LAND SUITABILITY EVALUATION FOR LAND USE PLANNING IN SHAMBHUNATH MUNICIPALITY OF SAPTARI DISTRICT, NEPAL

A Dissertation

Submitted to the Faculty of Humanities and Social Science of Tribhuvan University in fulfillment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

in

GEOGRAPHY

By

BIKASH KUMAR KARNA

Ph. D. Regd. No. 06/072 Magh

T.U. Regd. No. 30499-94

Tribhuvan University

Kathmandu, Nepal

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CERTIFICATE

LETTER OF RECOMMENDATION

We certify that this dissertation entitled **"Land Suitability Evaluation for Land Use Planning in Shambhunath Municipality of Saptari District, Nepal"** was prepared by Mr. Bikash Kumar Karna 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.

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Professor Hriday Lal Koirala, Ph.D.
Supervisor

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Associate Professor, Shobha Shrestha, Ph.D.
Co-Supervisor

Date: 2080/09/19

DECLARATION

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

Signature:……………….
Bikash Kumar Karna
Date: 2080/09/19

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January, 2024 **Bikash Kumar Karna**

ABSTRACT

Land use pattern is an outcome of natural and socio-economic factors and their utilization by humans in time and space. The demand of land for multiple use raises land use conflicts among different interest groups which necessitate proper allocation of land use for sustainable development. Land evaluation is one of the basic policy tools to design appropriate land suitability model for allocating specific land use. So, it is essential for proper allocation of land resource through land use planning. The present research has attempted the land evaluation process for land use planning. The specific objectives are to analyze the existing land use practices issues and spatio-temporal pattern of land use change since 1986 A.D., to evaluate the suitability of land for different use, to develop framework model for optimum land use plan, and to recommend the appropriate strategy for implementation of land use plan. This research has also attempted to evaluate the land use at the best option from the land suitability evaluation and land use simulation incorporating physical infrastructure and risk factors in land use planning for sustainable land management.

The research work was carried out in Shambhunath Municipality of Saptari district, Nepal. It was basically guided by sustainable spatial planning approach and accomplished by both quantitative and qualitative techniques. Primary data was collected from filed visit, observation, rapid rural appraisal, participatory rural appraisal, key informant interviews, and focus group discussion. Holistic approach was adopted in analysis with six process such as analysis of land use pattern, identification of parameters, spatial modeling for risk layers, suitability evaluation for land use class, simulation of land use, and preparation of optimal land use plan with its implementation strategies. Land use changes were analyzed from 1986 to 2017. Potential land use zones were identified through land suitability analysis using AHP, MCE and GIS in relation to the risk factors such as flood, soil erosion, landslide and fire. The infrastructure development plan was allocated based on land use suitability index maps and planning guidelines. Land use simulation was made through Cellular Automata technique. Land use plan was developed based on simulated land use and optimized through SWOT analysis. Implementation strategy was developed based on legal framework to implement land use plan at the local level.

Land use change pattern from 1986 to 2017 showed that agriculture land is increased with 842 ha through deforestation and encroachment of forest, barren land and open

space area, whereas the forest land is decreased with 135 ha. The built-up area (residential, commercial and industrial) is also rapidly increased with 175 ha in scattered form along road network and surrounding the settlement. The major risk factors are occurred mostly surrounding the foot of Chure hill and along the Khando River. Total 27 criteria are identified for the land suitability analysis in local situation in the context of Nepal. GIS integrated with MCE-AHP based quantitative technique was applied for land suitability analysis to evaluate the land quality assessment for different land use. The suitability index map described the more appropriate site for specific land use. These suitability index maps were applicable in developing infrastructure plan and decision making process of land use planning to resolve land conflict for proper allocation of land use. Planning guideline was developed based on national and international standard and applied in designing physical infrastructure. Physical development plan is designed to allocate the public service facilities, utilities, and infrastructure based on the local people requirement. Land use plan is developed based on simulated land use incorporating the developing infrastructure plan and risk area. The developed land use plan is preserved the strength and opportunity as well as incorporating the weakness and minimizing the threats in optimization process. Almost 46 percent of the total areas have been planned for future agriculture land use followed by residential, commercial, industrial, and public uses accounting 201 ha, 26 ha, 3 ha, and 345 ha respectively. Implementation strategy is a framework for enforcement of compliance of land use zone and penalties for noncompliance, and acts as a guided land development activities for implementation of land use plan.

Land use changes are found rapidly in the foot of Chure hill, surrounding existing settlement and along the transportation route. The suitability index map describes the suitable site for specific land use. These suitability index maps are applicable in developing infrastructure and decision making process of land use planning to resolve land use conflict for proper allocation of land use. Land use plan considers the spatial structure, economic value, physical infrastructure, risk layers, and strategic issue of land in an effective manner. Also, it covers the strength and opportunity of framework of study, incorporating the weakness and minimizing the threats. It is technically feasible and reliable; socially acceptable to local people by involving in planning process; and implementable at local level. It follows the basic assumption of Hoyt’s theory of land use and sustainable planning process. It also uses as a periodic plan to construct the basic infrastructure for land development in sustainable manner.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FUGURE

ABBREVIATION

ADSL	Asymmetric Digital Subscriber Line
AHP	Analytical Hierarchy Process
ANN	Artificial Neural Network
AUC	Area under the Curve
CA	Cellular Automata
CBD	Central Business District
CBO	Community Based Organization
CBS	Central Bureau of Statistics
CI	Consistency Index
CLUP	Comprehensive Land Use Planning
CR	Consistency Ratio
DDC	District Development Committee
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
DRR	Disaster Risk Reduction
DSS	Decision Support System
DUDBC	Department of Urban Development and Building Construction
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
FLM	Fuzzy Logic Model
FR	Frequency Ratio
GCP	Ground Control Point
GDP	Gross Domestic Product
GIS	Geographic Information System
ICT	Information Communication Technology
ILUP	Integrated Land Use Planning
KGK	Krishi Gyan Kendra
KIA	Kappa Index of Agreement
KII	Key Informant Interview
KVDA	Kathmandu Valley Development Authority
LC	Land Cover
LCM	Land Change Modeler
LESA	Land Evaluation and Site Assessment

LMA	Land-use Management Areas
LMU	Land-use Management Unit
LR	Land Readjustment
LRMP	Land Resource Mapping Project
LRM	Logistic Regression Model
LSI	Land Suitability Index
LSM	Landslide Susceptibility Model
LSS	Land Suitability Simulation
LU	Land Use
LUC	Land Use Change
LUCC	Land Use Cover Change
LUCIS	Land Use Conflict Identification Strategy
LUIS	Land Use Information System
LULC	Land Use Land Cover
LUP	Land Use Planning
LUPAS	Land Use Planning and Analysis System
LUT	Land Use Type
LUZ	Land Use Zoning
MAGISTER	Multi-criteria Analysis and GIS for Territory
MCA	Multi-criteria Analysis
MCDA	Multi-criteria Decision Analyses
MCE	Multi-criteria Evaluation
MFT	Main Frontal Thrust
MLC	Maximum Likelihood Classifier
MODIS	Moderate Resolution Imaging Spectroradiometer
MOLA	Multi-objective Allocation
MSS	Multi-spectral Scanner
NDVI	Normalized Difference Vegetation Indices
NDWI	Normalized Difference Water Indices
NEMRC	National Earthquake Monitoring and Research Centre
NGO	Non-Government Organization
NLUP	National Land Use Project
NSO	National Statistics Office
PAN	Panchromatic

PBCI	Parcel Based Cadastral Information
PGIS	Participatory GIS
PLUP	Participatory Land Use Planning
PR	Predicted Ratio
PRA	Participatory Rural Appraisal
PSS	Planning Support System
RCM	Rational Comprehensive Model
RF	Relative Frequency
RMSE	Root Mean Square Error
ROC	Receiver Operating Characteristic
ROW	Right of Way
RPC	Rational Polynomial Co-efficient
RRA	Rapid Rural Appraisal
RS	Remote Sensing
RSLUP	Risk Sensitive Land Use Planning
RUSLE	Revised Universal Soil Loss Equation
SEGA	Socio-Economic and Gender Analysis
SMCA	Spatial Multi-Criteria Analysis
SMCE	Spatial Multi-Criteria Evaluation
SOM	Spatial Optimization Model
SVM	Support Vector Machines
SWOT	Strength Weakness Opportunity Threat
UNDP	United Nations Development Programme
USDA	United States Department of Agriculture
WLC	Weighted Linear Combination

Chapter - 1

INTRODUCTION

1.1 Background

Land is a natural resource on the earth surface which provides the basic necessity to human beings. It offers the space for human beings and supports the life through the production of food, fodder, fiber, fuel, timber and other biotic materials for human use (FAO, 1995). It also provides shelters, filters and stores water and supplies space for urban and industrial development, leisure and many social activities (Verheye, 2009). Land resources are the primary sources of nutrition, income and employment, and are the basis for security, status, social identity and political relations (Veit, 2011). The demands for arable land, grazing, forestry, wild-life, tourism and urban development are greater than the land resources available. So, land and its resources lie at the heart of social, political and economic life for the people (Veit, 2011). Nepalese livelihood is mostly dependent on land resources. Although land is a fundamental factor for agriculture production, fertile agricultural land in Nepal has been converted into non-agriculture use, mainly for urban and sub-urban settlement (Paudel et al., 2013) and informal land development towards urbanization (Devkota, 2012) in the unplanned way. Also, some agriculture land, mainly in the rural area of hilly region, has been converted into abandoned land or covered by shrub/bushes. As a result, the country is in a severe threat of facing hunger or food crisis in the future. All the activities related to land resources should be complementary to economic development, social equity and maintaining a sound environment, but they are frequently found to be in competition with each other. Land resource management is reflected in land cover/use and notably attempted to address land use policy and land use planning.

Land use (LU) describes the functional activities of human beings for specific purposes with some sorts of management practices (Khanal, 2000) associated with a specific piece of land. So, it is the functional dimension of land for different human purposes or economic activities. It is essential to have the knowledge of an area for land based analysis and demonstrates with the economic activities of an area that reflects the degree of human activities directly related to land and making use of its resources or having an impact (Boakye et al., 2018). It also reflects the surface utilization of all developed and vacant land on a specific point at given time period with defined location in space. LU is diverged in nature influenced by different factors such as the physiographic, topographic, climatic, lithology, soil type, climate, rainfall pattern, settlement pattern, cultural and traditional practices, and socio-economic factors, etc. So, it is a functional unit of the land and the consequence of interactions between the natural environment and the human activities. It is a highly complex issue due to its interrelation with physical external patterns and socio-economic situation (Hao, 2013). Different official document reflect that land use is one of the priority sectors of the Government of Nepal (GoN). To address land use sector, the Eighth five-year periodic plan has identified a long-term program (NPC, 1993) for the first time. The Ninth five-year periodic plan has focused for sustainable development of land and natural resources for preservation and extension of ecological sectors (NPC, 1998). This plan has identified the need of the formulation of land use plan based on the land form, climate, soil etc. for agricultural production, protection of environment and maintenance of other facilities. In the same way, the Tenth fifth year periodic plan has focused to the formulation and activation of land use policy to discourage the use of arable land to other non-agricultural purposes and creation of national geographic information database related with land resource maps (NPC, 2003). These land resource databases have been utilized for allocation of specific land use meeting the immediate human needs through land evaluation process in land use planning.

Land evaluation is an assessment of land performance process for proper allocation of land use to alleviate land use conflicts in terms of sustainable development (Li & Liu, 2008) and meeting the demand of land use from multiple aspect and different interest groups. It is a prerequisite for land use planning. It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use (FAO, 1976). It is an interpretation of land properties in terms of suitability of the land for proper land use and its allocation in land use planning process (Verheye, 2009). It is the assessment of the land suitability and performance for any use in culture, forestry, engineering, hydrology, regional planning, recreation etc. (Van Diepen et al., 1991). In land evaluation process, land suitability analysis is used for selection of proper land use from limiting criteria. Land suitability analysis is carried out for identifying suitable site for specific use, sustainability for environment protection; the inputs needed to obtain from land in terms of production and economic return for economic growth, proper building construction and infrastructure development as well as land development for fulfill the social basic needs (Verheye, 2009). The results from land suitability evaluation is utilized in the land use planning process for the allocation of proper land use without knowing their match to the current land use pattern in another step (Ziadat & Al-Bakri, 2006) and generally applicable in the process of land use planning.

Land use planning (LUP) is a scientific, aesthetic, and orderly disposition of land, resources, facilities and services with a view to securing the physical, economic and social efficiency, health and well-being of urban and rural communities (CIP, 2000). It is carried out in a systematic and iterative process in order to create an enabling environment for sustainable development of land resources which meets people's needs and demands (GIZ, 2011). It is conducted for enhancing the socio-economic conditions and expected developments in and around a natural land unit for growing and migrated population. It assesses the physical, socio-economic, institutional and legal potentials and constraints with respect to the optimal and sustainable use of land resources, and empowers people to make decisions about how to allocate those resources (FAO & UNEP, 1999). So, it should be a decision making process that facilitates the allocation of land for specific land use and its alternatives use to meet the economic and social conditions in order to select and adopt the best land use options that provide the greatest sustainable benefits to the society. It is ultimately about people and their relationship with land and other natural resources, and the skills that planners and land managers bring to these processes are those of recognizing and accommodating competing or multi-layered and co-existing interests (PIA, 2007). LUP has been an ideal estimation tool for allocating and reallocating land resources for development and sustainable development purposes (Nha, 2017).

