findings in the world.

## **5.6 Implication of Land Use/Land Cover Change**

There is an intrinsic relationship between human activities and their surrounding landscapes. Agriculture through hill terrace farming system is the main occupation and means of main income for the rural farmers in the study area. However, agriculture has not improved due to the lack of agro-infrastructure. For instance, the study area has its 21.6 percent cultivated land being irrigated by perennial irrigation system (DADO, 2013). Subsistence agriculture has been practiced by the farmers, which was just to produce good required to feed their families themselves. Further, landholding size is characterized by extremely small farm size having 0.51 hectare in Syangja district, which is quite lower than the national average of 0.8 in 2011 (CBS,

2013). Till date, the situation of traditional practice of subsistence practice is not improve and the situation of traditional practice of agriculture is deteriorating day by day due to labor shortage in the village and the land productivity is decreasing day by day in the hill slope parts in the study area. Some efforts of commercial agriculture practices are not being sufficient in the fast rate of abandoned cultivated land. Despite there is comparably higher comparative advantage in diversity of cropping practice due to altitudinal variation, weather change, source of water, biodiversity, etc. the highlands of the hill areas is unable to take advantage of those benefits due to the lack of basic agro-infrastructure. This area is highly potential for the production of various commercial crops such as comparatively testy orange, large cardamom, coffee and other various tree products in the hill slope areas, which have already been practiced by local people. Government effort is being very limited rather than farmers' effort themselves. Control of topographic factors such as elevation, slope gradient and slope aspect converting agriculture land to vegetated area is found in many parts in the world (Chidi 2016b; Birhane, Ashfare, Fenta, Hishe, Gebremedhin, Wahed et al. 2019; Manadhar & Ghimire, 1996) which is clearly visible in the study area as well.

Major permanent restrictions of agriculture in mountain areas are the natural landscape with their steep slope, climate and altitude (European Commission 2009), which is being major limitations and opportunities in highland areas of Nepal and the study area as well. Heavy loss of hill farmers during the last two decades is caused by scarcity of agriculture land and lack of off-farm job opportunities in the uplands and expanding commercial farming in the lowlands, growing economies in urban areas and foreign countries (Pratap, 2011; Fatima & Hussain, 2012; Barah, 2010) are being the major driver of land use/ land cover change in the study area as elsewhere in large parts of world (Tukahirwa, 2002; VanWey, 2003). Lack of sufficient land for cultivation, low productivity and other facilities are the motivated factors of farmers out-migration in the study area. This situation in the Hills of Nepal was started after the recruitment of Gorkha soldier by British-India in which Gurung and Magar ethnic groups were involved from the study area (Kansakar, 1982) and some of them did not back to their hill town at all. After eradication of malaria during 1950s, hill people started to migrate from the Hill to the Tarai region in Nepal (Graner, 2010). Nevertheless, foreign labor migration of recent past has the greater impact of labor shortage in the Hill area than any other types of migration in the history of Nepal.

Out-migration of the farmers from the hill slope has released population pressure on the farmland, which was already more than land carrying capacity in the past for traditional agriculture practice in the hill slope areas. Degradation of land and natural vegetation including wildlife has been a crucial issue in the hills of Nepal (Blaikie & Brookfield, 1987). Higher human intervention in the hills increased land degradation in the past (Regmi, 1978; Carson, 1985; Mahat, 1985). At that time, overgrazing of livestock on abandoned land has increased land degradation in the hills of Nepal (Khanal & Watanabe, 2006), but now observation reveals that decreasing intensity of livestock number and decreasing human population has resulted into decreasing soil erosion from abandoned land due to mostly covered by vegetation and low intervention of human and livestock. However, increasing abandonment of cultivated land has not only caused a decline in the level of agricultural production in the villages, but also seriously affected the livelihoods of marginal and small farm households in the villages (Khanal & Watanabe, 2006) in the mountain region of Nepal and the study area as well. Decreasing human and livestock population (Appendix VI: Photo C & E) resulting to increasing greenery and wildlife population make the suitable situation for interspecies competition (Mackenzie, Ball & Vardee, 2002) between wildlife and human population in the study area, which is common phenomena in many abandoned land (Hua, Yan, Li, He & Li, 2016; Benayas, Martins, Nicolau & Schulz, 2007). Due to the frequent damage of crops by wildlife and killing livestock by tiger, local people are being unable to protect their crops and livestock. The situation is increasing trend day by day which indicates that the further abandonment of village and cultivated land in near future in the rural hill slope of the study area. Usually, groundwater recharge is due to increasing natural vegetation (Mohan, Western, Wei & Saft, 2018), but there has been a crucial issue of drying up of water sources due to climate change in Nepal (CBS, 2017; GoN, 2014). There was decreasing discharge of several spring water, many people shifted to outside due to lack of drinking water in the village. There is not visible impact of ground water recharge due to increasing greenery. Lack of drinking water resources in the village is not only because of the drying of water resources but also population growth in the past and increasing consumption of water resource in recent years. Drying up of water might be because of the past deforestation process in the study area. However, further scientific verification is required. Depopulation of farmers in the agriculture does not always results in land abandonment, while because of the decreased land value, it is

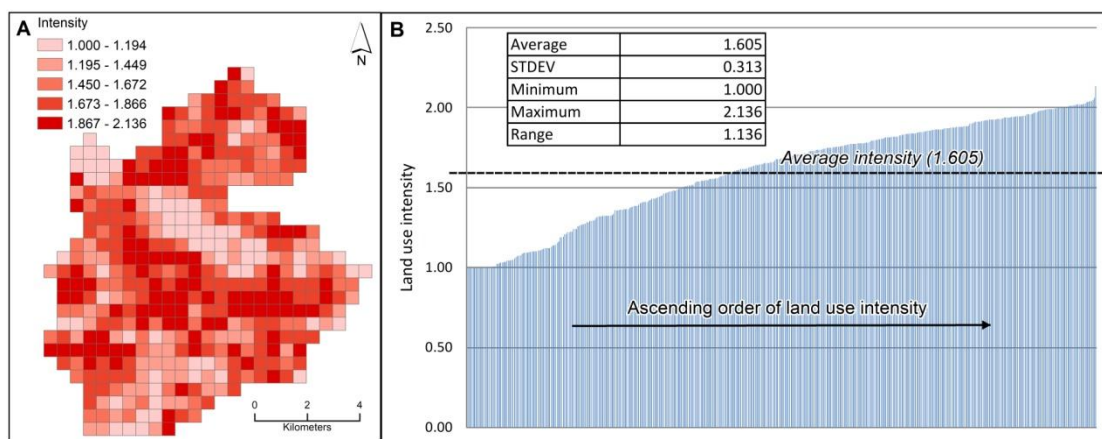
possible to make for land pooling of fragmented small pieces of land holding size for commercial purpose (Ellis, 2004; Izquierdo, Grau & Aide, 2011). Hill slope farmers manage their crops land by terracing, planting vegetation and canalling surface water to protect soil erosion and land degradation. However, down power of summer rainfall sometimes becomes out of control of farmers. For this region, hill farmers require support from outside, which will be very helpful for watershed ecosystem in the hill slopes of Nepal and the study area as well. In a watershed ecosystem, highland farmers are responsible for controlling land degradation due to protecting vegetation and proper land management, but they are rarely compensated by lowland people who are benefited due to the better ecosystem services (Bagura, 2012; FAO, 2011). This can be a suitable concept of watershed management in the mountainous country like Nepal and the study area as well.

## CHAPTER VI

### LAND USE INTENSITY AND CHANGE

#### 6.1 Land Use Intensity 1996

The distribution pattern of land use intensity seems more random pattern in 1996. However, most of the higher intensity area is at lowland, along with the highway and other roads. Some higher parts have also higher intensity of land use because of the existence of cultivated land and settlements at the hill slope and at the top of the hill (Figure 6.1A). The lowest intensity region is mostly dense forest area having steeper slope and rocky mountainous area where the human occupancy is the least possible.



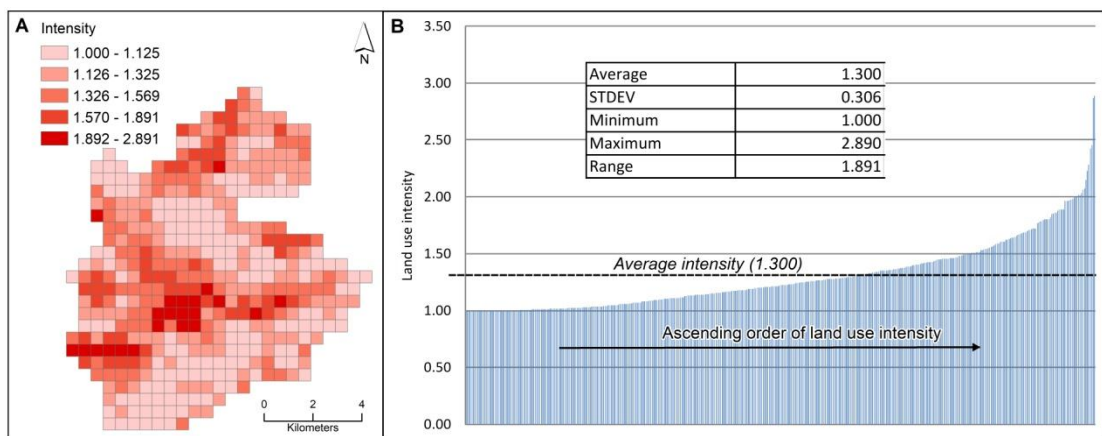
**Figure 6.1: Land Use Intensity (dimensionless unit), 1996**

The average land use intensity in the study area is 1.61 having standard deviation of 0.31. Eighteen observations consists of minimum value of land use intensity among total 426 units and maximum value 2.14 is of only one unit which is also visible in the diagram (Figure 6.1B). These values indicate that none of the observation grid has the highest value five of land use intensity that was defined in methodology which indicates complete built up area in a grid. The distribution pattern of intensity value seems smoothly distributed in both vertical and horizontal dimensions that can be observed in both figures (Figure 6.1A and B). However, the values of intensity of 182 observations are below the average while 244 observations consist of higher intensity than the average. It means, ratio of intensity below and above the average intensity is 43.57 percent. It is assumed that, if the values are normally distributed the values of land use intensity of 68.27 percent of the observations should be under the range of ( $\mu$

$\pm \sigma$ ) (Gupta, 2017). In this study, only 62 percent of the observations are in this range which proves the deviation of data, but not so worse than normal.