For the long terms perspectives, LUP has been applied to allocate the land use for meeting the changing human needs and its conservation through socio-economic and ecological function in sustainable manner. So, sustainable LUP requires recognition of the limitations of the biosphere and the need for a balance of social, cultural and economic uses within these natural limitations (Chalifour, 2007). It is also related to planning process that fundamentally integrates five dimensions of sustainability as: social, cultural, environmental, economic, and governance. The planning and execution of LUP is increasingly important for retaining ecological integrity and ensuring food and fiber system that resilient enough to absorb shocks and stresses and avoid the degradation of land and water resources (FRP, 2005; World Bank, 2006).

In land use planning, land unit is delineated with the delimitation of homogenous area on the basis of land characteristics: topography, soil, vegetation, land cover (LC), forest type, ecological system etc. and termed as land use zone. Land use zoning (LUZ) define the restrictions area of land to use other than assigned land use within the delimited area (Basta et al., 2008), and it is essential component for land use plan. So, LUZ process has derived from the key problems, major challenges and/or main potentials of the planning area or if already identified from the planning objectives (GIZ, 2011). It is the process by which lands are evaluated and assessed to become a basis for decisions involving land disposition and utilization. It generally involves zoning of appropriate types and forms of land uses, as well as infrastructure and open space area planning directed at the efficient utilization of land in order to provide benefits to the broader population, the economy and the environment. Land use zoning regulation and restriction are used by local government to control and direct the development of property within their boundaries (Wafaie, 2008).

The implementation strategy of LUP described the guideline document as legal provisions for land development and its proper use. These legal provisions assist to enforce the implementation of land use plan and its monitoring process for sustainable land development and management in planning area. When implementing at the bottom administrative level, local people have involved in land use planning process towards sustainability. Sustainability initiatives that make economic sense today and that logically move the community towards a future of social inclusiveness, cultural vibrancy, environmental stewardship and strong governance practices. Practical aspects of sustainability planning include (among others) growth management, housing choice and affordability, and inter-jurisdictional coordination. The land use practice has a direct impact on environment, ecology and other socio-economic factors.

LU acts as a process of organizing the use of land to meet occupant's needs while respecting the capabilities of the land. Whereas LUP allocates the preferable use of land for specific use that balances the property right, socio-economic activities with the desired needs of the community. Also, LUP conserves the land quality, soil degradation, and enabling environment. So, LUP requires land use regulation to control the activities of LU and its change that typically requires LUZ. LUZ acts as planning control tool that regulates the LU types accommodated on a given land plot and parcel as well as the amount of space for developing structure such as buildings, services, utilities and other infrastructures.

1.2 Statement of the Problem

In Nepal, the demand on the land resources is increasing exponentially due to the growing population at the current annual rate of almost 1.35 percent in 2011 having 3.43 percent in urban areas and 1.03 percent in rural areas (CBS, 2012; MoUD, 2017). The increasing population growth rate generates the pressure on land and need to increase the agriculture productivity from land through proper allocation of agriculture land (Mandal, 2013). Nepal is recorded as one of the top ten fastest urbanizing countries in the world (UNDESA, 2015). Migration has mostly taken place from mountain and hilly regions to rural areas of Tarai region, which have been gradually urbanized after eradication of malaria and the construction of East West highway (Khanal, 2000). The census of 2001 indicated that the internal migration rate was 8.6 percent (CBS, 2003). It was further corroborated by very high migration rate of 37.7 percent (MoUD, 2017) from rural settlement to urban area for searching job (employment) and educational opportunities. The internal migration occurred mainly due to poverty, inequitable distribution of income, unemployment, difficult livelihood, and food insecurity (KC, 2004). Occasional natural calamities like floods and landslides have also forced people to flee from their birth place to other location for opportunities to enhance their livelihood. So, there requires urgent rescue and help to the people in disaster prone area to resettle in safe area through displacement process (KC, 2004).

LRMP (1986) estimated that only about 20 percent of total land was under cultivation while forests (37.8 percent), shrub land (4.6 percent), barren land within cultivated areas (6.5 percent), pastures (11.8 percent), snow and ice packs (3.4 percent), lakes and ponds (0.1 percent), urban areas (0.1 percent), and rocky, sandy or stony surfaces (15.7 percent). Likewise, agricultural land was 28 percent (of which 21 percent is cultivated and 7 percent uncultivated); forest area occupied about 40 percent; pasture covered 12 percent; and remaining 20 percent area was other types land (CBS, 2013). However, FRTC (2019) revealed that cultivated land occupied 21.88 percent, other land occupied 28.68 percent, forest area occupied 44.47 percent, grassland covered 2.60 percent, settlement covered 1.15 percent and wetland having 1.22 percent from google image using supervised image classification. Mainly in Tarai region, the agriculture land has been fragmented regularly for housing and informal land development purpose towards urbanization (Devkota, 2012) due to many reasons. For informal land development and urbanization, the urban built-up area has increased by 420 percent whereas agriculture land has decreased by 4 percent in Tarai region between 1989 and 2016 (Timilsina et al., 2019). The average land holding of majority of farmers was 0.79 hectares in 2001 (Paudel et al., 2013) and it gradually decreased to 0.68 hectares in 2011 (CBS, 2013). Also, agriculture land has not been properly utilized for crop production practices mainly in hilly area and converted into barren/abandoned land or growing of shrub/bushes in increasing trend because of limited available of agriculture labor and lesser working age population live there. Many settlements in Nepal are facing with slum problems mainly in urban and semi-urban areas (Devkota, 2012). These slum problems have been created by landless, scattered and jobless people by encroaching the public and state land, such as forests and barren land along the river flood bank. These slum settlement has mainly occurred in risk prone area of flood and other risks. Also, environmental deterioration has raised due to the forest encroachment of forest area and water body feature. The eco-environment of Chure Range has been extremely fragile and vulnerable to human activities, terrestrial ecosystems, natural disasters, and climate change with the occurrences of geo-hazards, such as debris flow and landslides, which greatly threats the life and property of local people. In Tarai, flood, soil erosion and fire incident mostly occur every year that also generate threats in the life to the local people and agriculture land. So, land use/cover change (LUCC) is occurred mainly due to increase in population, internal migration, demand of built-up area, needs of infrastructure development, increase of slump settlement and occurrence of different disasters/risks.

Most of land use land cover (LULC) research has been carried out for determining the dynamic use of land by using robust modeling, statistical analysis and change detection algorithm tools in qualitative, quantitative, and mixed of both technique (Cheong et al., 2011). The results of these LULC analyses showed that land use changes occurred in different pattern having inconsistence nature having different causative factors of the local situation of terrestrial system. So, monitoring of the LULC activity is a challenging task for land use planner to design the eco-friendly and sustainable land development to achieve high rate of economic growth and meeting the demand of people in the society. Therefore, land use issues are closely related with the society, development activities and environment. These land related issues is needed to be resolved and reduced land use conflict for equitable access of land resources, control fragmentation of high fertile agriculture land , well-being sufficient social and physical infrastructure, well arrange environment, and mitigation risks in efficient and effective way. Also, lack of effective land use policy/regulation and planning mechanism has affected the overall governance system in a country. To cope with these challenges, available land resources could be managed properly in planned and systematic manner through land evaluation to allocate specific land use for the best practice in decision making process of LUP.

In land use planning, land evaluation is mostly used to response the need of land changes from the currently land use and served to screen preliminary land use options that should be considered for land suitability analysis. So, land suitability analysis is conducted to assign the specific land use from suitable sites of various land use. Most of the land evaluation research has been carried out for specific site selection of proper land use as agriculture, residential, commercial, industrial, forest and so on. There is essential to identify the suitable land use site using different factors and constraints. These factors and constraints used in the land suitability research works have varied in nature depending upon the site and location of planning area. These factors and constraints play the major role in land suitability analysis to focus the priority level of specific land use. Therefore, it is required to identify various factors and constraints before conducting the land suitability for specific use, then analyzed through cross-reference to the existing land use practices and reference with these suitability land use index data.

Generally, land use planning involves the allocation of land to different uses across a landscape in a way that balances economic, social and environmental values. So, its main purpose is to identify the combination of land uses that is best able to meet the needs of stakeholders while safeguarding resources for the future in a given landscape. Most of the researches in land use planning have been carried out for specific land use not as a general land use of combination of different use using different tools and techniques. These research works do not consider the government policies, legal framework for developing the multi-sector plan, planning norms/standard, citizen perception, and constraints like different risks in the planning process and management of land use activities. Therefore, it requires the coordination of planning and management across the many sectors concerned with land use and land resources in a particular region. Also, the effective land use planning provides direction on the manner in which land use activities should take place and encourage synergy effects between different uses of land. Land use plan is essential document for specific use of land in terms of land use zone for getting the optimum benefit from scarce land resource in LUP.

Likewise, land use plan should be implemented within a framework of legal documents as laws, policies and customary norms that guide the uses to which land zone for proper use. These legal provisions for implementation of land use plan are limited and they have been mentioned in scattered form in different laws and regulation. But, these legal provisions have not been sufficient to implement land use plan properly at local level Also, land use plan is utilized for monitoring land use changes caused by different activities, and control the unplanned physical infrastructure development and construction of housing building through planning permission and granting of permits. So, land use implementation strategy is designed and developed as an instrument that provides guideline for controlling land use changes, and adoption of land use zoning with its regulations through development code and its monitoring mechanism.

In this context, the present study has attempted to explore, understand and identify the issues of land resources particularly for sustainable land use planning in Shambhunath Municipality of Saptari District, Nepal. In order to carry out this research project, the following research questions have been formulated:

i. What are the issues related to existing land use practices?
ii. How and why is land use pattern changing?
iii. What are the criteria for suitability evaluation of different land use?
iv. What is the relation between current land use practice and potential suitability of proper land use?
v. How are the land suitability options, public opinion, government policies incorporated to allocate the land for specific use in optimum land use plan?
vi. How to do land use authority implement the optimum land use plan with proper monitoring mechanism?

1.3 Research Objectives

The main objective of the research is to make land suitability evaluation for land use planning to sustainable land management in Shambhunath Municipality of Saptari District, Nepal. The followings are the specific objectives:

i. To analyse the existing land use practice issues and spatio-temporal patterns of land use change since 1986 A.D.
ii. To evaluate the suitability of land for different use.
iii. To develop framework model for optimum land use plan.
iv. To recommend the appropriate strategy for implementation of land use plan.

1.4 Significance of the Research

Land use is a crucial component in a developing nation like Nepal. The land provides a fundamental means of subsistence to the majority of people, but all lands and locations are not equally suitable or profitable. As a result, alternative farming is needed for development activities through commercial and industrial production. So, both agriculture and non-agricultural purposes, including establishment of industries, business area, housing, roads, parks, railway lines etc. are essential for sustainable nation building. Due to the haphazard construction of infrastructure building and unplanned urbanization to produce better returns in short period, land is being rapidly converted from one use to another. Also, such processes invite the emergence of numerous unsolvable land-related issues for overexploitation utilization of land resources and uncontrolled patterns of land development. These land related issues can be resolved and managed through land use planning for allocation of specific land use. Land use plans are produced to meet competing demands, and to reduce land use conflict. It also assures a reasonable and orderly land development activities in sustainable and environmentally responsible manner. The preparation of a land use plan is a crucial step in land development for nation growth. Also, it seeks to identify, articulate and satisfy the basic social/human needs with the available economical/financial resources and technical knowledge. Therefore, LUP has required to identify the major components as: land use pattern, infrastructure development plan, land use plan, and development control.

Land use pattern is an outcome of natural and socio-economic activities and their utilization by human being in time and space. The optimal use of land use information is the essential for selection, planning and implementation of land use schemes to meet human needs and welfare. Generally, social and economic needs of local people are identified and articulated themselves by politicians, community groups and sometimes by the technical experts. These people's needs are concerned with the infrastructure development activities that make citizen's lifestyle easy to live and translate into a spatial form as land use plan, and development actions. Also, the infrastructure development represents the blueprint of overall development process, providing basic facilities and future shape of a country. So, need assessments are to be carried out to identify the necessity of physical, social and economic infrastructure. Only then the infrastructure for the future population is to be developed.

Some areas of land are more suitable for some types of LU activities than others, and some LU activities have negative impacts on the land and its environment. Also, use of land for one activity often prevents the use of land for another activity at the same time. In this research, land suitability assessment is carried out for the potential sites for specific land use in the light of economic, social and environmental consideration in order to develop different alternatives for the use of land in an area. Then, land evaluation process is applied to compare or match the requirements of each potential land use with the characteristics of each kind of land on the basis of feasible characteristics, past trend of land use, and considering the population growth rate, and constraints of development guidelines to develop an actual land use in LUP. It is carried out to allocate proper use of land in zoning ordinance (land use plan) from suitability site of different land use, considering infrastructure development plan, and incorporating constraints as different risk factors in sustainable manner. For implementing the land use plan on the ground reality in a rational manner, the development control is essential. So, the land use implementation strategy is designed based on federal, provincial and local level legal provisions and standard guideline for monitoring the dynamics of land use.

Furthermore, Nepal lacks of land use plan at local level covering the country as a whole. LUP is inevitable for making the best use of the limited land so far. In this context, the present research could be an important guideline for the local level land use planners of Nepal to diverse their respective plans for sustainable use. The present research aims to develop sustainable land use paradigm model to integrate all land use related information for land management towards monitoring land market, land economic activities, security of land rights and land tenure incorporating parcel based cadastral information. The developed land use paradigm model demonstrates the land suitability analysis that identify potential sites for specific land use acts as alternatives options in decision making to allocate land use. In land use planning process, spatial modeling tool is used in decision making to compare the potential land use with reasoning characteristics of land, incorporating developing infrastructure, and different risk factors as constraints. Therefore, the land use paradigm model of this research could be useful for the local bodies, planners and the researchers of the same field.

1.5 Limitation of the Study

The major limitations of this research study are as follows:

Land utilization map 1986 and topographical map 1996 were only available land resource data before 2000 in the study area. So, these land resource maps are used in this study for analysis of land use practice and its pattern. Land use classification schema has been designed based on available land use categories in the study area that is compatible with land use zone classes mentioned in the Land Use Act, 2019. Land use change has been analyzed based on the available previous land use maps as land utilization map 1986 and land use map derived from topographical map of 1996 before 2000 and land use map prepared from satellite image acquired in 2016.

The parameters and criteria used in land suitability analysis are limited. Data/information for the criteria such as environment pollution, land degradation, water layer deflection, impact of seismic hazard risk, potential for soil quality etc. are not available. Some data of the criteria are collected qualitatively and converted into quantitative scales through interaction with stakeholders, politicians and citizens, then rating the rank through pairwise comparison process. Similarly, land suitability index map presented quantitatively with threshold range rather than the actual representation.

Limited risks factors such as flood, landslide, forest fire, and soil erosion are thoroughly conducted. Some specifically developed models are applied in the risk assessment process: HECRAS and GIS based analysis model for flood; RUSLE (Revised Universal Soil Loss Equation) for soil erosion; bivariate analysis using frequency ratio (FR) and predictor rate (PR) technique for landslide susceptibility analysis; and fuzziness MCE-AHP used in the fire risk assessment. Landslide risk is not a major risk component in Tarai low land, but occurs in Chure region in forest area and applicable for managing forest land use and protection for nature conservation. Fire risk assessment is conducted on the occurrence of fire incident based on moderate-resolution imaging spectroradiometer (MODIS) data. But liquefaction, geological hazard, lightening from thundering etc. are not conducted and considered in the physical development plan and allocation of land use in planning process.

In physical development planning process, only guided development infrastructure has been planned based on the available development guideline developed by the Department of Urban Development and Building Construction (DUDBC) for physical development plan only. Each and every required sectorial development plan has not been developed. Land use planning has been carried out in broad sense of general land use plan, so the further subdivision of land use categories could be prepared by the local level authority themselves. This study has focused on model based planning tool, but not generated sophisticated customized planning decision support system.

The limited land use implementation strategy has been developed and suggested in terms of development code and provision of construction permit. For implementing and monitoring the land use plan, detailed development code is required for each and every activities carried out in the local level. The developed code is used to control land fragmentation and construction of building in safe location with safety manner.

1.6 Structure of the Dissertation

This dissertation has been organized in nine chapters.

The first chapter deals with background, statement of the problem, objectives, significance and limitation of this study.

The second chapter deals with review of literature including the land use, land evaluation and land use planning and its evolution; review of the empirical studies of land use pattern, land evaluation, land use planning; International and national policy for land use planning; research gap, and conceptual framework for this study.

The third chapter describes the research design, sources of data, tools and techniques, and adopted methodology in the research work.

The fourth chapter focuses on the location, physiography, topographical situation, social-economic activities, culture and environmental status in the study area.

The fifth chapter deals with results and analysis of land use pattern, land use change, trend of land use change and concentration measurement.

The sixth chapter deals with analysis of risk zone and its impact on existing land use, land suitability, and evaluation of land use classes.

The seventh chapter focuses on the development of infrastructure plan and carried out land use planning for optimal land use plan.

The eighth chapter describes the development of land use implementation strategy with the development code and monitoring mechanism.

Lastly, the ninth chapter outlines the summary of results, conclusions and recommendations for the further studies.

Chapter - 2

LITERATURE REVIEW

The present chapter discusses the review on the theories and empirical researches on land use pattern and its changes, land evaluation and land use planning, land use policies of government together with research gaps and conceptual framework for the present research.

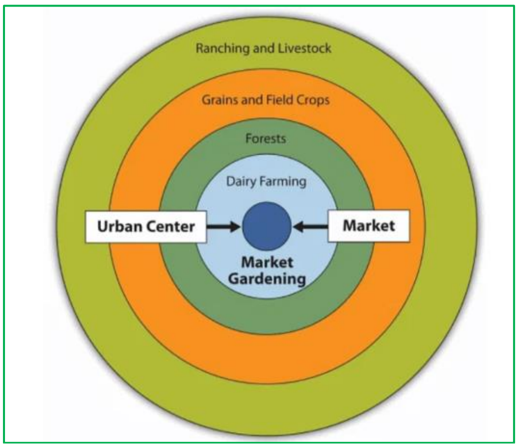
2.1 Concept and Theory of Land Evaluation and Land Use Planning

This section describes the theory, concept, method and tools in land use pattern and its changes, land evaluation and land use planning process.

2.1.1 Classical Theory on Land Use

Some classical theories and concepts reviewed on land use in this study are described as follows:

The Johann von Thünen introduced theory of agricultural location for land use model in 1826 as “The isolated states” that govern the interaction of agriculture prices, land uses and distance from city center to maximum benefit for farmers (Okelly& Bryan, 1996). The city is located centrally within “the isolated state" which is self-sufficient and has no external influences (Hall, 1966). The von Thunen theory states that a pattern of five rings around the city would develop in the form of different land use (Angelsen, 2007).

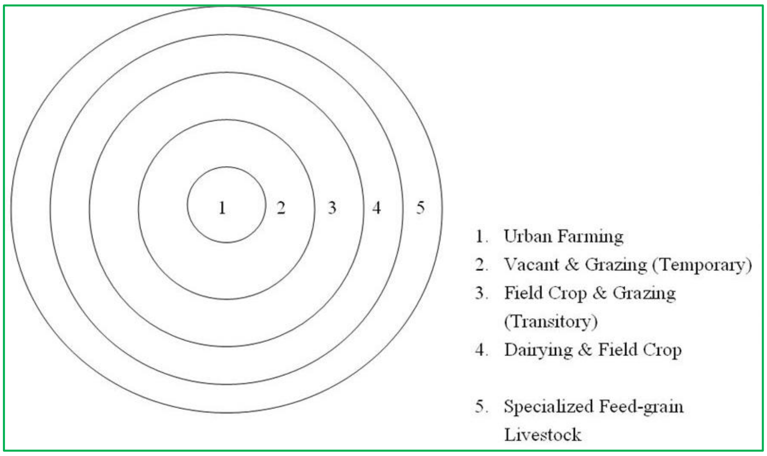


Source: EduRev, 2023

Figure 2.1: Von Thunen's Land Use Model

The first ring is used for market gardening as urban/market center. The second ring closest to the urban center is applicable in dairy farming (fruit, milk and other dairy products). The third ring is used for managing forest. The fourth ring is used for intensive agriculture of grains and field crops (rice, vegetables, fruit, grains and other cash crops). Lastly, the fifth ring is applicable for open access forest, and old dense forest (EduRev, 2023). The form of residential and commercial area in urban center has occurred mainly along the river or canal surrounding plain fertile agriculture land. The von Thünen theory also focuses on land rent, based on an assumption that land is allocated to the use generating the highest land rent (surplus) (Angelsen, 2007). The von Thunen theory has considered the three aspects as the ring pattern of agricultural commodity production, the structure of transport costs, and the presence of an urban system and the patterns of economic interaction within it (Parr, 2015).

Sinclair theory is an agriculture pattern of rural land use theory developed by Robert Sinclair in 1967 and basically based on von Thünen theory but the model of land use zone in anticipated urban encroachment-distance relationships. The urban encroachment form has an impact on production in surrounding agricultural land (Yusof, 1985). Sinclair postulates a land use zone around expanding built-up areas into five zones.

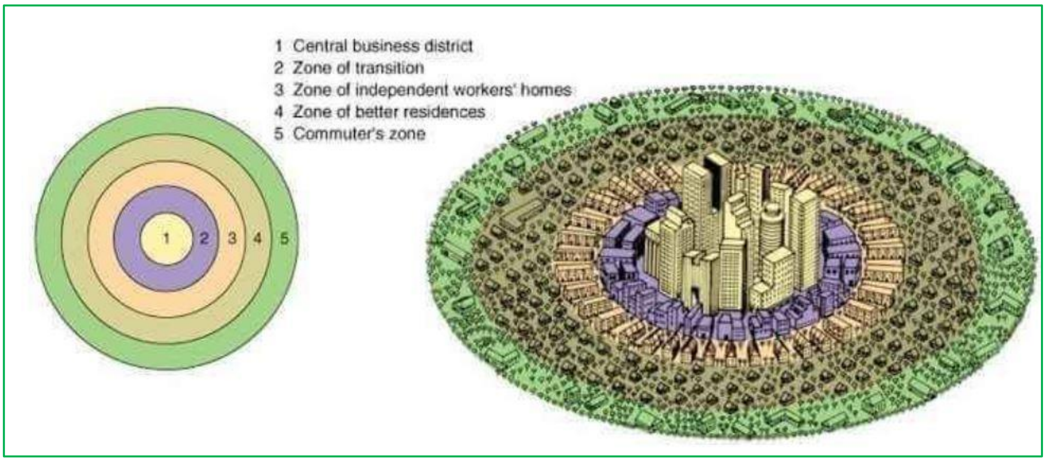


Source: SlidePlayer, 2023

Figure 2.2: Sinclair's Land Use Model

First zone is urban farming located at the edges of the built-up area for future urban development. Second zone is vacant and temporary grazing land for occasionally farming practice and not occurred urban subdivision yet. Third zone is transitory field crop and grazing area for temporary agricultural farming practice and expectation of urban area at a later time. The forth zone is dairying, field crop farming and extensive agriculture. Lastly, the fifth zone is specialized feed-grain livestock (SlidePlayer, 2023). According to this theory, farmers realized that the complete urban land uses in future would occur at considerably higher location rents and influence on agriculture land surrounding to the built-up border. As a result, the fear of displacement brought on by city growth is felt in the affected inner rural zone, and mirrored in the spatial behavior of farmers (Yusof, 1985).

Burgess's theory is the descriptive urban land use theory based on the concentric zone model developed in 1923. This theory describes "The growth of the city" on the outward expansion of the city and the socio-economic groups of the city in a series of concentric zones (Johnson, 1967). The development of a city takes place away from its periphery in the form of a series of concentric circles as central business district (CBD) and explains urban social structures (Najja, 2018). The five zones are formulated around the city.

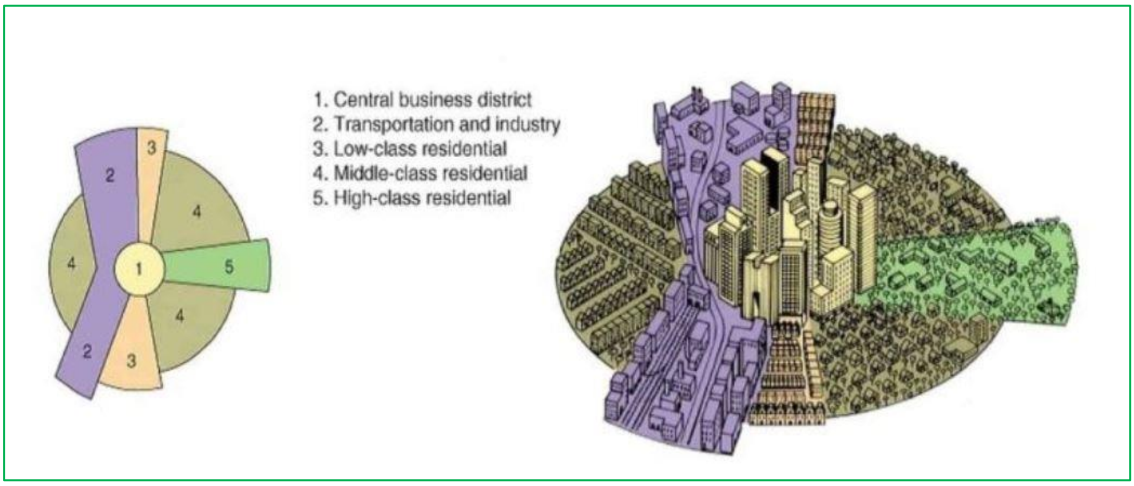


Source: Urban Design Lab, 2023

Figure 2.3: Burgess's Land Use Model

The first zone is CBD for commercial use having the major shops and offices with services center, entertainment and accessible of transport routes. The second zone is transition area having older houses with deteriorating slum property area, light industry and inhabitants of poor people. The third zone is densely residential use as low-class housing mainly for the escaped people from transition zone and others (labors and factory workers) who need to live close to factory area in order to reduce travel costs. The fourth zone is low density residential use for medium–class housing for middle-class families and private housing, as well as apartment blocks. Lastly, the fifth zone is low-density residential use for high–class housing for richer people having high property values with big building separated from CBD (Waugh, 2002). This theory explains the effect of market forces upon land use patterns (Chapin & Kaiser, 1979), situated on a level lacustrine landscape with very few topographic anomalies (Mayer, 1969), and attempted to provide a descriptive framework for the spatial arrangement of urban land uses (Herbert, 1972).