## 6.2 Land Use Intensity 2016

The distribution pattern of land use intensity in 2016 seems more clustered. Higher intensity areas are mostly in lowland and lower intensity areas are at hill slopes. Very few areas of higher slope have higher intensity along the major road access than most of the hill slope areas. Most of the hill slope areas have lower values of land use intensity (Figure 6.1A). This indicates that the clustering pattern of land use intensity.

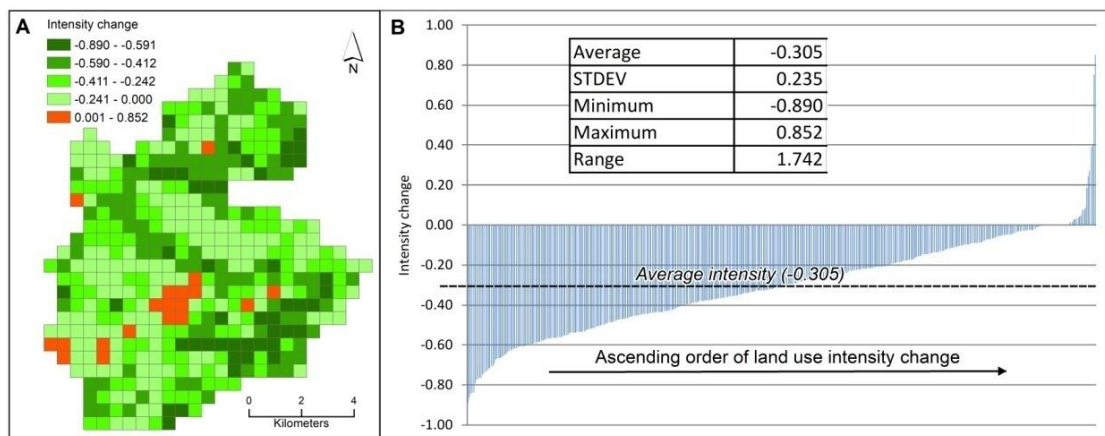


**Figure 6.2: Land Use Intensity (dimensionless unit) 2016**

The average land use intensity is 1.3, which is less than in 1996 and standard deviation is 0.306 which is higher than in 1996 (Figure 6.2B). Thirty four observations consist of minimum values of land use intensity "one" and very few areas consist of highest intensity values than others. The maximum value of 2016 was exceeded value than that of 1996. Range value 1.891 also indicates that there is higher fluctuation of distribution pattern of land use intensity between 1996 and 2016. Nearly two third parts (62%) of the total study area consists of the land use intensity below the average and remaining 38 percent of the areas consist more than the average intensity. It also proves that there is higher clustering of land use intensity. None of the observation has less than  $(\mu - \sigma)$  value and 85.45 percent observations have the intensity values under the range of  $(\mu \pm \sigma)$  and remaining less than 15 percent of total area has higher intensity. It also proves the higher clustering of intensity values. This indicates that there was higher change of land use intensity during 1996 to 2016.

### 6.3 Land Use Intensity Change

Most of the areas were negative change of land use intensity and only some areas were positive change (Figure 6.3A). The highest negative change is at remote and marginal area and positive change is mostly along with the highway and urban area which is the most accessible area than others. Expansion and origin of new urban area at low laying parts have resulted positive land use intensity change. Average land use intensity has been decreased during these 20 years of time period. The average value of land use intensity was 1.6 in 1996 and 1.3 in 2016 having average value of land use intensity change is - 0.305 (Figure 6.3B); and it is proved that the average values of land use intensity in 1996 and 2016 are significantly different at 5 percent significance level. It implies that the land use intensity has significantly changed during this period. Decreasing average land use intensity is due to the decreasing cultivated land in the large part of the study area. Positive change is in very limited area due to the urban expansion at limited part of lowland and accessible area. Therefore, the average land use intensity seems to be negative.



**Figure 6.3: Land Use Intensity and Its Changes (dimensionless unit)**

Only 20 observation grids were positive change of land use intensity and 15 observation grids were not any changes. Remaining grids were negative change. It means that large part of the study areas has decreasing land use intensity. Some of the highest positive changes have very high than that of other grids of positives changes. The range of  $\mu \pm \sigma$  includes 67 percent of the total area, which is nearly similar proportion of normal distribution, but the extreme values of the highest positive and the highest negative are more extreme than general pattern (Figure 6.3B).

#### **6.4 Land Use Intensity and Land Suitability**

Quality of land is characterized by a complex attribute, which acts in a distinct manner in its influence on the suitability for a specific use. Therefore, land quality is relevant to a certain type of use that influence either the level of input required and magnitude of benefit obtained (FAO, 1982). Land capability (KESL, 1986b) defined the potentiality of land for agriculture is lower at highland and the highest potentiality of low land areas in Nepal. Increasing land use intensity in the marginal land as compared to lower land capability in the past due to high population pressure has been decreased in recent decades. Decreasing land use intensity in the hill slope and increasing in lower part in the study area is similar results with many parts of highland areas of Europe and Asia (Rico, and Maseda, 2008; Zhang, Li, and Song, 2014). Land use intensity is correlated with land capability (Mecella, Francaviglia, Marchetti, and Riccioni, 2018) although land capability is defined on the basis of physical factors mainly for agriculture suitability (Grose 1999; KESL 1986b). Increasing general land use intensity in lowland area is not only because of the physical suitability of land, but also accessibility (Saghapour, Moridpour, and Thompson, 2017) to various services and facilities such as education, health, electricity, marketing and opportunities for commercial activities as well.

Highway along with the lowland area has promoted for the development of market center and availability of basic service facilities has accelerated the increasing urbanization and agriculture intensity resulting increasing general land use intensity. In general carrying capacity of land determines the land use intensity change which is mostly related to physical factors (Huimin, Fang, Jiyuan, Xiangming, and Yuanwei, 2017) in which anthropogenic factors are also indirectly related to physical factors that is why balancing cost and benefit system works in natural process. Land use intensity change is also dependent on the intensity of solar radiation because crop growth is highly dependent on it (Duriyaprapan and Britten 1982). The intensity of solar radiation is highly dependent on slope aspects in the hill slopes. The highest proportion of land abandonment was in the northern slope aspect and the least was in the south and southeast facing slope (Chidi 2017) in Andhikhola watershed in which present study area is also the small part of the watershed. It indicates that slope aspect is also one of the most important controlling factors of land use intensity of agrarian

economy, but this condition may not always applicable in this integrative land use intensity concept, which has been proven by some evidences in the study area. Some southern part of the Andhikhola watershed, there is increasing land use intensity at the hill top because of the urbanization, which is the least suitable on the basis of the classification for agriculture suitability. It is not because of the agriculture suitability, but because of the easy access to market, transport and other services (Chidi, 2016a). Thus, it can be concluded that land suitability for this integrative approach of land use intensity study is more complex than that of agriculture intensity.