The sector or wedge theory is the modification of the concentric ring theory for urban land use developed by Hoyt in 1939 (McDonagh, 1997). This sector model is the classic models of urban spatial form (Herbert, 1972) that stated the mixed land uses developed away from the CBD and towards the periphery in the form of sectors (Herbert, 1972; Chapin & Kaiser, 1979); land development occurs in directional way (Van der Merwe, 1989); and focused on the highest rent trend as commercial and residential area mainly along transport routes (Mayer, 1969). Particularly, land uses found in each sector tend to expand outwards along these principle transportation routes and represent the lines of least resistance. Transport routes represent the natural boundaries between each sector (McDonagh, 1997). According to Hoyt's model, an urban area is developed in five sectors of land and rental value that radiate from the urban center in different land use pattern conditioned by the arrangement of transportation route.



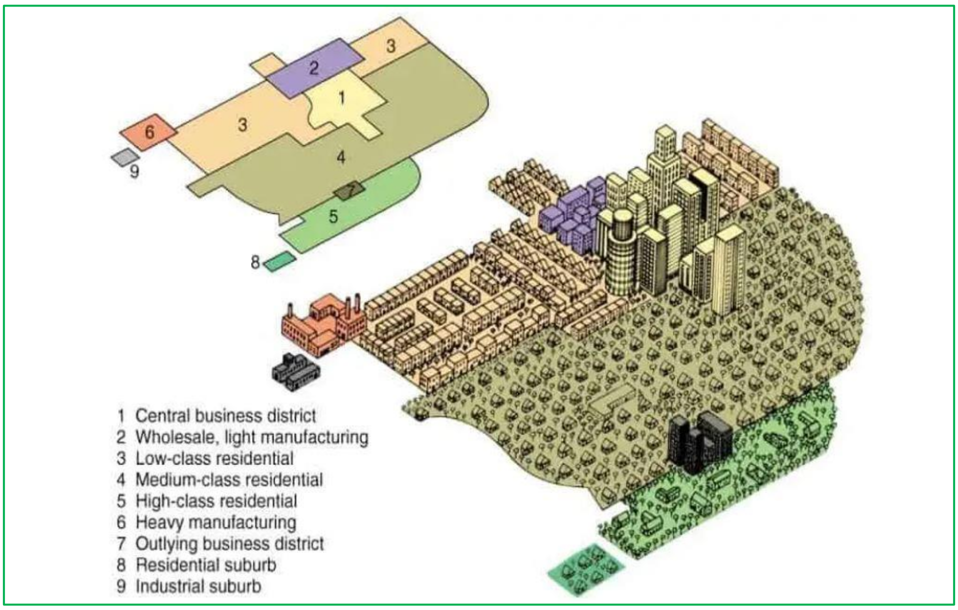
Source: Urban Design Lab, 2023

Figure 2.4: Hoyt's Land Use Model

The first sector is CBD area for commercial use with the major business complex, offices of services center, entertainment area, and accessible of transport routes. The second sector is transportation and industrial area that occurred in ribbon type street frontage developments for wholesale and light manufacturing between the extended street frontages. The third sector is a low-income housing neighborhood adjacent to the manufacturing, industrial area and connected to the CBD that reduce the travelling costs for job and services. The fourth sector is the largest residential use area for moderate income people to desirable location further from industry and pollution with accessibility of school and good transportation routes, making their commute easier, safe and clean neighborhoods. The fifth last sector is recognized an area of high-income housing that established once at the outer edge of urban areas (Johnson, 1967).

The Hoyt's theory incorporates the synergistic relationship between land uses that advantage in similar land uses being located adjacent to each other. This theory also emphasized the topographical factor that affects high-priced land move towards high ground, undeveloped water fronts, land with views, or similar areas with natural beauty; but handily accessible to high speed transportation routes (McDonagh, 1997).

The multiple nuclei theory is also the classic models of urban spatial structure (Herbert, 1972) and developed by Harris and Ullman in 1945 around one center (Johnson, 1967). The multiple nuclei theory produce a more realistic urban model having more complex and to some degree less clear than its predecessors than concentric zone and sector theory. The main distinctive quality of the multiple nuclei model is that it abandoned idea of CBD as the sole focal point of the city, and replaced it with a number of integrated discrete nuclei (including the CBD) around which land uses develop (Johnson, 1967; Herbert, 1972; Chapin & Kaiser, 1979; Pacione, 2005). This model has been able to meet the need for maximum accessibility to a center, to keep certain types of land uses apart, for differences in land value and, more recently, to decentralize (Chapin & Kaiser, 1979). Also, this model considers the effects of economic and social force on the development of land uses as the attributes of specific sites (Johnson, 1967) and applied for all cities acceptable with social, cultural and industrial circumstances that differ from city to city (Pacione, 2005). Basic concept of the multiple nuclei model is that nodes develop on the edges of the periphery and beyond, which lead to development and outward growth of the urban area (Van der Merwe, 1989).

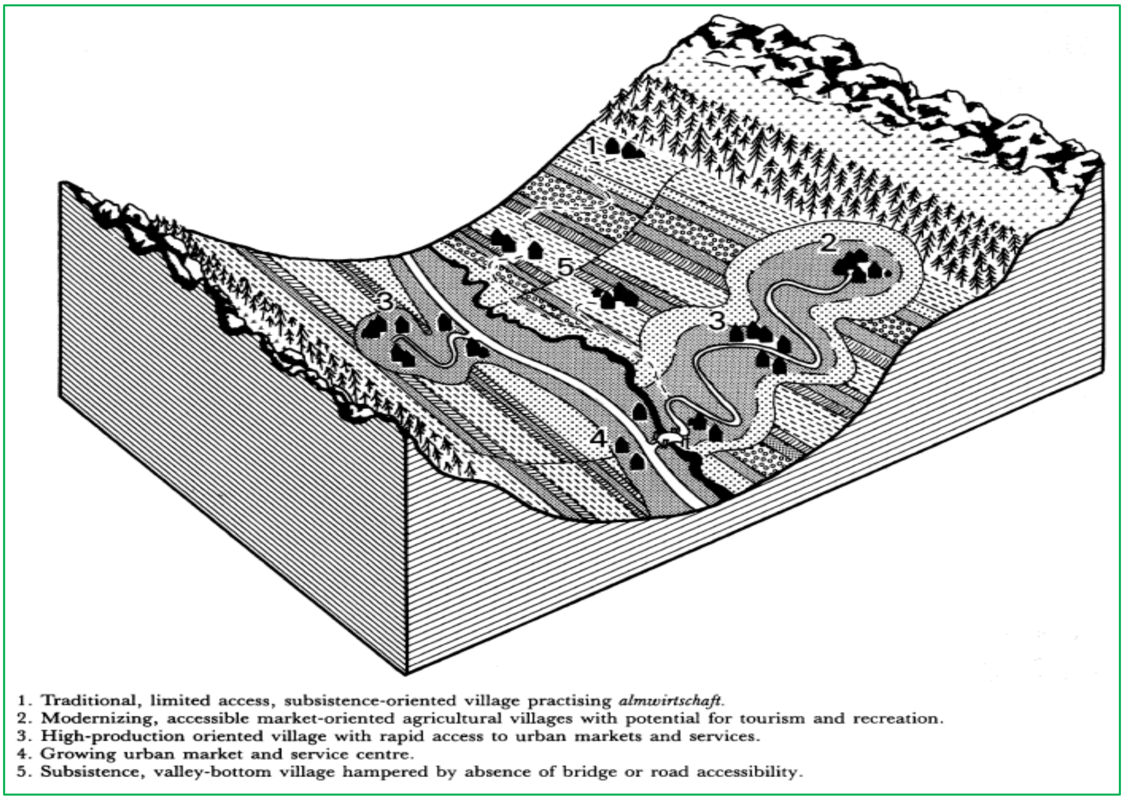


Source: Urban Design Lab, 2023

Figure 2.5: Multiple Nuclei Land Use Model

In the multiple nuclei model, first node is portrayed as the highest-order node at core city area. The second node is within the CBD with the most convenient access from all parts of the city with highest land value for wholesale commercial use and high manufacturing district. The third node is adjacent to the CBD and commercial area for low class residential areas. High class residential area is located on well drained high land away from noise, smoke, odors of CBD as fifth node. The medium class residential area is located in between low class and high class residential areas as fourth node. The sixth node is located near the present or former edge of the city for heavy manufacture having good accessibility of transportation route. The seventh node is outlaying business district located at the edge of high class residential area towards CBD. The eighth node is the residential suburb for newly developable urban area. Lastly, the ninth node is industrial suburb located near the present or former edge of the city that requires large tracts of land having good transportation facilities.

Mountain landscape pattern includes alpine pastures, forests, and farmland from low relief to high relief, and in a valley of up to 3,500 m. After the availability of transportation facilities like road, bridge and track, the land use patterns in mountain area are changing. Accessibility model of mountain land use is formulated five locations in the mountain landscape. Location 1 is a traditional mountain rural settlement only accessible through footpaths, no tracked vehicles available, and with limited agro-pastoral activities for cultivation. Location 2 is a marked contrast settlement area having excessive population migrated from highly rugged terrain to the lowlands. Location 3 is the market-oriented expanding commercial area in the middle mountain that links Location 2 with Location 4. Location 4 is newly developed settlement area after the construction of a new road, which acts as market with the availability of government services such as police and civil administration, and also acts as catalyst for the transformation of mountain valleys. Location 5 is remote villages untouched by modern developmental activities, where livelihood is based on the traditional pattern (Allan, 1986).



Source: Allan, 1986

Figure 2.6: Accessibility Model of Mountain Land Use

2.1.2 Concept and Theory of Land Evaluation

Some of the theories and concepts reviewed on land evaluation in this study are described as follows:

The traditional land evaluation theory mainly focuses on the physical suitability of land only. This theory identifies the levels and geographical patterns of biophysical constraints and evaluates potential capacity of land and its sustainable use in qualitative aspects (Yitbarek et al., 2013). Physical land evaluation concept is based on the classical approach using qualitative models that consider only a basic structural knowledge of the specific land as object. This approach has commonly employed in general planning purposes, mainly based on the physical productive potential of the land with relative suitability expressed in qualitative terms (Bagherzadeh & Daneshvar, 2011). It is particularly used in quick decision making for achieving result and/or lacking sufficient required data for quantitative based models (Liu et al., 2005; Ayine et al., 2015).

Economic theory has applied for predicting and implementing the micro-economic value of land use system on a given land area as land evaluation process (Rossister, 1996). Economic theory based land evaluation measured the economic suitability as gross margin, net present value, and internal rate of return, benefit/cost ratio, and utility functions. Economic land evaluation model measured the precise calculation of costs and returns (Bagherzadeh & Daneshvar, 2011). The economic value of geographic land characteristics has been determined by spatial analysis. In economic land evaluation model, single or multi-criteria economic optimization with risk analysis has for natural resource management as well as land management unit (Rossister, 1996). In economic approach of land evaluation, land use potential has analyzed based on demand and supply of land for specific purpose as cost that used in land suitability analysis for the corrective measures of benefit (McCormack, 1986).

FAO has designed standard land evaluation concept as "*a framework for land evaluation*" that is used for comparing land qualities (as soil, physical, environmental, infrastructure and social aspect) in each land unit (FAO, 1983; 1985; 1993). FAO land evaluation model has been used to determine the potential of land for predefined categories of major land uses in general purpose (Beek, 1978). Generally, FAO approach of land evaluation was used in land capability assessment of land evaluation for crop growth conditions and management operations for soil conservation practices (Van Lanen, 1991). So, it has been used for identification of the suitable location for crops based on climatic, terrain and soil properties (Nisar-Ahamed et al., 2000) in step-by-step approach.

Land evaluation and site assessment (LESA) developed by USDA in 1983 as land evaluation model was used for the site selection of agriculture land use (Wright et al., 1983). LESA has been carried out considering the factor of natural, environmental, social, economic, recreational feature and population pressure. LESA has evolved more specific and quantified assessments rather than soil factor and generally used non-soil factors (Van Diepen et al., 1991). LESA has been applied for broad land evaluation in planning process with physical criteria at the beginning and contribution for economic and social analysis has limited to a check on the relevance for these land use (FAO, 1976).

In the mid-twenty century, the forward movement in remote sensing (RS), geographic information science (GIS) and system theories, especially the developing complexity is stimulating a new development wave of modeling as complexity theory (Cheng, 2003). Complexity theory assumption is that considering the resurgence interest in complexity issues with understanding the systems or phenomena (Wu & David, 2002; Cheng, 2003); new mathematical methods that create new means to represent and quantify the complexity; and remote sensing and GIS guarantee the availability of data on various spatial and temporal scales (Cheng, 2003). In complexity theory, the scientific understanding must be based on complexity issues in the system and identified through multi-disciplinary framework. Complexity theory is applied in urban environment to the analysis of urban evolution and its flows of materials. The complexity approaches that capture the complexity of large urban systems, and efforts to integrate the various themes are rare (Kropp, 1998).

2.1.3 Concept and Theory of Land Use Planning

Some of the planning theories reviewed in this study are described as follows:

Classical planning theory is the *"theory in planning."* It is concerned with the form of the planning process and the operations of the planner. This theory is used in LUP based on location as foundation and administrative units are the planning units as "*planning environment*" and consider it as part of a wider network of services (Lagopoulos, 2018). Likewise, the *"theory of planning"* is concerned with process of planning for generating and implementing land use plan. The planning theory is also concerned with processes and techniques which are employed by planners in their work as well as the operating modes of planning agencies (Thomas, 1979). The planning theory encompasses the rationale *"of planning as a rational process of thought and action"* and the construction in substantive (behavioristic) model of planning agencies; within a multi-dimensional social (in the wide sense) as "*environment*" (Lagopoulos, 2018).

Procedural theory is referred as '*technocratic planning*' due to its emphasis on technical expertise and skills to solve problems occurred in landscape. The procedural theory assumed that optimization of the set of planning tools is used for the best possible solution of the problem coordinating with planning organization (GTZ, 1999; Iorliam & Ogwuche, 2014). In this theory, planners used their experience and knowledge gained from past project and utilized in the current project in order to get the desired outcome. Based on this theory, LUP has been carried out in more technical knowledge of planners that involved in sectorial planning for land development.

Comprehensive rational planning theory acts as a procedure and declares that "the planning theorist depends on first-hand experience, reflects upon it, and puts it into context" (Faludi, 1978). It is centered on decisions and principles based on reason, logic and scientific facts with little or no emphasis on values and emotions. This theory is based on the rational comprehensive model (RCM) considering the assumptions that are inherently consistent, interactive combined into the complete rationality and systematic synthesis as internal requirements and became the mainstream regulation for a long time planning theory. This theory also realized the transition from design art to rational science in the transformation process (Taylor, 1998) and considered a normative (theoretical) model which values higher rationality in the face of multiple organizational and political pressures (Lagopoulos, 2018). This theory is also based on a holistic model of the land use system, the system forecasting as whole, stratified according to ranked sub-models and providing the support for the plans as model of spatial system considering the design aspect in spatial planning (Lagopoulos, 2018).

Communicative planning theory is alternative to classic rational planning theory as *"the theory of communicative action"* (Habermas, 1984) and meet the need to improve the level of planning implementation (Innes, 1995). In communicative planning theory, decision making process is conducted based on the communicative way as *"communicative rationality"* that interaction involving collective reasoning, argumentation, and analysis which is developed as unified vision of reality, social integration, group solidarity and coordinated action (Habermas,1984). Based this theory, planning is undertaken by communicative action to achieve a greater public good and promotes democratic principles in decision making and more accurately reflects the pluralistic nature of society (Murray, 2005). Rationality for decisions or actions within communicative planning paradigm is constructed predominately through techno-scientific analysis and deductive logic and through the prevailing voices which appeal to those forms of knowing/reasoning (McGuirk, 2001). This theory set out to reconstruct planning's decision making process to create an inclusive approach that is more reflective and heterogeneous (Healey, 1997) and powerful interests within community as local elites (both interest groups and individuals) utilize their influence to bias outcomes in decision making processes (McGuirk, 2001; Bradshaw, 2003).

Local elites express power (government bodies) through political channels that produce policy influence enduring agreements between involved stakeholders (Brown, 2002). The local elites also use their power for controlling what type of information is introduced and what alternatives are open for discussion that affects outcomes in decision (Buchy & Race 2001; Parkins, 2002).

Sustainability planning theory has a holistic outlook for integration of the goals of the three Es (Economic, Environmental and Equity concerns) into an organized coherent system for a long-term objective formulation and plan implementation (Wong et al., 2008). This theory is based on the sustainability concept consideration and applied in spatial planning by means of systematic and organized land use activities. So, spatial planning is carried out with long-term development perspective in the decision making process for preparing land use plan. Spatial planning has conducted in isolation process, as the stretching and deepening of global-scale processes has exerted intricate interaction and reaction in one way or another on local scales (Wong et al., 2008). The process of spatial planning considered the manner of land use and the spatial structure of land and the economic value of each piece of land. In this regard, emphasizing the efficient use of land in sustainable development approach presented a new perspective on land use planning as a strategic issue. Therefore, land use planning is one of the key components of sustainable land management which reduces the pressure on land resources (Khademi, 2019).

The evolution concept in the land use planning is reviewed as follows:

Conventionally, land use planning was conducted by the technical approach as the first model of land use planning where the planner acts as leader (Poccock & Hudson, 1978). It is an expert driven approach where LUP has been carried out by the technician or team of technicians. The expert is involved in the specific project for sectorial planning/land use planning. This approach followed the procedural planning concept with modernist theory in rational manner with the assumption that the best possible solution of problem was to be optimized in the planning process (GTZ, 1999; Iorliam & Ogwuche, 2014). The expert driven approach of LUP also considered the planners as the value neutral, apolitical technical expert acting for the good of the community as well as national interest and closely associated with the judgment of the expert without involvement of the politicians' interests (Iorliam & Ogwuche, 2014).

On the basis of post modernist theory, LUP is carried out in top-down approach in which plan formulation is based on planning strategy as proactive in logical way at high level in new endeavors (Ray & Ganguly, 2009). In top-down approach, the set of criteria and indicators are defined by the expert (planner) based on previously completed works and policies; then planner carried out LUP with modification of these set of criteria according to local situations (Prabhu et al.,1996; Khadka& Vacik, 2012). In top-down approach, technical factors are only considered rather than social factors and decision on land use plan carried out by the technical and or bureaucratic person based on the political priorities. So, there is lack of legitimacy and ownership in the eyes of stakeholders and local people (Khadka & Vacik, 2012). Top-down approach also considered the several guideline for formulating the lower level plan, and cascading with upper level plan.

Comprehensive land use planning (CLUP) is an instrument for spatial planning developed on rational planning theory towards balanced regional development and physical landscape (Metternicht, 2017). CLUP is conducting through strategic planning concept as periodic plan and or master plan considering rational territorial arrangement of land uses to meet the balance demands of people for development and protect local environmental conditions. CLUP is applied for optimization of landscape structure in terms of infrastructure construction and land use system for land development within limited territory. Generally, CLUP is used for detailed analysis for the most beneficial land use arrangement and development activities (Metternicht, 2017). In CLUP, special land use zones are allocated for proper land use harmonized with sector development plans (GIZ, 2011) with a view to improving the spatial composition in territory based on public needs (Kavaliauskas, 2008). The land development plans are prepared that address both land use zone and infrastructure development guideline with land use policies and strategies for increasing multi-sectorial coordination through law enforcement (Metternicht, 2017).

Participatory land use planning (PLUP) is bottom-up approach of planning process based on the dialogue amongst stakeholders which aims the negotiation and decision for allocation of land use (Yong, 1993; Schewedes & Werner, 2010). PLUP follow the communicative planning theory based on interactive discussion with local communities and determine how to manage land in their locality. PLUP conduct in motion social processes of decision making and consensus-building concerning the protection of private, communal or public land use (GTZ, 1999). PLUP is guided by planning goals and its objectives based on the understanding of problems and constraints, available resources, and development demands for local community and environment (Schewedes & Werner, 2010). In PLUP, local indigenous people and community knowledge is used to choose methods, circumstances, procedures and tools in planning process. In PLUP, the planner provides technical support as the role of facilitations for providing technical knowledge about planning guideline for its necessity and advising local people in community to make decisions on their choices on allocating land use. Land use options are confirmed on demands of markets and the community needs (Yong,1993).

Risk sensitive land use planning (RSLUP) is planning that integrates risk reduction, to allow communities to find the right mix of both development and risk reduction (Sudmeier-rieux et al., 2015). RSLUP adopts the comprehensive rational planning theory and incorporates the risk reduction activities for infrastructure development and allocation of land use in planning process. RSLUP identifies the safest areas in order to prioritize immediate investments in development of land and infrastructure (GTZ, 1999). In RSLUP, the land use plan is prepared through collaboration with local people and involvement of stakeholders within the community. So, RSLUP carries out participatory approach that utilizes information related to potential hazards and resource constraints within the area and develop more risk resilient settlement and infrastructure development considering risk reduction practices (Burby et al., 2000). RSLUP considers fragmented approach to disaster risk reduction (DRR) practices that emphasize on preventive measures on spatial planning in long term investments (Johnson, 2011).

Agenda 21 (1992), described the integrated approach of land use planning that finds expression in the coordination of the sectorial planning and management activities concerned with the various aspects of land resources. Integrated land use planning (ILUP) approach is designed to achieve sustainable land development through integrating various elements of landscapes and constructing comprehensive view of landscape and sectorial development activities involving multiple stakeholders (FAO, 2017). ILUP promotes the interaction among land users, political decision makers, professional and technician expert for the documentation of land use plan (Kutter & Ulbert, 2009) and focused on the long-term rational utilization of natural and cultural-historical resources (Izakovicova et al., 2018). ILUP is applied for efficient land allocation and anticipating competition for land resources (Metternicht, 2017). The effective land allocation of specific land use is conducted on the multi-functionality of the land system through efficient supply of multiple ecosystem services for sustainable land management (Ziadat et al., 2017). ILUP is considered as geo-ecosystem with natural, human, cultural, historical potential and social development. In ILUP process, the assessment of land use is carried out for optimal land use based on the interaction between natural capital, represented by the supply of natural regional resources and environmental conditions to meet the demand represented by community need for development (Izakovicova et al., 2018). ILUP is used to minimize conflicts, to make the most efficient trade-offs and to link social and economic development with environmental protection and enhancement for achieving sustainable development (Ting & Williamson, 2000; UNDSD, 2000; Abwe, 2015).

2.1.4 Methods, Tools and Model in Land Evaluation and Land Use Planning

Some statistical methods, tools and models used in land evaluation for land use planning process are reviewed as follows:

Logistic regression model (LRM) is traditional techniques in predictive modeling using the dependent variable as a binary presence or absence event for the two periods of images/variables. The logistic function gives the probability of changes in dependent variable as a function of the explanatory variables. The probability of changes in the dependent variable for each pixel is a function of the values that the other variables have for the same pixel. The logistic function gives monotonic curvilinear response bounded between 0 and 1 (Schneider & Pontius, 2001). It can only model a single transition at a time. It is used to assess the relative significance explanatory variable on dependent variable in first period and to predict the probability of dependent variable in second period based on the transition occurred in the first period (Eastman, 2009).

Geographically weighted regression (GWR) is a predicting model as a spatial extension of multiple linear regression models by considering the spatial variability of subsidence factors (Blachowski, 2016). It is used to model the relationship between one variable as subsidence and another variable as explanatory variables. It is also used to explore and analyses the spatial distribution of variables by fitting a regression equation to every point in space. It provides a local model of the analyses or predicted phenomenon (dependent variable) and identifies the coefficients of variables at each location. In this method, the assumption is that these relationships are consistent geographically take into account the spatial locations of features, permitting the estimated parameters to vary locally, and better reflecting the spatially varying relationships between the dependent and independent (explanatory) variables. In addition, the GWR method is used in studies of economic, social and environmental phenomena that show spatial variability (Blachowski, 2016).

Some optimization methods, tools and model used in land evaluation for land use planning process are reviewed as follows:

Spatial optimization model (SOM) is used for sustainable land use allocation by addressing the variety of sustainability aspects (contiguity, compactness, connectedness, and infill development) with the spatial characteristics mainly in urban area at the regional scale (Ward et al., 2003). It produces fractions of land use to aggregate spatial units, and assigns the specific land use proportions to finer grained spatial units based on several local scale suitability measures. It is also used to measure sprawl development (density, continuity, concentration, clustering, centrality, mixed uses and proximity) and utilized in spatial optimization process in land use allocation. It solves the multi-objectives as maximization of single use clustering, density maximization, contiguity maximization and cost minimization for land development in land allocation process. It allocates land use zone (rural residential, urban residential, commercial, industrial, recreational and special use) and aggregates planning units based on population projections in sustainability manner (Ligmann-Zielinska et al., 2005).

Mathematical programming interactive process is developed to evaluate different land use strategies and translated in the land allocation process for preparing optimum land use plan (Lu et al., 2004). It is applied in LUP as seeks the combination of land uses that optimizes one or more objective functions subject to a series of constraints (Chuvieco, 1993). Also, it compromises between the maximization of the gross margin and the minimization of the expected risk for a land use plan (Giupponi & Rosato, 1998). It has required interactive programming with an exchange of information between the decision-maker and the system (Malczewski & Ogryczak, 1995). In LUP, mathematical programming is used to maximize the compactness of areas having similar land use and to minimize the development cost of a land use plan (Aerts et al., 2003).