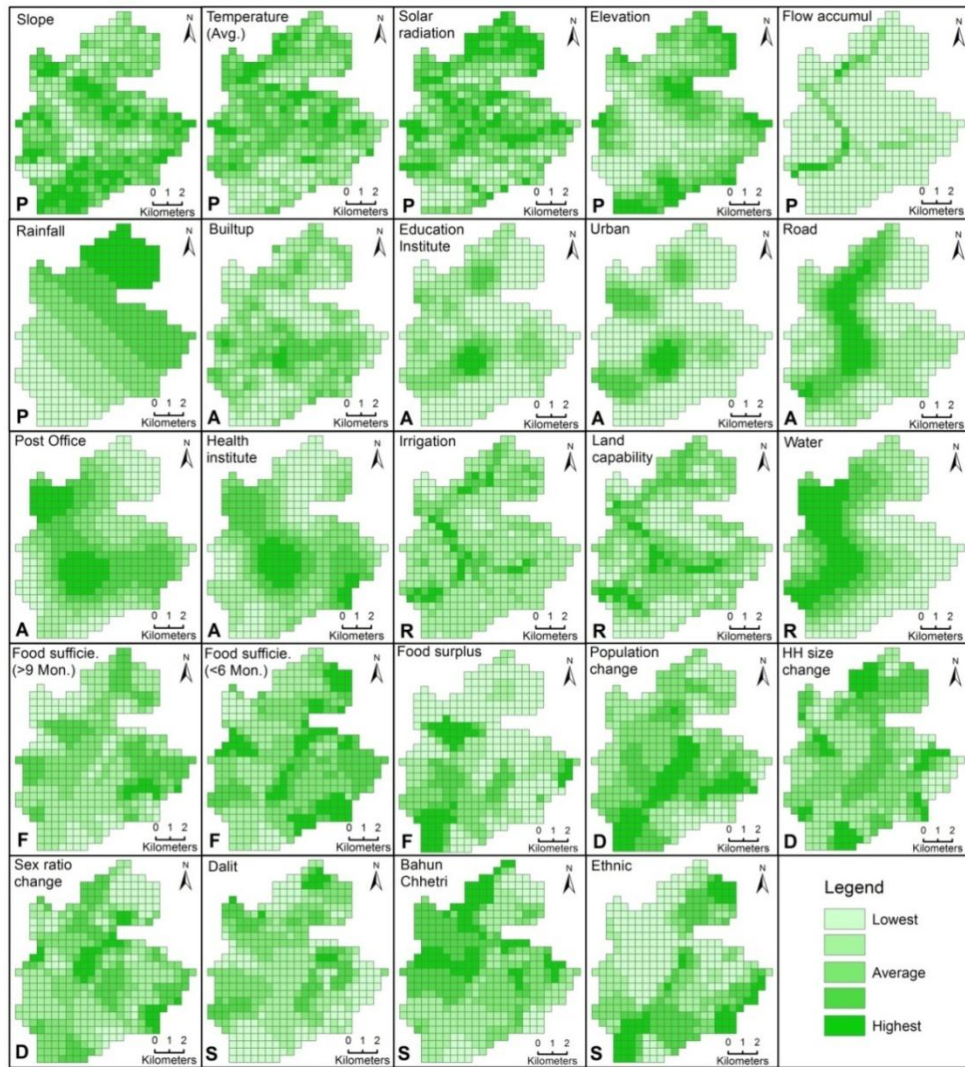
## CHAPTER VII

### DETERMINING FACTORS OF LAND USE INTENSITY CHANGE

#### 7.1 Explanatory Variables

The value distribution patterns of 24 explanatory variables have been presented in the Figure 7.1 in which most of the variables are spatially auto correlated. The distribution pattern of slope, average temperature, solar radiation and built up variables are the most randomly distributed over the entire study area. Pattern of values of demographic and food related variables are different than others. Distribution pattern of values of rainfall is quite different than other because of the distant location of meteorological stations, which was not able to capture micro level spatial variability. Concentration of single caste/ethnic groups in certain wards and region has created some unique distribution pattern of these variables.

Urban area has mixed caste/ethnic groups and rural area has a concentration of single or lower proportion of population of different caste/ethnic which has created patterns of uniqueness. The unique and more cluster pattern are due to the ward level generalization of food sufficiency, demographic and social group. Those patterns may not be suitable for the analysis of spatial relationship with land use intensity dynamics. Higher values of the flow accumulation are limited at a very limited part of the study area. Higher values of many variables are concentrated within limited part and larger areas have lower values. It is because most of the parts are steep hill sides and flow accumulates at lower limited areas. Road access and water resource are mostly at lower parts because highway has the highest weight than other road and most of the road crosses through lower parts of the study area. Water resource is river which is available for irrigation, flow at lower valleys. Highway is parallel with the main river. Therefore, the distribution pattern of water resource and road are similar. Most of the distribution pattern of the accessibility variables were concentrated at certain location whereas the distribution pattern of built up area is quite randomly distributed (Figure 7.1).



**Figure 7.1: Distribution Pattern of Values of Explanatory Variables**

## 7.2 Strengths of Explanatory Variables

Strength of the explanatory variables predicting land use intensity were identified deriving coefficient of determination of GWR model with land use intensity using bivariate analysis. The coefficient of determination ( $R^2$ ) gives the percentage variation in the dependent variable that is accounted for by the independent variable (Gupta, 2017; & Pal, 1982). In GWR model, local  $R^2$  is the coefficient of determination of each individual observed unit (square grid of this study) which represents the strength of explanatory variable in order to predict the land use intensity change during the entire study period of the study area. Local  $R^2$  was derived from the GWR model using different six grouping explanatory factors such as physical, accessibility, resource, demographic change, food sufficiency and caste/ethnicity. Finally, only selected variables were used so as to identify the maximum strength of the

explanatory variables. Coefficient of determination has been described to identify the strength of explanatory variables by individuals and group of variable.

### 7.2.1 Individual Variables

Bivariate results of WGR model of land use intensity with 24 individual variables have been given on the table 7.1. Among 24 GWR calculations of bivariate models, the distribution of standard residual of land use intensity change with flow accumulation seems clustered which means autocorrelation of the distribution of standard residuals. Other 23 models seem valid which standard residuals are out of autocorrelation, but they are not significant at 5%. Built up and slope gradient consists of highest strength of determining the land use intensity change followed by average temperature.

**Table 7.1: Bivariate GWR Result of Land Use Intensity of Explanatory Variables**

Factor	Variable	R <sup>2</sup>	Z score of Moran's I	P Value
Physical	Slope gradient (degree)	0.57	1.23	0.22
	Average temperature (LST)	0.54	1.65	0.10
	Solar radiation (watt/hour/sq. m.)	0.53	1.96	0.06
	Elevation (meter)	0.52	0.55	0.59
	Flow accumulation (10m pixel size DEM)	0.49	2.24	0.03
	Rainfall (mm)	0.46	1.63	0.10
Accessibility	Built up (kernel density)	0.57	0.21	0.83
	Educational institute (kernel density)	0.51	0.45	0.66
	Urban (kernel density)	0.50	0.49	0.63
	Road (kernel density)	0.49	0.90	0.37
	Post office (kernel density)	0.48	1.15	0.25
	Health institute (kernel density)	0.48	0.89	0.37
Resource	Irrigation (weighted)	0.53	0.72	0.47
	Land capability (weighted)	0.53	1.03	0.31
	Water sources (kernel density of river)	0.49	1.17	0.24
Caste/ethnicity	Dalit (proportion in wards)	0.51	1.20	0.23
	Bahun & Chhetri (proportion in wards)	0.50	1.13	0.26
	Janajati (proportion in wards)	0.50	1.65	0.10
Food sufficiency	More than 9 month (proportion in wards)	0.52	1.20	0.23
	Less than 6 month (proportion in wards)	0.50	1.51	0.13
	Food surplus (proportion in wards)	0.48	1.57	0.12
Demography	Population change (2001 to 2011 in wards)	0.51	1.01	0.32
	Household size change (2001 to 2011 in wards)	0.50	1.76	0.08
	Sex ratio change (2001 to 2011 in wards)	0.49	1.28	0.20

Source: Derived from GWR model of land use intensity dynamic (1996-2016)

Irrigation and land capability were equal strength having lower strength than average temperature. Rainfall was the lowest strength followed by post office, health institute and food surplus. Range of the lowest and the highest values of  $R^2$  were from 0.46 to 0.57 with difference value of 0.11. Coefficient of determination ( $R^2$ ) of climate variable was followed by food surplus, post office, health institute, water resource and road. It was higher concentration of higher and lower intensity values at limited locations with clustered pattern. Urban, household size change, food surplus for less than 6 month, Bahun/Chhetri and Janajati were average value of  $R^2$  among 24 variables. The distribution patterns of values of the variables were not highly clustered and nor randomly distributed. Model result of all factors on the prediction individual observation was reliable on the basis of condition number in GWR model.

### 7.2.2 Different Factors

Food sufficiency and demographic change have the least strength of prediction. Factor of caste/ethnicity has higher value of coefficient of determination than demographic and food sufficiency factors. Distributions of standard residuals of all grouping variables are out of autocorrelation. However, only physical and accessibility factors have reliable answer at 5% significance level (Table 7.2).

**Table 7.2: WGR Results of Different Factors**

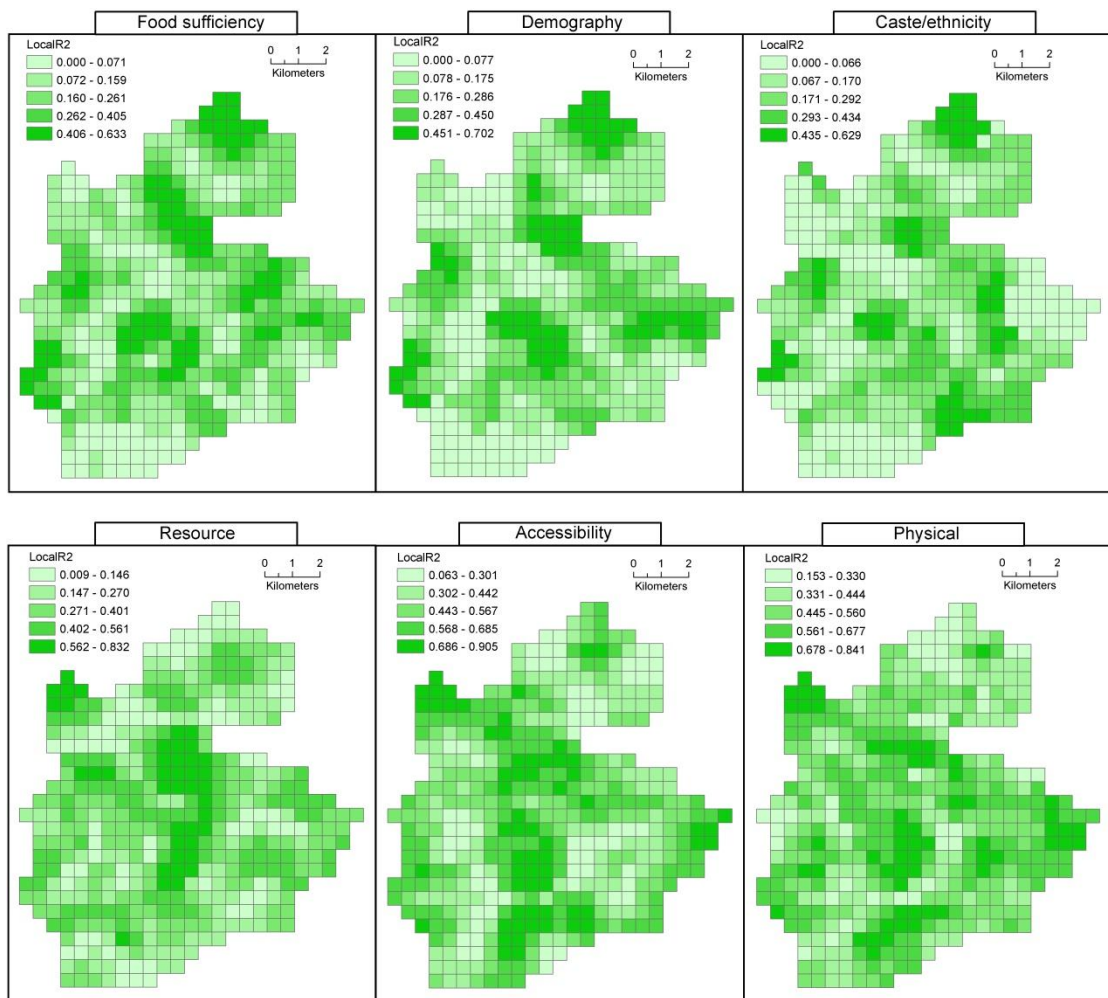
Factor	$R^2$	Adjusted $R^2$	Moran's I	Z score	P value	Prediction reliability of observations (%)
Physical	0.78	0.56	-0.06	-2.12	0.03	61.3
Accessibility	0.73	0.56	-0.15	-5.67	0.00	23.5
Resource	0.65	0.49	-0.02	-0.78	0.43	85.9
Caste/ethnicity	0.64	0.53	0.00	0.11	0.91	27.4
Demography	0.59	0.45	0.01	0.30	0.76	85.9
Food sufficiency	0.59	0.45	0.02	0.96	0.34	63.5