Multi-criteria evaluation (MCE) is designed as an interactive and flexible tool in geographic analysis and well-suited for modeling complex suitability analysis with considering the sustainability issues (Raddad, 2016) using quantitative techniques. It is considered as the decision maker's own choice, criteria, weights and assessments of achieving the objectives (Malczewki, 1999). So, it is conducted based on the identified criteria with its weight and standard rating. It is used in land suitability analysis by handling large amount of complex information in a consistent way. Also, it is applied to identify a single most preferred option, to rank option, to short-list a limited number of options for subsequent detailed appraisal or simply to distinguish acceptable from unacceptable possibilities (Malczewski, 1999). Likewise, MCE models is used in the decision making process to determine an optimal solution on the basis of an explicit set of objectives decided upon by a decision maker or an expert group (Aronoff, 1993). The optimal solutions are recommended through the set of alternatives that satisfy the largest extent of the expert group objectives. Similarly, it is used in conflict resolution of land use for its allocation in land evaluation process incorporating a wide range of information by manual aggregation or subjective to high levels of human error (Malczewski, 1999).

Analytical hierarchy process (AHP) is an effective technique used in MCE process that helps planners to analyze all data before arriving at a final decision for future land use transformation (Abdi et al., 2009). AHP integrated with GIS tools is used to identify the importance of the competing factors using pairwise comparison of factors/criteria in suitability evaluation (Banai, 1993; Eastman, 1995; Jun, 2000). The factors/criteria are arranged in a hierarchic order as performance matrix; the numerical values of each factor scaled on the basis of relative importance and synthesized with other factor in the expert subjective judgments. The performance matrix is generated by reciprocal pairwise comparison in which each row describes an option and each column describes the performance of the options against each criterion. Each factor parameter classes have been ranked by a 9-point rating scale in the entries on the performance matrix as developed by Saaty and shown in Table 2.1 (Saaty, 1977; Shahabi & Hashim, 2015).

AHP is used to compute the influence weight of each influencing factors/criteria in any subject and problem as a network of criteria, sub-criteria, and options in clusters together (Shahabi & Hashim, 2015). AHP provides numerical weights of criteria in quantitative or qualitative alternatives that constitute subjective judgments in decision process. Computed weight is tested by measuring maximum principal eigenvalue and number of orders in performance matrix (Alonso & Lamata, 2006) within acceptable limit on the basis of consistency ratio (CR). The CR represented the probability that the judgments generated randomly in the performance matrix with acceptable level of consistency (Alonso & Lamata, 2006). If the CR values is greater than 0.1, the AHP model automatically rejects the computed weight in the performance matrix (Shahabi & Hashim, 2015). After testing the consistency ratio, the weight of factors has considered as final and maintains the factor weights sum to one, which is essential in score computation in land suitability evaluation (Eastman, 2006).

Table 2.1: Pairwise Comparison Rating Scale

Intensity of importance	Description	Suitability class
1	Equal importance	Lowest suitability
2	Equally to moderate importance	Very low suitability
3	Moderate importance	Low suitability
4	Moderately to strong importance	Moderate low suitability
5	Strong importance	Moderate suitability
6	Strong to very Strong importance	Moderate high suitability
7	Very strong importance	High suitability
8	Very strong to extremely importance	Very high suitability
9	Extreme importance	Highest suitability

Source: Saaty, 1977

Multi-criteria decision analysis (MCDA) is used to facilitate the consideration of multiple criteria by decision makers in decision making process by aggregating multiple policy objectives (Marsh et al., 2016). It is used to logically evaluate and compare multiple criteria that conflict to make the best possible decision for appraising alternatives on individual, often conflicting criteria, and combining them into one overall appraisal (Keeneey & Raifa, 1993; Belton & Stewart, 2002). In MCDA, a number of factors for describing problems are arranged in a decision tree, selecting method from mathematical programming and heuristic algorithms and optimized multiple goals based on weighted addition of criteria values, attainment of criteria thresholds, or outranking of alternatives (Greene et al., 2011). Each criterion considers the relative weight reflecting its relative importance in decision context. The subject of the evaluation is scored according to criterion preformation. The aggregation of the scores is received for each criterion multiplied by their relative weights results in a composite score using weighted linear combination (WLC) operation. The scores of each alternative option can be compared to improve the objectivity, transparency and consistency of decision making (Inotai, 2018). Finally, MCDA aids decision makers in analyzing potential actions or alternatives based on multiple criteria, its aggregation rules and rating the possible option with alternatives rank (Eastman, 2009).

Some of the simulation based methods, tools and models used in land evaluation for land use planning process are reviewed as follows:

Spatial simulation method intends to examine the land use option based on projected land use system in land use allocation process. It is used in the genetic algorithms for land suitability analysis (Mathews, 2001), and applied optimization purpose for land use allocation in decision making process (Matthews et al., 1999). The procedure used in the land use optimization is based on simulated iteration and considering the energy function in terms of carrying capacity, environmental impact and development for allocation of specific land use (Mart et al., 1998; Alier et al., 1996; Aerts & Heuvelink, 2002). In simulation process, region/locality is also incorporated as a set of land use option and extrapolated alternatives based on suitability criteria and predefined growth rules in decision making process of LUP.

Cellular automata (CA) were developed by Ulam in the 1940s and used by Von Neumann (1949) to investigate the logical nature of self-reproducible systems (White & Engelen, 1993) as simulation model. CA is defined as: Cellular automata are simple mathematical idealizations of physical systems in which space and time is discrete, and physical quantities take on finite set of discrete values (Karna, 2013). It is an effective bottom-up simulation tool for dynamic modeling process, and provides a laboratory for testing the decision making processes in complex spatial systems (Cheng, 2003). It is used for the exploration of complex adaptive systems (Torrens & O'Sullivan, 2001) and different from top-down (macroscopic) approaches (Webster & Wu, 2001). It operates on a grid-based cells and transition rules that are applied to determine the state of a cell. The system consists of five elements; cell (lattice), cell state, neighborhood, transition rule and time (Barredo et al., 2003). Cells are the smallest units that must manifest some adjacency or proximity. The state of a cell varies based on transition rules as neighborhood functions. The neighborhood is central to the CA paradigm and especially useful tool for modeling urban spatial dynamics based on time period and encouraging the results that documented (Deadman et al., 1993; Batty & Xie, 1994; Batty & Xie, 1997; White & Engelen, 1997). The transition rule with CA model has a unique approach for simulation of rural-urban land conversion in fast growing metropolis (Wu, 1998). Multi-cellular automata using more than one CA transition rule has been used and implemented in GIS environment (Rinaldi, 1998).

Some of the GIS based other methods, tools and model used in land evaluation for land use planning process are reviewed as follows:

An expert system is knowledge based process that is designed to solve complex problems and provide decision making ability like a human expert (Diamond & Wright, 1988). It is a complex process for determining the selection of suitable location for specific land use through multiple decisions that relate bio-physical condition, socio-economic status and institutional arrangement (Teso, 1997). It is used to evaluate the suitability of several land use to select the optimum land use as the best option (Yialouris et al., 1999). This system allows to planners for designing a specific model that obtain a suitability map for each land use (Zhu et al., 1996) based criteria used in the model. Another application of expert systems is the selection of the best location for diverse facilities and solving location-allocation problems based on formulated criterion (Jun, 2000). In LUP, the expert system is developed for land use allocation dealing with spatial problems in land management, regional planning, etc. (Teso, 1997). Boolean logical model is a method to find out the suitable location with Boolean operations. It involves the logical combination of binary maps resulting from the application of conditional operators (Bonham-Carter, 1996). Generally, the operators AND, OR, XOR, and NOR are applied in evaluation process based on the input criteria to the output on binary condition (Bhowmick et al., 2014). The result from binary condition is only either 1 or 0 values to each unit area, whether it is satisfactory or unsatisfactory, respectively. Boolean logic is easy and not time consuming, so it can be used as first estimations for the best locations (Bonham-Carter, 1996; Riad et al., 2011). So, Boolean operations-based GIS model is a simple model (Bhowmick et al., 2014) that used to find suitable location through performing analysis using either query functions or generating map in spatial analysis.

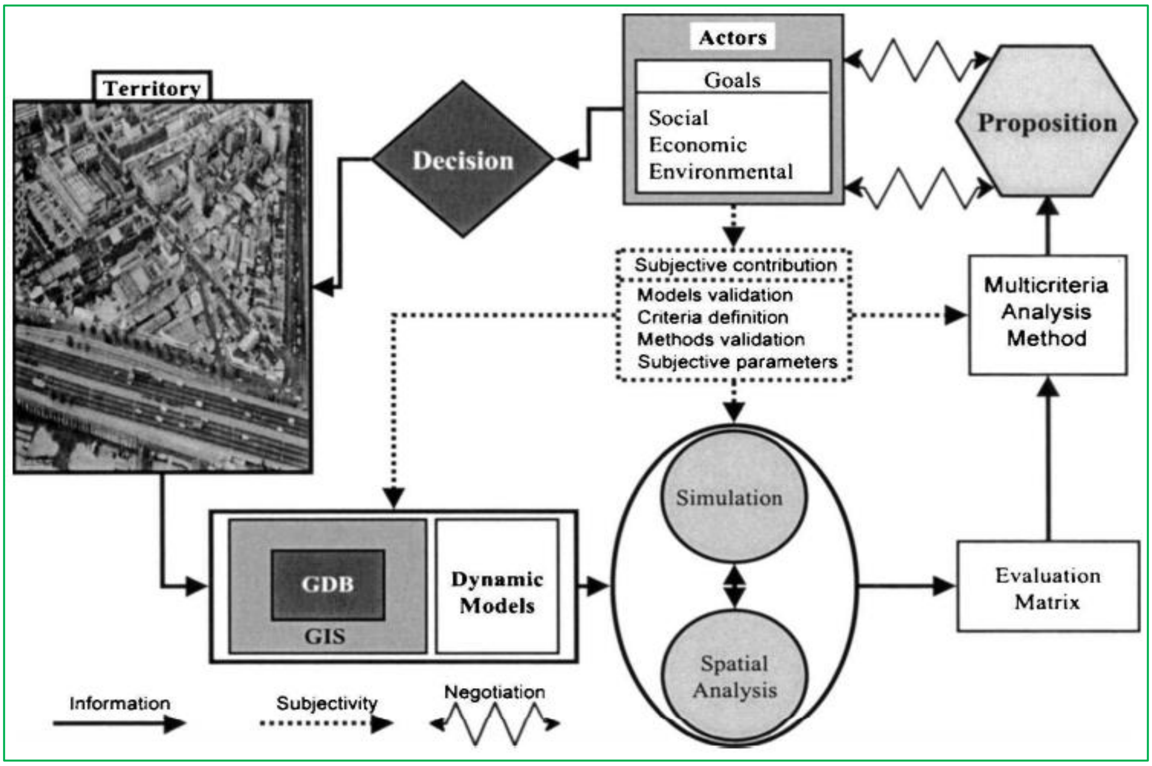
Fuzzy logic model (FLM) is the rule-based model, i.e. the collection of fuzzy rules describing a system, and integrated in a computing framework on the concepts of fuzzy set theory: the fuzzy inference system (Bosma, 2007). It is used to select the most suitable location with spatial and non-spatial data (Bhowmick et al., 2014) in land evaluation process. It deals with variables having linguistic values (i.e. human-interpretable) and their inference system is designed with linguistic uncertainty for making more appropriate in decision making (Bosma, 2007). In this model, fuzzy logic in the form of many valued logic deals with reasoning that is approximate rather than fixed and exact. The linguistic values associated with each variable is defined with the overlap of membership functions. The fuzzy membership values lie in the range (0, 1), but there are no practical constraints on the choice of fuzzy membership values (Bonham-Carter, 1996). Fuzzy logic system is able to adjust the probability values assigned to different parameters (Bhowmick et al., 2014).

Artificial neural network (ANN) is a dynamic model based on dependent/independent variable for machine learning process that provides a flexible way to achieve generalized linear regression functions (Venables & Ripley 2002) using the feedback propagation algorithm in qualitative or quantitative process. The back-propagation algorithm is used in layered feed-forward ANN models (Rumelhart et al., 1986) and provides a way to get these parameter values automatically (Li & Yeh, 2001). It is based on searching a performance surface (error as a function of neural network weights) using gradient descent for points with minimum error (Nefeslioglu et al., 2008). This error is then feedback (back propagated) to the neural network and used to adjust the weights to reduce error in each iteration process that gets closer to producing the desired output (Mas et al., 2004). In ANN, cross-validation is used to avoid the model over fitting in iteration process and average of the N-fold iteration results for the final result (Siljandar, 2010).

Decision support system (DSS) is a customized tool to design an interactive and flexible computer-based system to support specific users in achieving a better and more effective decision making while solving some problems at spatial level (Roy, 1996). DSS tool simulates the varied scenarios based on different potential factors and constraints, and decisions can be used to help practitioners make better decisions. It assists the planners as guidance and works as a reference frame while making decision land use planning (Wang & Zou, 2010). It includes knowledge based system that serves the process of management, operation and planning suited in complex sustainability issues for geographic analysis (Roy, 1996). It also helps to improve planning level and makes decisions rapidly without changing any rules not specified in advance. Generally, it is used for solving spatial problems based on the integrated expert knowledge and ability for supporting spatial data (Hao, 2013).