Source: Derived from GWR model of land use intensity dynamic (1996-2016)

Coefficients of determination of grouping variables into different factors were highly improved the strength of the variable predicting land use intensity change than in the calculation of bivariate model. The maximum coefficient of determination was 78 percent of physical factor whereas only 57 percent of each slope and built up in bivariate GWR model. Minimum value of coefficient of determination was also

increased from 46 percent to 59 percent from bivariate to multivariate grouping variables because of the increasing strength of combined variable as compared to individual variable.

Condition number evaluates local collinearity. In the presence of strong local collinearity, results become unstable. Results associated with condition numbers are larger than 30 which may be unreliable. The percentage of observation with condition number less than 30 out of total observation shows that resource and demography has the highest and accessibility has the least. The distribution pattern of local  $R^2$  of caste/ethnicity, demographic and food sufficiency are slightly different than other three factors. Figure 7.2 shows that there were more areas with minimum strength of prediction of three out of these factors. These factors were the least strength of prediction at southern part of the study area. Prediction strength seems more clustered at limited area. Distribution of standard residual seems random, but it is not confident that they are in actually or not.



**Figure 7.2: Local  $R^2$  Values of Different Factors**

Factors of resource, accessibility and physical variables have higher strength than other three factors. Among them, physical has the highest strength. The maximum local strength is highest in accessibility factor. Distribution pattern of local coefficient of determination of resource seems little bit similar with physical and accessibility factors, but not quite same and more clustered pattern of local coefficient of determination. Although the distribution pattern of standard residual seems random, it is not confirmed to say it is actually random or not.

Local coefficient of determination values of food sufficiency, demography and caste/ethnicity factors are more clustered than remaining three factors. It indicates that the lower strength of these factors were responsible on determining land use intensity change.

**Table 7.3: Local R<sup>2</sup> Values of Different Factors**

Factor	Average	Standard deviation	Maximum	Minimum	Range
Physical	0.52	0.14	0.84	0.15	0.69
Accessibility	0.50	0.17	0.90	0.06	0.84
Resource	0.33	0.17	0.83	0.01	0.82
Demography	0.22	0.18	0.70	0.00	0.70
Food sufficiency	0.22	0.16	0.63	0.00	0.63
Caste/ethnicity	0.19	0.17	0.63	0.00	0.63

Source: Derived from GWR model of land use intensity dynamic (1996-2016)

Average value of local R<sup>2</sup> is also the highest of physical factor followed by accessibility and resource which is similar to R<sup>2</sup> value. Caste/ethnicity has the lowest average value of local R<sup>2</sup> which is different than R<sup>2</sup> value. Standard deviation is the lowest of physical and the highest of demography. The highest range of local R<sup>2</sup> is in accessibility and the lowest is in food sufficiency (Table 7.3). Standard deviation, maximum, minimum and range of the local R<sup>2</sup> are not correlated with the average value of local R<sup>2</sup> as well. R<sup>2</sup> and local R<sup>2</sup> have similarities to some extent, but not exact same. It means the internal variability of the strength is higher than average strength. The factor of the highest strength has the lowest variability in local strength than the factors which have lower strength.

### 7.2.3 Selected Variables

Ten variables were selected through frequent test of different combinations of exploratory variables to maximize the strength of explanatory variables for GWR analysis from the total 24 explanatory variables. Finally, selected variables were slope, built-up, average temperature, solar radiation, irrigation, land capability, elevation, education institute, population change and urban density. The coefficient of determination ( $R^2$ ) is 0.87 which indicates that 87 percent of land use intensity dynamism is determined by 10 explanatory variables. Prediction result may be unreliable if the condition number is more than 30 in each observation. More than 46 percent of total observations value of condition number is more than 30, which indicate to be careful about local prediction. To remove unreliability of prediction, only six explanatory variables were selected from ten variables. Those variables are slope gradient, built up, average temperature, solar radiation, irrigation facility and land capability removing elevation, education institute, population change and urban density. The condition number derived in this model was less than 30 in each observation, which indicates the complete reliability of predicted values. Coefficient of determination of these six explanatory variables is more than 0.80, which means more than 80 percent of total land use intensity dynamism is determined by these six explanatory variables.

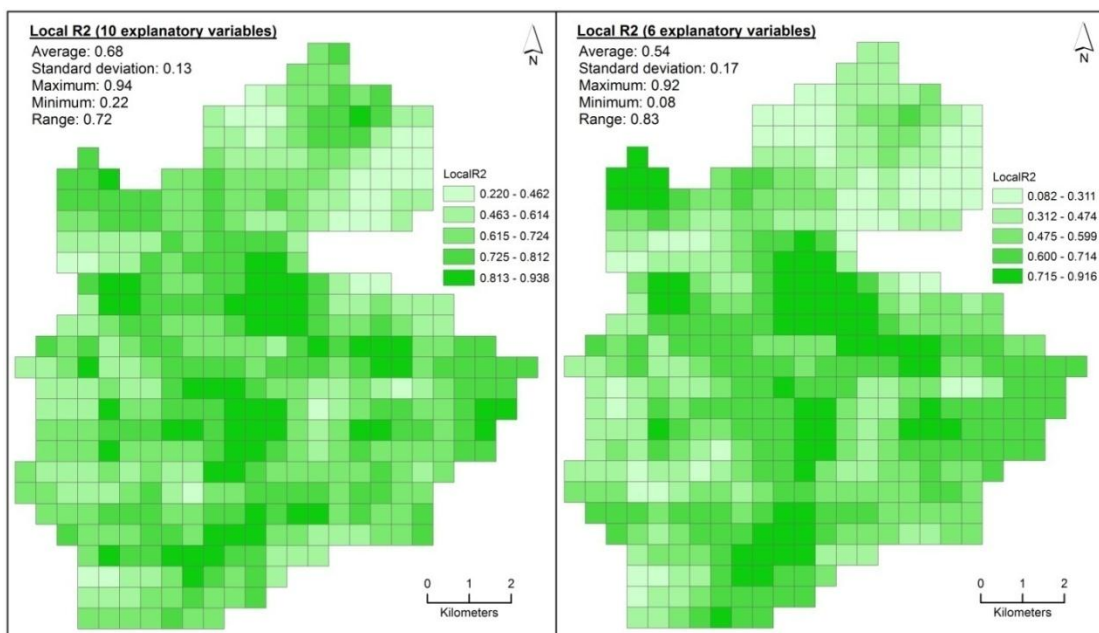


Figure 7.3: Distribution Pattern of Local  $R^2$  of Selected Variables

The average value of local  $R^2$  of 10 explanatory variables is also higher than 6 explanatory variables, but standard deviation and range of local  $R^2$  of 6 explanatory variables is higher than that of 10 explanatory variables (Figure 7.3). It is because of the higher strength prediction of 10 variables than 6 variables, but the prediction reliability may be very low of 10 explanatory variables. The distribution pattern of local coefficient of variation of 10 variables looks more random than 6 variables.

### 7.3 Prediction of Explanatory Variables

Prediction strength of land use intensity dynamism has been increased by selected 10 variables and six variables. The predicted values of land use intensity dynamism have been described into the followings subheadings:

#### 7.3.1 Different Factors

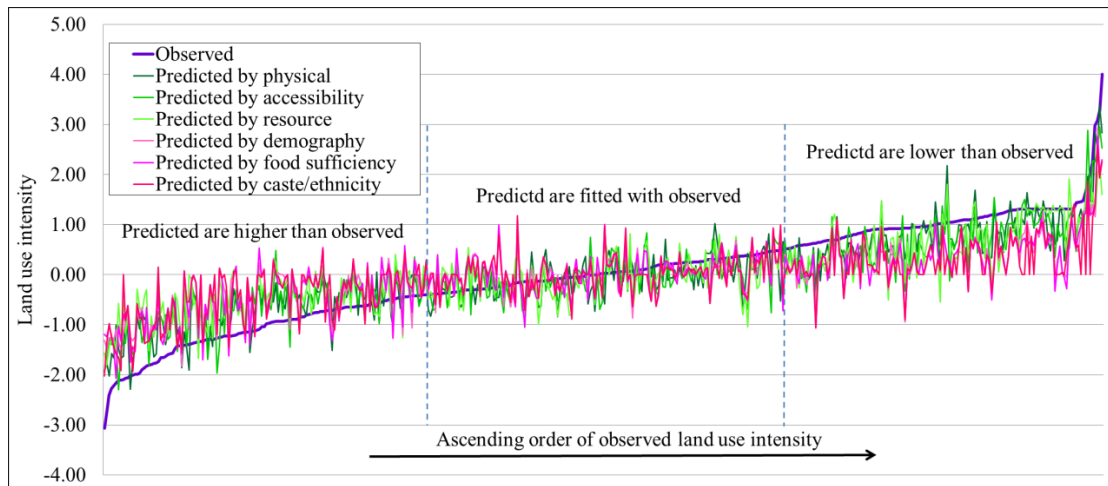
The observed values and estimated values using six grouping variables are given in the table 7.4. In comparison to observed values, the average estimated values of physical and accessibility factors are not so far different. Both of these factors have nearer estimated values of standard deviation, maximum, minimum and range with observed values. Caste/ethnicity factor has the biggest difference of the average value comparing to observed values. It has the highest difference of standard deviation also. From these values, physical factor has more accurate estimation followed by accessibility factor and caste/ethnicity has the lowest accuracy of estimation.