Land allocation decision support system (LADSS) is a decision support model developed for agricultural land use planning at The Macaulay Land Use Research Institute, UK (Matthews et al., 1999). It is a farm-scale integrated modeling framework (IMF) that is being developed in order to simulate whole-farm systems as a land use planning tool in the early 1990s. It has expanded beyond its original remit to focus much more on deliberative processes involving decision makers and other stakeholders (Cerreta & Toro, 2012). The LADSS framework is biophysical simulation model that provides a basis for the impact assessment of land use systems through changing in policy and environment. It has been designed to assist the decision making process involving the groups of stakeholders to explore options with a better understanding of the consequences of changes in land use and management. An integrated assessment approach is preferred in LADSS that enables to combine DSS with deliberative processes involving stakeholders (Cerreta & Toro, 2012).

MAGISTER (Multi-criteria analysis and GIS for territory) is a decision support model suited for land use planning (Joerin, 1997). The main objective of MAGISTER is to help land planners to 'translate general policy statements into concrete localization decisions' (Geertman & Toppen 1990; Joerin et al., 2001). It is a conceptual combination of qualitative and quantitative tools used in land use planning to assist land use planners in the form of descriptive and analytical needs with integration of necessary data syntheses Figure 2.7.

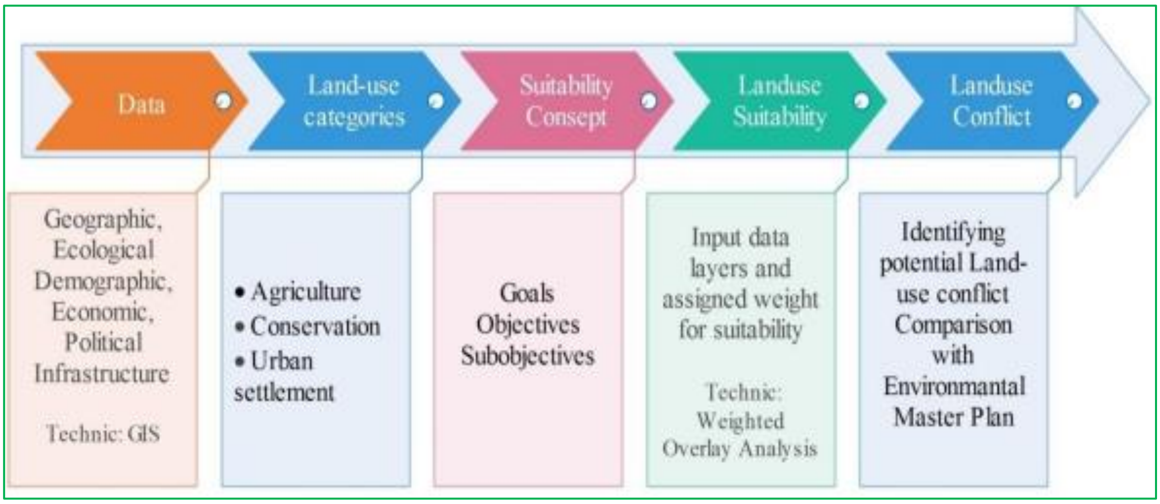


Source: Joerin et al., 2001

Figure 2.7: MAGISTER's Model

It is similar to DSS and includes three main components: a database management system, a set of models, and a module for the evaluation and selection of the alternative solutions. In MAGISTER, GIS is used for the detailed analysis of criteria's map in spatial decision context, ELECTRE-TRI algorithm applied for ranking the criteria's, and MCDA used to compare the set of identified alternatives and complex decisions solved within a short period of time from comprehensive set of criteria using quantitative tools for land use suitability maps. The decision support procedure is specially adapted to the local context (geographical region and scale) and to the given problem. It enables and promotes the participation of all secctors (e.g. decision- makers, neighbors, and lobby-groups) and experts (specialists using GIS, models, and MCDA) in the decision process (Joerin et al., 2001).

Land use conflict identification strategy (LUCIS) is a model developed by McHarg that identifies areas most suitable for specific land uses as well as where land uses could potentially conflict (Carr and Zwick, 2007). It is the areas of potential conflict where LUCIS can help to build multiple future land use and development scenarios, guided by different policy decisions through overlay techniques of layers in GIS environment. LUCIS model is developed in the ecological planning framework with consideration of physical and social variables in decision making process by probing in terms of their economic benefits. The stages used in LUCIS model are presented in Figure 2.8.



Source: Carr and Zwick, 2007

Figure 2.8: Stages of LUCIS Model

LUCIS model is adapted in the context of change in landscape pattern. The change in landscape pattern is considered as baseline for affecting and affected land use. These land uses are: agricultural areas (affected), conservation areas (affected) and urban settlement areas (affecting). Within the scope of the variables affected all three land uses (geographical, ecological, demographical, economic, political and infrastructure), for each of land use category, goals, aims and sub aims is defined, and then the suitability concept is developed through the weighted rates of each land use and obtained the suitability map for agricultural areas, conservation areas and urban areas (Gormus et al., 2017). Based on land suitability maps and land use priority, the conflict between urban settlement, agricultural lands and conservation lands is resolved through overlay of suitability map. Finally, the allocation of proper land use is carried out with high priority level in suitability map through visualization in decision making process. Integrated spatial assessment (ISA) is a decision making system that focusing on the assessment of territorial effects of planning options and integrating the information deriving from "*expert knowledge*" and "*common knowledge*" (Girard et al., 2005). ISA framework has tried to define possible actions and limiting conditions of development and enhancement of territory. It has considered the effects of plan and programs on economic and social contexts meeting with the concept of sustainable development. Thus, there is necessary to develop evaluation tools for every sector of investigation (specialized analyses) and evaluation methods in order to integrate the results of every discipline (integrated assessment). From this point of view, decision making process is designed as the integration of five systems: information, participation, planning, assessment and monitoring. Generally, an integrated process of sustainable planning is designed with a decisive role the elaboration of an adequate information system (data collection, identification of indicators, construction of a GIS, use of simulation models, etc.), the involvement of all stakeholders (public, private, social) interested to the plan, and the assessment of the proposed actions *(*Girard & Toro, 2007).

Some tools used in land evaluation for land use planning have been compared in terms of characteristic features of such tools as described in Appendix-1. In this research, logical regression was used for projection of population, entropy trend and different LU classes. Fuzzy logic method was used in landslide susceptibility analysis and fire risk assessment. Multi-criteria evaluation was applied in land suitability evaluation for different LU class. Cellular automata were used for simulation of land use for planning year 2037. Likewise, multi-criteria decision analysis was used in land use planning process.

2.2 Empirical Researches on Land Use Planning

This section provides the review of empirical researches as case study related to the land use pattern, land suitability evaluation and land use planning.

2.2.1 Researches on Land Use Pattern

Land use and land cover change analysis was carried out in an integrated framework describing the structure, land form using spatial overlay and multiple regression tool to determine pattern, pathway, magnitude and drivers of LULC in GIS environment. The changes of forest and shrub land into cultivated land took place in the lower and middle parts of the watershed with higher magnitude rate, whereas the area covered with forest and shrub was increased slightly and continuous trend of increasing forest in the upper part of the Madi watershed. The population growth, farm employment, education, health facilities were some causes for migration of people that acts as drivers of LUCC and significant impact on pathways, magnitude and pace of LULC changes (Khanal, 2002). Likewise, land use change analysis was conducted using satellite remote sensing, GIS and Markov Chain modeling in terms of stochastic process. The changes from one land to another land were described mathematically in the quantification way as probabilities of given pixel through LUCC matrix. The changes of urban or built-up land and horticulture farms was increased notably while cropland decreased for urban land development. But, the occurrence of the land use change and its trend pattern did not follow stable way (Weng, 2002). Similarly, land use changes occurred by human activities and socio-economic situation. The human activities and socio-economic data were analyzed through bivariate statistical analysis linking the causative driving factor with occurred land use changes. The industrialization, urbanization, population growth and economic reforms were the major causative driving forces contribution to land use change (Long et al., 2007).

Land use change detection analysis was conducted using supervised maximum likelihood classifier from satellite images along with spatial overlay function and quantification with cross-tabulation technique in GIS environment. The change detection analysis was used to assist in identifying the total change, its trend and rate of change in two period. Land use changes occurred mainly through increasing rapidity of built-up area surrounding to urban area and a reduction of agricultural farm land. The predicted land use followed the continuous trend and seemed to be concentration of development at the city center rather than expanding towards the outskirts (Zubair, 2006). Likewise, comprehensive LULC analysis conducted through integration of RS satellite image, GIS and land change modeler (LCM). LCM were used to understand the characteristics of LULC change and applied for quantification land use change and determination of transitional potential of land use classes in land change modeling; and projecting future LULC pattern (Paul, 2013). Similarly, land use change monitoring and modeling was used for LULC assessment and its dynamic process. The orchards, croplands, evergreen forests, rice field, and urban settlement areas were increased while deciduous forests and wetlands were decreased. Also, the deciduous, evergreen and orchards were acted as major drivers for LUCC and occupied in dynamic natures (Chaikaew, 2019).

Urban growth and land use change analysis carried out in Pokhara Sub-metropolitan city in Nepal Himalaya in holistic approach. The dynamic land use changes occurred in urban area with residential area increased rapidly whereas commercial area moderately and industrial area in nominal scale; however recreational area and open space area decreased in higher rate, vegetation and farm land moderately (Paudel, 2008). Likewise, the impact analysis was conducted on LUCC in relation to internal migration and human settlement in Lamjung district (middle mountains area) of Nepal.

LUCC analysis was conducted with Landsat images using support vector machines (SVM) algorithm. The internal migration pattern of household data were analyzed from focus group discussion for interaction with local communities. The fragmentation analysis was conducted with FRAGSTAT software and impacts on different human settlement through LULC using ArcGIS and FRAGSTAT software. The results reveal that forest land increased in higher elevation by decreasing cost of agriculture and shrub/grass land whereas forest land decreased in lower elevations by increasing agriculture and construction area (KC, 2015).

Land use change analyses were conducted based on spatio-temporal characteristics, patterns, and causes of land use as a dynamic regionalization method. The cropland decreased in the south and increased in the north, but the total cropland area remained almost unchanged in China. Initially, wood land decreased and then increased, built-up lands expanded rapidly, and grass land continued decreasing pattern. The dynamics of LUC were included as accelerated expansion of built-up land, shifted land reclamation, continuous transformation from rain-fed farmlands to paddy fields, and effectiveness of development activities (Liu et al., 2014). Simulation analysis of the land use patterns based on auto logistic method was used for predicting probability models of urban land use pattern with the application of auto logistic regression coupled with GIS. The spatial autocorrelation was used as tool of auto logistic regression based on land use types in urban area considering spatial land use pattern, terrain characteristics and infrastructural conditions. Urban land use patterns in terms of cultivation land, forest land, construction land and virgin land were simulated in appropriate location in using auto logistic probability model. The results showed to understand and explain the causes, locations, consequences and trajectories of urban land use change, and provide a great support service for land use planning and policy making activities (Wu et al., 2009).

As discussed above, the land use change analysis has been done using statistical/geostatistical with regression, probability matrix, and bivariate analysis; mathematically with the +-tabulation by spatial overlay in GIS and fragmentation analysis; and model-based system using LCM, Markov Chain. In this research land use changes and its pattern were analyzed through LCM in both quantification and descriptive way with spatial overlay in GIS. Also, the patterns of land use were presented spatially in maps. The aim of land use pattern is used to evaluate and identify the influencing factors as parameters for land suitability evaluation and allocation of land use. Likewise, it is attempted to project the future land use trend with its compactness of built-up feature. These future trend with its compactness helps for generating and developing infrastructure plans for land development.

2.2.2 Drivers and Factors for Land Evaluation

The drivers and influencing factors were incorporated the existing bio-physical (natural and manmade) condition of land, socio-economic status, cultural aspects to support spatial decisions in the land suitability evaluation and land use planning processes. The external forces and internal factors were used as drivers mainly concerned with the physical, social, economic, environmental and hazardous risk condition (Khanal, 2002). Existing land use, slope, distance to river, and streamline, density of greenery surface (intensity of vegetation), distance to pollution center, distance to road network, and distance to residential areas were used as parameters in industrial site selection (Dia et al., 2008). Population growth rate, government policies in land use and land right, land value and taxation, use of labor force, trade and industry, transportation facilities, use of technology, and environmental hazards (diseases, landslides and floods) was used as drivers of land use and land cover change (Khanal, 2002).

Similarly, the physical surface water parameter as normalized difference water indices (NDWI), normalized difference vegetation indices (NDVI), soil penetrability, soil fertility, slope, foundation capacity, resistant land use information and landscape value have used as factors in spatial analysis for urban expansion (Yang et al., 2008). The erosion, soil hydrology, soil depth, soil structure, soil texture, vegetation type, vegetation density, rainfall, temperature, slope, elevation, land use, distance from urban (population) centers and distance from water surface (stream/lake) have used as criteria for determination of range lands as forest land use (Jafari & Zaredar, 2010). The existing land use, population, rainfall, settlement, elevation, NDVI and availability of road facilities have used as influencing parameters in the scenario model for allocation of forest and agriculture land use in Aswa Basin, Northern Uganda (Nyeko, 2012). Soil load capacity, disaster/risk, noise and air pollution, topography (slope), proximity to settlement, proximity to service facilities, proximity to road, proximity to water and sewerage system and proximity to business area have been used as factors for residential use. Similarly, soil load capacity, disaster/risk, slope, proximity to business area, proximity to road, proximity to road crossing, proximity to settlement and proximity to water and sewerage system have been used as factors for commercial use. Likewise, soil load capacity, far from settlement area, slope, proximity to road network, and proximity to water and sewerage system have been used as factors for industrial use (Tims, 2009).