**Table 7.4: Observed and Predicted Values of Land Use Intensity by Factors**

Factor	Average	Standard deviation	Maximum	Minimum	Range
Observed	0.00	1.00	4.00	-3.07	7.07
Predicted by Physical	0.01	0.80	3.39	-2.29	5.68
Predicted by Accessibility	-0.01	0.78	2.95	-2.29	5.25
Predicted by Resource	0.03	0.70	2.20	-1.81	4.01
Predicted by Demography	0.02	0.62	2.92	-1.82	4.74
Predicted by Food sufficiency	-0.03	0.63	2.77	-2.07	4.84
Predicted by Caste/ethnicity	-0.04	0.59	2.57	-2.02	4.60

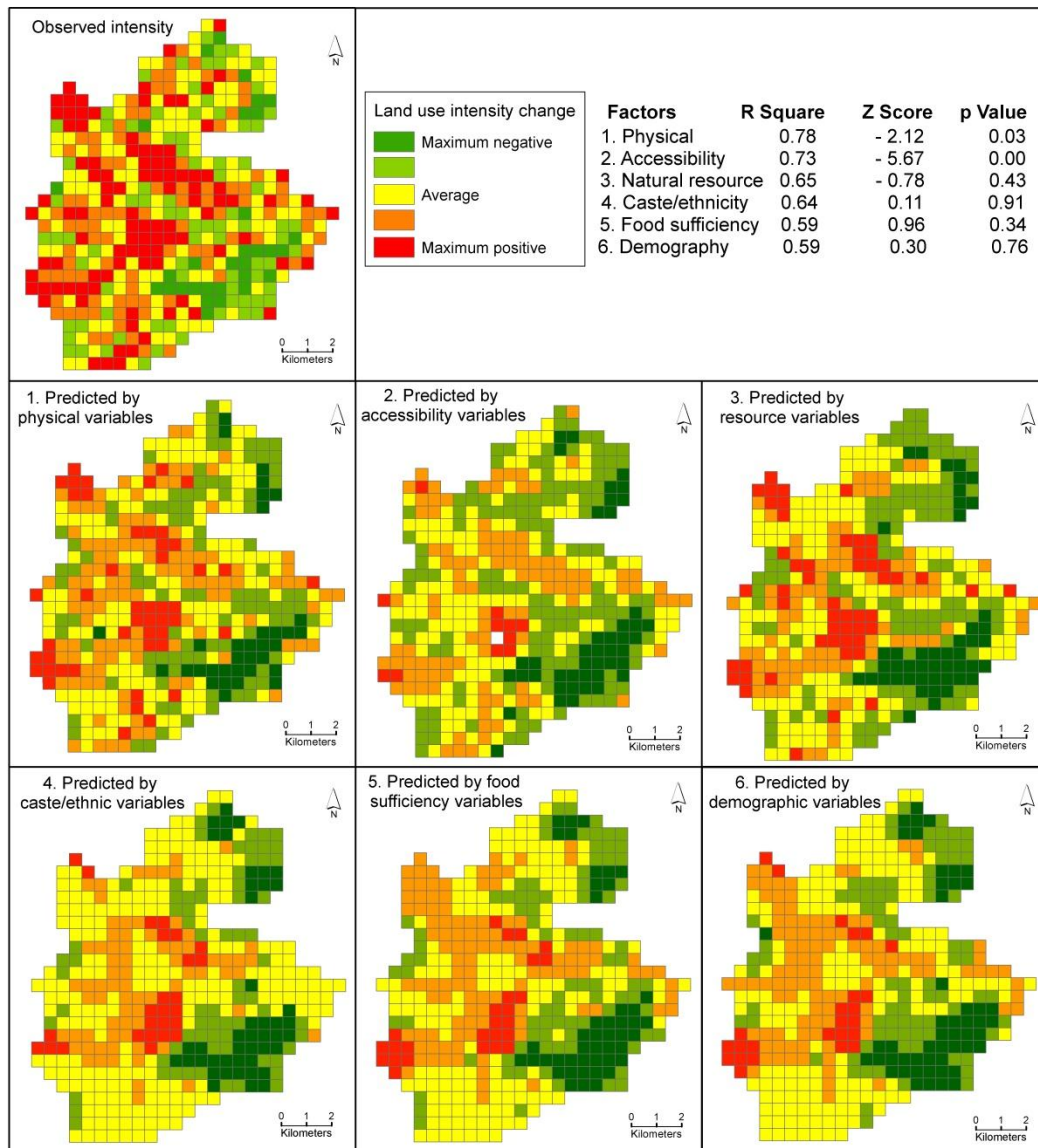
Source: Derived from GWR model of land use intensity dynamic (1996-2016)

Figure 7.4 shows that the line of physical factor (dark green) has the most accurate estimation followed by accessibility (light green). Inversely, caste/ethnicity (dark red) is the farthest from observed value which is followed by food sufficiency and resources. Estimated values of demography are in between the farthest and nearest estimated values.



**Figure 7.4: Observed and Predicted Change of Land Use Intensity by Six Factors**

Although the fluctuation of the predicted value is highly unstable, the general trend of predicted by six different factors are clearly visible in Figure 7.4. The distribution pattern of estimated value by food sufficiency, demography and caste/ethnicity factors are quite different than observed values. There are higher predicted values where the observed value is less than average and less predicted values where the observed value is higher than average. Physical factors are more accurately predicted even in the area of extreme high observed values. The similarity of predicted values with observed values are related with the strength of prediction of explanatory variables. Higher the value of coefficient of determination, higher the similarity of estimated values with observed value (Figure 7.4 & Table 7.4). Higher prediction strength of the variable has the better prediction accuracy from which more similar estimated and observed values have been derived. Local coefficient of determination and coefficient of determination have given some different results. However, general trend of local coefficient of determination, coefficient of determination and local predicted values became similar in GWR model.



**Figure 7.5: Distribution of Observed and Predicted Change of Land Use Intensity by Different Factors**

Figure 7.5 deals with the distribution pattern of predicted values of different factors. Predicted values of food sufficiency, demography and caste/ethnicity factors seem quite different than observed pattern. They are more clustered pattern rather than dispersion of the values of higher and lower predicted values, which is clearly visible on observed value. Distribution pattern of predicted values of physical, accessibility and resource factors are more similar with the distribution pattern of observed values. However, they are also not quite same. The best distribution comparing with observed value is of physical factor which is already indicated in coefficient of determination, average value of coefficient of determination and spatial trend of predicted value. Therefore, physical factors have the greatest strength among six factors which has more accurately predicted the land use intensity change in multivariate GWR model.

The multivariate GWR model has proven that scale of the data base is the most important for factors for analysis. Physical variables such as slope, elevation, land surface temperature, solar radiation were taken from minimum 30 meter spatial resolution image, which was higher strength of prediction. Human factors such as food sufficiency, demographic and social factors were weaker strength because of the ward level generalization of data which was unable to capture the local variability. Inversely, built-up variable has the highest strength of prediction because this data was developed on the basis of exact location of built up points. Therefore, scale of the data source is the most important things in spatial analysis.

### 7.3.2 Selected Variables

Figure 7.6 represents the spatial trend of observed and predicted values of land use intensity change. The predicted value of six explanatory variables (red line) is highly fluctuating than that of the predicted values of 10 explanatory variables (green line). It is also proved by residuals (Table 7.6) of observed and predicted values in which both total and average residual of 10 variables are lower than that of 6 variables.

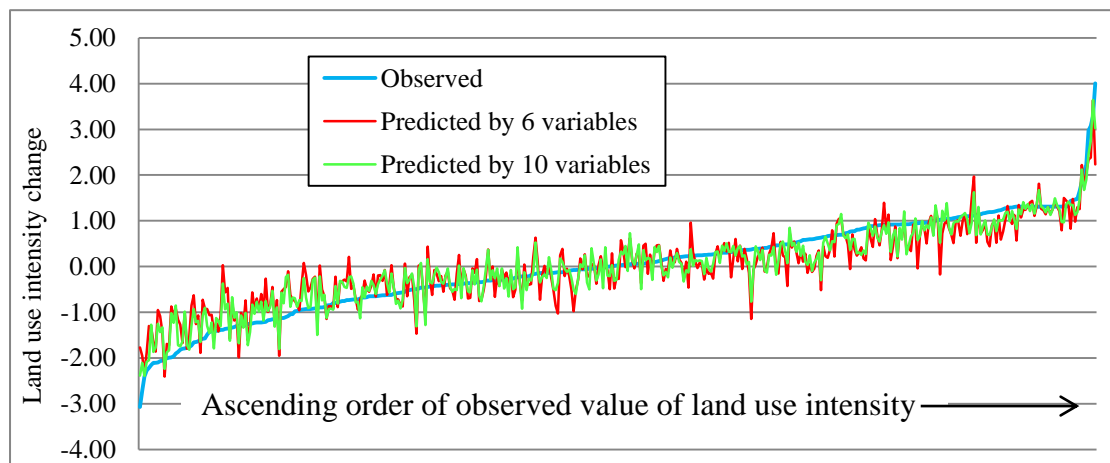
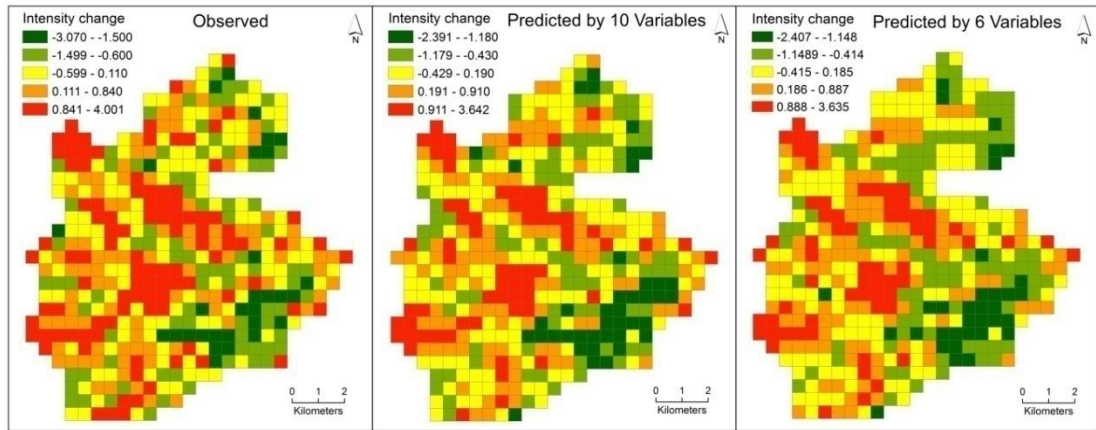


Figure 7.6: Observed and Predicted Change of Land Use Intensity

The general trend shows that the predicted values of ten explanatory variables are closer with observed values than the predicted values of explanatory six variables. Therefore, the predicted values of 10 variables are more accurate than predicted by six variables, although, the condition number shows more unreliability of prediction of 10 variables than predicted by six variables.



**Figure 7.7: Observed and Predicted Values of Land Use Intensity Change**

The distribution pattern of observed and predicted values of land use intensity change show that distribution pattern of predicted values by 10 explanatory variables seems more similar with the distribution pattern of observed values than distribution of predicted values of six explanatory variables (Figure 7.7).

It is already defined that the coefficient of determination ( $R^2$ ) defined by ten explanatory variables is higher (0.87) than that of six explanatory variables (0.80), but adjusted  $R^2$  value of six variables has exceeded to adjusted  $R^2$  value of 10 variables.

**Table 7.5: GWR and Moran's I Values of Selected Variables with Observed Values**

Theme	Observed	Predicted by 10 variables	Predicted by 6 variables
$R^2$	-	0.87	0.80
Adjusted $R^2$	-	0.56	0.57
Z-score (Moran's I)	-	-4.33	-2.20
P value (Moran's I)	-	0.00	0.03
Average (local $R^2$ )	0.00	0.00	0.00
Standard deviation (local $R^2$ )	1.00	0.88	0.84
Maximum (local $R^2$ )	4.00	3.64	3.64
Minimum (local $R^2$ )	-3.07	-2.39	-2.41
Range (local $R^2$ )	7.07	6.03	6.04
Total Residual	-	115	147
Average Residual	-	0.27	0.69

Source: Derived from GWR model of land use intensity dynamic (1996-2016)

However, in GWR model, adjusted  $R^2$  is not usable as in OLS for model validity. Residual values help to check the strength of the variable and model validity as well. Randomness calculation (Moran's I) result represents more random pattern of residuals of six variables than ten variables, although both of them are dispersed. Condition number has decreased the reliability of prediction by 10 explanatory variables because nearly half of the observations have the condition number more than 30. The average values of observed and predicted are the same and standard deviation of predicted values by 10 variables is nearer to observed than that of six variables. Maximum, minimum and range are also similar in both predicted values which are greater than observed value (Table 7.5).

The distribution pattern and spatial scale of the explanatory variables have higher role on prediction strength of land use intensity change and prediction accuracy. Most of those variables derived from natural factors have higher strength of predicting capacity, but rainfall and flow accumulation variables became very weak strength. Highly disperse meteorological stations for rainfall data seems incompatible spatial scale for this study. Resource variables were generated from natural resources like river and land suitability. Built up variable was derived from large scale individual built up point which has also the higher strength of prediction. Previous study has proved that population change has higher relationship with landscape change in watershed level analysis, but it became weaker in this study because of the incompatible spatial scale of data source. Distribution pattern of the values of individual explanatory variables indicates the expected strength of explanatory variable. The similarity of distribution pattern of observed value and explanatory variables indicates the strength of explanatory variable. If distribution patterns are similar, the higher strength of prediction can be expected. Physical factor variables have the highest strength and human has the lowest. Ten variables gave the highest strength than any other combinations of explanatory variables but condition number of several observations indicated suspicious on predicted values. Therefore, only six variables were selected out of ten. These six variables have weaker strength of prediction than of 10 variables but it gave full reliability on the basis of condition number. The value of adjusted  $R^2$  is also higher of six variables as compared to ten variables. However, predicted values of 10 variables are closer to observed value and the residual value of 10 variables is lower than that of 6 variables (Table 7.5). The

model validity of GWR model depends on residual values rather than adjusted  $R^2$  (Formingham, Charlton and Brunsdon 2002). Total and average values of residuals of ten variables are quite lower as compared to six variables. Thus, it is concluded that selected ten explanatory variables are the best for predicting land use intensity dynamics in the study area.

#### **7.4 Implication to Land Use Intensity Change**

This study result reveals discussion on many aspects related to land use intensity, relation between land use intensity and its suitability, driving factors of land use/land cover and its intensity change, nature of integrated agriculture system, implication of intensity change and evaluation of study method. These aspects have been described in detail below.

##### **7.4.1 Land Use Intensity**

This research used unified approach to understand the integrated traditional subsistence farming system in the hills of Nepal. Land use/land cover category is closely related to each others. The change in one category deliberately affects another category including whole farming system as well. Therefore, individual land use/land cover category analysis is very difficult to understand the whole landscape pattern change in general. In recent years, land use intensity analysis is emerging approach in various fields (Yan, Liu, Liu, Xiao & Qin, 2017; Chaudhary & Brook, 2018). The intensity of land use differs with different parts of the world even within a country or a region because of the different characteristics of land resource system and economic activities. It is the most difficult task to standardize common weighting of land use intensity even adopting the same land use/land cover category. Land-based production system encompasses all activities that convert some combination of input into outputs dependent on properties of the system (Kuemmerle, Erb, Meyfroidt, Muller, Verbung & Estel, 2013) in which land-based production system embedded within a territory should be at the center of the research (Erb, Haberl, Jepsen, Kuemmerle, Lindner & Muller, 2013). Weighting of land use/land cover category of this study differs than used in Yellow river basin in China and other parts of the world (Aldwaik & Pontius, 2012; Wang, Liu & Ma, 2010) because of the unique land-based production system. This study adopted its own weighting system of land use/land cover categories on the

basis of local traditional agriculture system of Nepal and local situation of the study area. The result reveals that this method is suitable for the traditional agriculture areas in the hills of Nepal and other similar areas as well.

#### **7.4.2 Drivers of Intensity Change**

Over the decades, poverty in rural area of Nepal is quite higher despite the decline of national poverty level in Nepal and average monthly income of rural area is lower than urban people. Therefore, peoples are less interested in agriculture sector because it is less attractive in terms of cash income. Agriculture sector is deteriorating day by day because national policies of Nepal could not attract new generation toward agriculture sector. Agriculture sector reminds stagnant because plans and policies have failed to address agriculture problems and issues in Nepal (Chaudhary & Brook, 2018). Watershed level analysis on the basis of ward level observation unit shows that there is high correlation between population change and agriculture land abandonment (Chidi, 2016a; Chidi, 2016b) which indicates that major driver of land use intensity change is the population change in the study area. The lower prediction strength of population change on land use intensity change in the study result is due to the incompatible spatial scale. The higher strength of built up predicting land use intensity also proves compatible spatial scale is the first requirement in spatial statistical analysis. Lack of agriculture labor in recent decades is not only because of decreasing number of farmers, but also increasing enrolment in education of 10-25 years age population, some of which were agriculture labor in the past. Additionally, the decreasing proportion of agriculture occupation has sharply declined in the mountain and hills of Nepal during the census 2001 to 2011 (Suwal & Dahal, 2014). Decreasing land use intensity in mountain areas of China is because of the policy intervention (Li, Li, Sun, Cao, Fischer & Tramberend, 2018), but this situation never happened so far in Nepal because the implication aspect of land use policy became always weak (Basnet 2016). However, labor migration policy of Nepal become highly effective due to the low carrying capacity of sloppy marginal land for cultivation. Therefore, past land use intensity decreased from the marginal hill slopes. Higher strength of physical determining factors is the result of the decreasing intensity at marginal land at first rather than suitable area. Flow of rural farmers to urban and the

Hill to the Tarai migration have further accelerated decreasing land use intensity in the marginal hill slopes.

#### **7.4.3 Nature of Integrated Agriculture System**

Traditional subsistence agriculture system is integrated systems interrelating with cultivated land, livestock and other natural resources (Weceke & Kimenju, 2007). Decreasing number of farmers has multiple effects on total farming system that's why general land use intensity in the hill slope is decreasing. Decreasing number of farmers' resulted lack of labor force in agriculture with decreasing livestock numbers in the household. Finally, it has resulted agriculture land abandonment and decreasing demand of forest product and grazing land. One the one hand, the process of agriculture land abandonment decreased the human occupancy on abandoned agriculture land and, on the other hand, decreasing demand of forest product reduced the human intervention on vegetated area (forest, shrubs and grass). In many parts of the study area, decreasing demand of public forest product also helped successful implementation of community forest. Built up area has increased along the lower plain area, which is the most accessible and suitable for human occupancy. Therefore, land use intensity is increasing in lower plain area. Successful implementation of community forestry has also contributed to the increment of forest area in the hills of Nepal (Gurung, Karki & Bista, 2011) and similar situation was found in the study area. It is due to decreasing demand of forest product due to decreasing human and livestock population. In recent years, greenery is increasing not only in the community forest, but also on private land and abandoned cultivated land in the study area.

#### **7.4.4 Consequences of Intensity Change**

Groundwater recharge is usually because of increasing natural vegetation (Mohan, Western, Wei & Saft, 2018), but in the study area, there is a crucial issue of drying up of water sources due to climate change (CBS, 2017; GoN, 2014). Villagers from the hill slopes were shifted to plain area due to the scarcity of drinking water in the past. It was also because of the increasing human population pressure on limited water resources. There is not visible impact of ground water recharge in the study area at present, but local people have experienced of decreasing natural spring water in

several parts of the study area. However, further scientific verification is required why such natural spring resources being limited. Decreasing human occupancy in the hill slopes has increased intra species competition (Mackenzie, Ball & Virdee, 2002) with wildlife which resulted difficulties to protect their crops from wildlife damage in remote and marginal parts in the study area. Similar results were also found in many abandoned cultivated lands in the world (Hua, Yan, Li, He & Li, 2016; Benayas, Martins, Nicolau & Schulz, 2007). It is an indication for further pressure of wildlife to decrease human occupancy in the marginal parts of the hill slope areas. Furthermore, higher proportion of decreasing land use intensity has the implication on food security, livelihood and environmental sustainability.

## CHAPTER VIII

### SUMMARY, CONCLUSION AND RESEARCH ISSUES

#### 8.1 Summary

Recent advancement of information technology has accelerated the application of new technologies in land use/land cover change study. Most land use/land cover analysis is concerned only one or few themes in which integrated system to understand complex land system is lacking. Quantifying based on the intensity of production system of land is being major concern in recent years. This holistic approach helps to understand the complexity on men land relationship to a spatial extent. Therefore, land use/land cover science has so far mainly focused on broad land cover conversion rather individual land character. Land use intensity should follow an integrative conceptual framework focusing on input to the land, output from the land and human induced, but unintended outcomes of land use intensification. Therefore, this research aims to assess the land use/land cover and its intensity change with its major determining factors.

This study was conducted in the northeastern part of Andhikhola watershed of Syangja district of middle hill region of Nepal. Being in the hill slope area, complex topographical situation with complex climatic situation even in a short span of spatial distance is the major characteristic of this study. Higher rainfall situation than national average rate with dominant subtropical to warm temperate climatic region are the crucial features the study area. Traditional intensive subsistence farming is dominant economic activities of their baseline livelihood including some other nonfarming activities. Small farm size and high population pressure on steep hill slopes were the major problems of decreasing soil productivity and land degradation. In the hill areas, outmigration of rural farmer due to the increasing opportunity to foreign country and further acceleration of outmigration to urban and Tarai region released the population pressure on hill slope agriculture land in recent decades. Outflow of rural farmers from the hills slope has resulted in the shortage of labor force in the farmland influencing whole farming practices. As a result, large amount of cultivated land has been abandoned and resulted into forest, shrubs and grassland due to the increment on labor shortage in the village which is going to be increased in the near future. Forest,

shrubs and grassland are beneficial in order to increment on environmental aspect as it was degraded in the past. Remittance from out migrated people has helped for urbanization and further increment on internal migration from rural to urban and the Hill to the Tarai. The impact of the population mobility on landscape change is clearly visible. High land and remote areas are being converted from cultivated land into wilderness greenery and inversely lowland and more accessible areas are converted into built up, commercial agriculture and other off farm activities. Although, the recent land use/land cover change is highly depend on population change. The local variability of change has been controlled by many other physical and socioeconomic factors.

Most of the geographical data are spatially clustered which violates the assumption of parametric statistical analysis. Geographical data are more related with nearer than farther things which cannot be defined by general stationary methods. Semi-parametric GWR model is very suitable for calculating the geographical relational data base. However, till date the study on land use intensity dynamic based on spatial statistical analysis of complex topographical hill region of Nepal is still lacking. Therefore, this study is concerned with assessing land use/land cover dynamics and prediction of land use intensity dynamics. This research finding is very good information and helpful for the further research and policy maker for landscape management as well. Still having some data limitations, researcher has conducted this study using maximum variables in order to maximize the prediction capacity of explanatory variables.

This study is mostly based on secondary data sources such as aerial photo, remote sensing image, maps, population census data, districts profile of different line agencies in the district. Field observation, ground reality of remote sensing image and reality check approach were the major methods deployed in order to update and verification of data. Additionally, informal discussions with local people were conducted and field notes were also prepared. Remote sensing image was classified in Erdas Imagine, eCognition and other vector and raster based processing were done in ArcGIS. SPSS and Microsoft Office Excel were used for data processing generated from image, vector data and other attribute data. OLS were calculated in SPSS in order to identify the nature of relationship of variables and validity for their further

modeling. Total 30 explanatory variables were generated for detail analysis of land use intensity dynamics. Among them, only 24 variables were used in final GWR model because of the auto-collinearity or multi-collinearity among some variables and contrasting among variables. Strength of individual 24 explanatory variables was calculated in GWR model so as to estimate the land use intensity change. Land use intensity was estimated using six different factors (grouping explanatory variables) on the basis of nature of databases. Finally, only 10 and 6 explanatory variables were used in order to maximize the strength of prediction of land use intensity dynamics.

Based on the study, the following summary of the findings have been drawn from derived results concerning on land use/land cover change, land use intensity change and determining factors of land use intensity change.

- More than half of the cultivated land during 1996 to 2016 has been converted into other land use/land cover categories, mostly into shrubs and forest. Increment of shrubs is more than 3.5 times during this period. Built up area has increased due to the urbanization and highland to lowland migration of the people in the entire study area.
- Most of the parts in the study areas have negative change of land use intensity. Very few areas have positive change where the urbanization process is going on along with the highway and major roads. Decreasing land use intensity seems to have confirmed to the decreasing population density in the study area.
- Suitable land for agriculture has been the major controlling factors of land use intensity change. Higher values of negative change area are mostly marginal land for cultivation, which is less suitable for agriculture. Land use intensity is integrative concept not only for agriculture suitability, but also the major controlling factors of land use intensity in the study area. It is because of the agriculture suitability and accessibility in the same area. However, some parts have higher intensity, which is less suitable for agriculture, but those areas were more accessible than other hilly areas.
- Physical variable such as slope gradient, land surface temperature, solar radiation and elevation seems stronger to predict land use intensity change pattern than human factor. However, built up has also equal strength like slope

gradient. Accessibility variables are in second position followed by resources such as land capability, irrigation and water resource.

## **8.2 Conclusions**

High population pressure on hill agriculture was the major factor for foreign labor migration during last two decades resulting in the abandonment of agriculture land. Urbanization and increasing commercial activities in low land and accessible areas has further accelerated this situation. This study has revealed that population mobility is serious issue for land use/land cover change. Remote sensing and GIS seem inevitable tool for data extraction, processing and analysis in this study.. GWR model is very valuable in order to predict of land use intensity dynamics than general linear model. GWR model is fruitful in order to find out variability of local relationship among response and explanatory variables.

Previous watershed level analysis has proven that population reduction is the major driver of conversion of cultivated land into vegetated due to the abandonment of agriculture converting into forest, shrubs and grassland. However, spatial variation of them is highly controlled by elevation, slope gradient and slope aspects. The higher proportion of cultivated land conversion into vegetated area in the study area has given similar result with watershed level analysis because cultivated land conversion is increasing toward north.

Average land use intensity change in the northeast part of the watershed has negative because of the large part of the cultivated area has been converted into vegetated area mostly to shrub and forest. Positive intensity change is in limited parts of urbanized area along the highway. There is the relationship between agriculture suitability of land and land use intensity, although land use intensity is not only for agriculture. It is because of the similar situation of agriculture suitability and accessibility. Thus, it may not be the same result in other parts in the world. Physical factors are more effective in order to predict the land use/land cover intensity dynamics than human factors. However, built up density has also the highest strength of explaining land use intensity dynamism. Multivariate GWR model of ten explanatory variables have the highest strength and reliable prediction of land use intensity dynamics in which built up density and slope gradient has the highest strength. Watershed level land

conversion analysis has proved that the population change is the vital driver of land use dynamics. However, physical suitability, resource availability and accessibility have dominant role on spatial variability of land use intensity dynamism. GWR model has also given the highest strength of built up density explaining land use intensity dynamics. Weaker strength of human factors is also because of the incompatible spatial scale of available data. Therefore, data scale should be carefully applied in such a large scale data analysis. Land use intensity method keeps very valuable concept in order to understand complex land use/land cover change and landscape ecological system as well in which GWR model is very useful tool for quantitative spatial modeling than any other general linear models. This spatial statistical tool is very useful in geographical data analysis where most of the data violate the assumption of parametric statistical analysis.

### **8.3 Research Issues**

During this study, it is revealed that there are several implications related to this study which are not possible to incorporate in this study are further research issues in the future.

- Food security is another greater issue of land abandonment which is the valuable insight for land use policy and rural livelihood. Therefore, the study on the relationship between food security and rural land abandonment may be an essential research for the improvement of livelihood of rural hill people and country as well.
- Soil erosion is one of the major issues of land use/land cover dynamic area in such steep hill slope. Different soil erosion rates have been found in different part in the world and in Nepal. It has several implications to soil productivity, sediment production and environmental sustainability. Thus, it is the first requirement of the need to have up to date and accurate information of soil erosion.
- Some research findings in Nepal have claimed that increasing invasive plants and decreasing biodiversity are the root cause of cultivated land abandonment. Therefore, further research on biodiversity change on abandoned cultivated land would be another important issue of this research.

- Field experience proved increasing wildlife due to the decreasing human population. It has created interspecies competition among human and wildlife. It would be one of the research fields so as to identify the further acceleration of land abandonment and ecological analysis of human and wildlife.
- This research revealed the increasing greenery, but this information is not sufficient to understand the change in biomass intensity. From the field study it was found that total biomass of the vegetation has also increased but further research is required in order to find out the detailed information.
- Decreasing water resource due to the climate change is being critical issue of research in the world and even in Nepal. Increasing greenery is the suitable situation for ground water recharge. Thus, it requires the study of relationship between increasing vegetation coverage and its contribution to ground water recharge in the study area.
- Returning of rural farmers to their villages due to Covid19 pandemic in 2019/20, cultivation on their abandoned farmland is increasing in some rural areas. Although, it is still not sure that how far this recurring situation will remain, there is a new research issue of recurring of land use/cover change.

## APPENDICES

### Appendix: I

Value Inflation Factor (VIF) of variables derived by Ordinary Least Square (OLS)  
( $R^2 = 0.44$  and adjusted  $R^2 = 0.40$ )

S.N.	Variables	VIF
1	Irrigation	3.9
2	Land capability	4.1
3	Average temperature	1000.0
4	Summer temperature	1000.0
5	Winter temperature	1000.0
6	Temperature difference	1000.0
7	Population change	1.9
8	Household size change	1.8
9	Sex ratio change	1.5
10	<i>Bahun Chhetri</i> population	7.7
11	<i>Dalit</i> population	1000.0
12	Food sufficiency less than 6 month	2.9
13	Food sufficiency more than 9 month	2.2
14	Food surplus	2.2
15	<i>Janajati</i> population	1000.0
16	<i>Dalit Janajati</i> population	1000.0
17	Road kernel density	3.5
18	Slope degree	10.7
19	Solar radiation	10.3
20	Elevation	4.8
21	Urban kernel density	10.3
22	Built up kernel density	3.7
23	Water kernel density	5.2
25	Post Office kernel density	5.1
26	Educational institute	9.9
27	Health post kernel	4.0
28	Rainfall	3.4
29	Flow accumulation	2.2

## Appendix II

VIF calculation of grouping variables by OLS technique

<b>Physical</b>	<b>R<sup>2</sup> = 0.196, Adjusted R<sup>2</sup> = 0.182</b>	
	<b>Variables</b>	<b>VIF</b>
1	Average temperature	4.40
2	Slope degree	4.70
3	Solar radiation	2.00
4	Elevation	1.50
5	Rainfall	1.90
6	Flow accumulation	3.30
<b>Availability</b>	<b>R<sup>2</sup> = 0.19, Adjusted R<sup>2</sup> = 0.18</b>	
1	Urban kernel	6.83
2	Built-up kernel	1.98
3	Water kernel	2.12
4	Post office	3.43
5	Education Institute	6.96
6	Health kernel	2.99
<b>Caste/ethnicity</b>	<b>R<sup>2</sup> = 0.03, Adjusted R<sup>2</sup> = 0.02</b>	
1	Bahun Chhtri	2.94
2	Dalit	1.39
3	Janajati	2.99
<b>Demographic</b>	<b>R<sup>2</sup> = 0.044, Adjusted R<sup>2</sup> = 0.038</b>	
1	Population change	1.00
2	Household size change	1.00
3	Sex ratio change	1.00
<b>Food Sufficiency</b>	<b>R<sup>2</sup> = 0.080, Adjusted R<sup>2</sup> = 0.076</b>	
1	Food sufficiency less than 6 month	1.09
2	Food sufficiency more than 9 month	1.07
3	Food surplus	1.16
<b>Resource</b>	<b>R<sup>2</sup> = 0.098, Adjusted R<sup>2</sup> = 0.091</b>	
1	Irrigation	2.10
2	Land capability	2.26
3	Water	1.26

### Appendix: III

VIF of 10 selected variables by OLS technique

<b>Physical Factor</b>	<b>R<sup>2</sup> = 0.196, Adjusted R<sup>2</sup> = 0.182</b>	
	Variables	VIF
1	Irrigation	3.10
2	Land capability	3.26
3	Average temperature	3.26
4	Population change	1.39
5	Slope degree	4.69
6	Solar radiation	4.66
7	Elevation	2.73
8	Urban kernel	6.72
9	Built-up kernel	2.15
10	Educational institute	6.82

## Appendix: IV

### Questionnaire for household survey

1. History of household and village

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2. Changing situation of agriculture system and livestock ranching

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3. Land ownership and abandonment of household

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4. Government services for education, health service and agriculture inputs etc.

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5. Services of NGO/INGO and other local organizations

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6. Use of resources (public and private forest, shrubs, grassland, water, stone, soil etc.)

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7. Income and expenditure of household

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8. Changing lifestyle

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9. Alteration of changing situation

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10. Causes and consequences of changing situation

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11. Changing landscape in and around the village

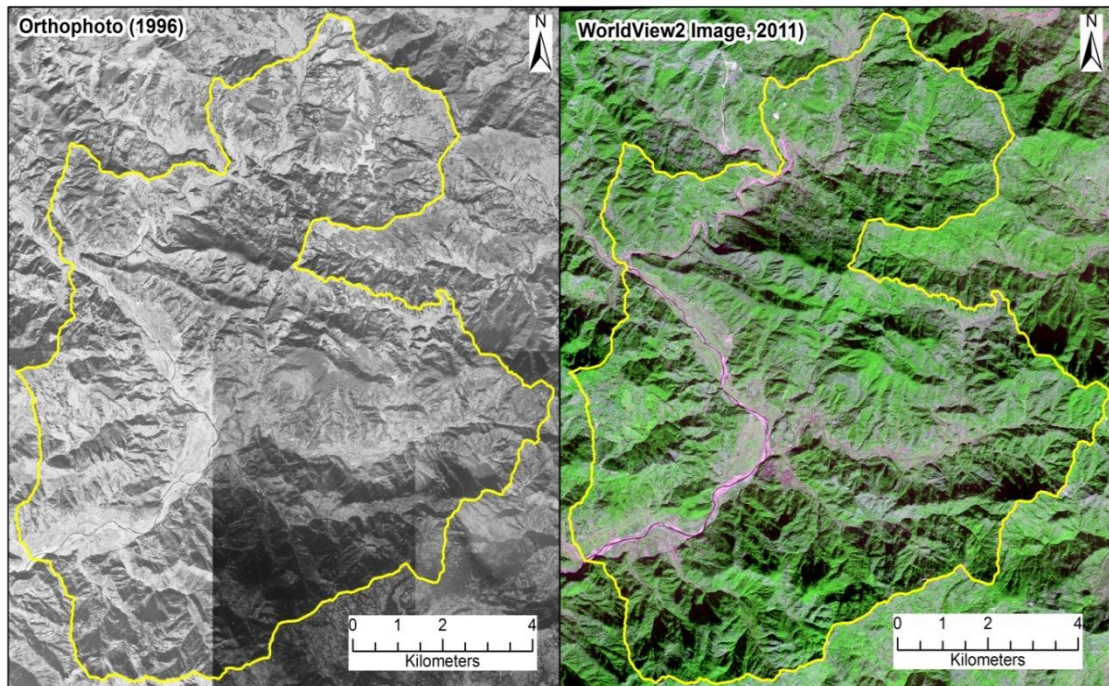
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12. Any comments and suggestions

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## Appendix V

Orthophoto (1996) and WorldView2 (2011) image are the main data source of land use/ land cover



## Appendix VI



Photo by: Chhabi Lal Chidi (2016)

Photo A: An overview of the study area showing lowland flat area with irrigated paddy field of river basin, and settlements and cultivated land in hill slope area.



Photo by: Chhabi Lal Chidi (2016)

Photo B: Paddy field along with the river channel, rain fed maize cultivated of rain fed area of river basin and tree crop at the lower hill slope.



Photo by: Chhabi Lal Chidi (2016)

Photo C: Abandoned village and cultivated land (Godargaun). There were 18 households in the village 30 years before, but now all cultivated land and houses have been completely abandoned and most of them had already damaged.



Photo by: Chhabi Lal Chidi (2016)

Photo D: Urbanization along with the Sidhartha Highway (Badhkhola).



Photo by: Chhabi Lal Chidi (2016)

Photo E: Partially abandoned village and cultivated land (Nuwakot). Former headquarter of Syangja district.



Photo by: Chhabi Lal Chidi (2016)

Photo F: Partially abandoned cultivated land. Maize cultivation is at limited parts and most of the cultivated land have been abandoned and converted into grassland.



Photo by: Chhabi Lal Chidi (2016)

Photo G: Commercial vegetable farming at the hill top (Gyudanda) accessible area which is supplied to the market centers such as Syangja and Pokhara.



Photo by: Chhabi Lal Chidi (2016)

Photo H: Orange farming in the Hill slope (Dandaswara) which is the major cash crop of the study area.



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