Topography, geology, climate, soil, hydrology, pollution (noise, air, water and light), political boundary, land ownership, easement, registration system, land use regulation and guideline, population, employment, neighbor community influences, production (local gross domestic product (GDP), consumption (property value, rent), cultural values (aesthetics, visibility, visual quality, local environment, architectural styles, landscape, historical features (historical building and landmarks), archeological sites, former and current land uses pattern, transportation (road, traffic volume, internal circulation), and service utilities (sewer, electric, transport hub, medical center, open space) have used as factor in planning support system (PSS) for renewal urban land evaluation (Hao, 2013). Existing land use, slope, geology, hazard zone, land capability, geomorphology, population density, distance to road, distance to settlement and distance to stream have used as parameter for land suitability analysis in road network planning (Karna, 2013). Land use, soil type, elevation, slope, aspects, soil moisture, geology, drainage and distance from roads have used in land suitability model for agriculture production in hilly areas in Darjeeling district, India (Pramanik, 2016). Pollution noise, load area, soil contamination, polluted water flows, damage of vegetation, radio activity, nature reserve, protected zone of water resources have been used in the sustainable land use management process (Izakoviˇcová et al., 2018).

As discussed above, the drivers and factors used in land suitability analysis were varied in different physical, social, economic, environmental and hazardous condition. In this research, the common drivers and factors related with physical, socio-economic and risk situation were identified in similar planning area and relevant context. These identified drivers and factors were conceptualized through expert and stakeholders' interaction that represent the local situation. These factors or criteria are considered the parameters and applied in land suitability evaluation for specific land use that used in allocation of proper land use.

2.2.3 Researches on Land Suitability Evaluation

GIS-based geo-environmental analysis was used to address land suitability evaluation for urban site selection. AHP technique was applied to measure the appropriate weighted factors of criterions and evaluated the development suitability for each LU category using multi-criteria analysis (MCA) along with weighted linear combinations (WLC) algorithm in quantitative approach. The suitability map for each category land use (high rise building, multi-story building, low rise buildings, waste disposal and natural conservation) were determined having high functionality located in urban area (Dai et al., 2001). Similarly, suitability assessment for urban development was done by using GIS- based approach along with AHP process in the identification suitability site for the city on the perspective of engineering geology. The suitable sites for urban land use were mostly occurred within the city and falls into four classes of suitability (low suitable, moderate suitable, suitable and high suitable). The developed suitable maps were need to serve as a reliable base for effective assessment as the foundation for decision making process in urban development (Aly et al., 2005).

GIS based habitat suitability model was used to support strategic landscape evaluation and to provide a method for identifying sites for locating potential site of grassland restoration. Habitat suitability modeling was carried out by GIS based bivariate approach and fuzzy set approach to establish clear relationships between the occurrence of the potential area to be identified for managing landscape and enhance the conservation practices of grazing area (Burnside et al., 2002). Likewise, a fuzzy modeling approach as parametric model was applied in the land suitability evaluation in GIS environment that described the conceptual model appropriate to land management decisions for current and future land use to ensure its sustainability. The developed GIS based model was designed on the basis of land quality. This model was used for defining the land management units (LMUs) from available biophysical information. The model provided the cost-effective applications for the identification and assessment of homogeneous land units, using spatial data at a finer scale (Baja et al., 2002). GIS-based economic land evaluation system was applied for agricultural resources using a fuzzy set approach. The dynamic model of economic land suitability accomplished by assigning field survey data to land mapping units using spatial interpolation for major economic crops in a continuous scale. The unit costs for inputs and outputs were entered through the user graphic interface, allowing constant updates of economic values in the system. Scenarios of agricultural land use planning were formulated by users depending on policy or economic circumstances (Samranpong et al., 2009).

Spatial analysis system was designed for evaluating the suitability of urban expansion by incorporating RS, MCE-AHP based GIS, GRA landscape/ecological analysis and to resolve the uncertainty, complexity and hierarchy characteristics of suitability evaluation through both qualitative and quantitative techniques. The highly suitable areas waere found in low yield farmlands, no natural vegetation, poor landscape and average slope less than three degree. Also, spatial analysis system was used in environmental protection, land management and regional planning for the policy makers and urban planners, especially in developing countries (Yang et al., 2008). Karna (2013) land suitability evaluation was conducted for land use change and road network planning for sustainable urban development in Kirtipur Municipality, Nepal. GIS and RS with object-based classification techniques were used for creating LULC maps, land suitability evaluation for built-up area, agriculture and forest using MCE, AHP and GIS technique. AHP pairwise comparisons were used for computing of each criteria and generated each suitability map using weighted overlay spatial analysis function with MCE and GIS as quantitative tool. GIS based MCE helps planners to reduce complexity in planning and achieve more accurate results desired in decision making process (Karna, 2013).

The model of Dai et al. (2008) was used for evaluating land suitability for industrial land use planning and to minimizing negative impacts on the local environment. MCE within GIS technique was employed to derive a suitability map in quantitative technique. The derived suitability map was compared with current industrial land use to identify areas for relocation of current industries to incorporate qualitative evaluation in industrial site allocation process. The most suitable industrial site occurred surrounding to existing urban area, such type of ecological suitability evaluation applied in land use planning for industrial cities having similar environmental and ecological problems (Dai et al., 2008). GIS-based land suitability model was used in agricultural planning based on soil survey data using spatial analysis. In this model, GIS was used to classify and map the landscapes by studying the expressions of landscape structures and anthropogenic activities considering the four important aspects (landscape potentialities, suitability for different land uses, characterization of natural and anthropogenic stresses, and existing land use pattern). Soil data was interpreted based on land suitability and fertility assessment for agricultural land use in both qualitative and quantitative technique. The land units were identified as a potential area for crop diversification and delineated through linking crop response with the integrated nutrient management for various cropping systems (Bobade et al., 2010).

Land suitability analysis using multi attribute decision making approach was applied to examine the most suitable areas with different criterions for range lands in Darjeeling district, India. These criteria were selected from literature reviews of internal and external references, interviewing with experts (questionnaires) and availability of data. Suitability assessments were used for resolving different issues regarding environmental and economic land properties, and identified the suitable location of range land. The spatial GIS-MCE-AHP technique was used for decision making process (Jafari & Zaredar, 2010). Similarly, site suitability analysis for agricultural land use were conducted using AHP and GIS techniques to assess for agriculture in hilly regions. AHP with the integration of GIS-based multi-criterion decision making approach was utilized to evaluate land suitability for the development of agricultural productivity. The site suitability modeling was developed to establish appropriate and potential locations for agricultural development based on a group of constraints and criteria depending on their significance and importance (Pramanik, 2016).

As discussed above, land suitability evaluations were conducted based on issues of different land use using quantitative technique for agriculture, forest, built-up area, residential, industrial, range land and urban land use. These research works mostly used MCE based GIS in suitability analysis for site selection. Some research were also used fuzzy-based statistical model for landscape restoration and grazing land (Burnside et al., 2002). Also, fuzzy based parametric model using GIS was used for identification of the homogeneous land unit. Likewise, economic land suitability model used for agriculture land for crop monitoring. Ecological suitability evaluation model was applied in suitable site for industrial land evaluation for solving environmental and ecological problems. These research works did not include the risk layers as parameters in the suitability evaluation process. In this research, land suitability evaluation was conducted with MCE-GIS based spatial modeling approach using quantitative technique for determination suitability sites for agriculture, residential, commercial, industrial and forest land use considering the risk layers mainly flood, landslide, soil erosion and fire risk.

2.2.4 Researches on Land Use Planning

Multi-criteria decision making approach was used for the allocation of land use types in urban area at a regional scale using MCE-AHP process in GIS environment (Ullah

& Mansourian, 2015). Study on land suitability assessment of urban-rural planning was conducted to explore land use option in quantitative evaluation process for urban-rural planning. The developed process used to provide a reliable basis for the in-depth analysis and improve the decision making through objective evaluation. Comprehensive congruence analysis was used to allocate various elements rationally, in the most optimal location in urban-rural planning (Lingjun et al., 2008). GIS-based approach was assessed using multivariate variable for land use planning with the participation of local people. In this approach, land suitability assessment was carried out by GIS based multivariate approach based on the identified criteria from public participation base and provided the alternative option for different land use. The alternatives were acted as the technical basis for sensible land use planning, and incorporated the legal framework towards environmental conflict resolution, and improving the decision making process (Bojorquez-Tapia et al., 2001).

Participatory land use planning (PLUP) approach considered the local people perceptions strongly for land utilizations using PRA technique. Land use planning and analysis system (LUPAS) was developed using PLUP approach considering the guidelines developed by FAO in 1999. In LUPAS, land use types (LUTs) were determined using MCE-GIS tool, and socio-economic assessment conducted for each LUT's as socio-economic indicators. LUPAS system was used by decision maker to prepare land use plan considering feasible development and optimize goal. PLUP was applied for sustainable land use plan that fit local realities and aspirations (Trung et al., 2006). Also, socio-economic and gender analysis (SEGA) tools was developed by FAO in 2001 for PLUP framework. SEGA tool was designed to investigate land use problems, their causes, effects and possible solutions with the integration of GIS to get possible conflicts or synergies between different land use options by different ethnic groups in Burkina Faso in West Africa. Pictogram method was used to allocate alternative land use options using spatial analysis in GIS. Local knowledge and scientific idea were used to integration process for developing options of land use in discussion process and created concrete land use plan that fit for local realities (Hessel et al., 2009). Likewise, participatory GIS (PGIS) were developed and applied to evaluate the capacity of the general public and effectively contribute in land use planning outcomes through analyzing the mapping effort in consistency with land use zones and increased the spatial data quality (Zolkafli et al., 2017).

Urban land use approach was attempted in quantitative analysis for future urban land use scenario with the alternative scenarios using CA model. CA model was applied in simulation process in quantitative evaluation, whereas the driving forces of the urban sector was analyzed in qualitative based on the interpretation process of urban demand model in economy principle. Also, CA model included three steps: an interpretation of urban-development pathways with its alternatives; the development and application of a simple statistical model to estimate the future demand for urban land; and the development of rules to allocate urban demand geographically through the consideration of land use planning goals. Similarly, urban-demand model was included the two driving forces: the population, representing demographic trends and the demand for housing; and the gross domestic product, reflecting the economic level and dynamism. Likewise, the spatial patterns were also included three variables*:* accessibility to the transport network; the degree of restriction arising from land use planning policy; and the relative attractiveness (in terms of residential location choice) of small, medium, and large cities. The urban land use change model was based on a multilevel quantitative analysis that integrates theory and empirical evidence in modeling process. CA model was presented in the form of four urban land use scenarios as alternatives. The comparison of these alternative scenarios was analyzed in transparency manner for allocation of future land use in decision making process (Reginster & Rounsevell, 2006). Yu et al. (2011) land suitability simulation (LSS) model developed based on spatial multi-criteria evaluation (SMCE), and used in planning purpose. LSS has a dynamic process that used CA model for allocation of irrigated agriculture land with AHP–CA–GIS tool. In AHP–CA–GIS tool, the user allowed to modify model inputs as the adjustable parameter values for deriving different scenarios and practically applicable in decision making process. Also, AHP–CA–GIS model was applied to simulate an evaluation of irrigated crop for agriculture land. The resultant suitability map was compared with existing land use. The potential for irrigation expansion area for agriculture practices has allocated by optimizing land allocation and making better in land use planning decisions (Yu et al., 2011).

Girard & Toro, (2007) integrated spatial assessment (ISA) approach of land use planning focused on the aim to integrate territorial and environmental aspects within the elaboration of strategies and planning choices, while recognizing the important role of environmental effects within the decision making process and the selection of alternative options. In this approach, AHP based MCE has used for determination of susceptibility level for the localization from the used criteria; land use allocation assessed through the planning choices elaboration technique to define possible actions based on the alternatives land use and locate land use site from alternatives in decision making process within urban and territorial planning for environmental and territorial sustainability (Girard & Toro, 2007). Similarly, integrated land use planning approach was applied to assess for sustainable agriculture and natural resources management with the integration of both bio-physical and socio-economic data. Land use scenarios were formulated by number of criteria that set up for the suitability land use map in quantitative technique, and integrated the socio-economic driving forces in qualitative technique. Land use options and management measures were made upon land suitability analysis and the socio-economic data to secure the rural livelihoods with respect to restoration of degraded native ecosystems (Nguyen et al., 2008). Integrated landscape approach was designed to understand landscape with natural, human, cultural, and historical potential as a geo-ecosystem. GIS based MCA was applied for generating suitability factors map. Then the prepared factors map were integrated with the factual information of stakeholders' preferences, values, and associated impacts. Optimal land use plan was generated using spatial multi-criteria analysis (SMCA). SMCA were applied in decision making process with the interaction between the supply of natural resources and environmental conditions and the demand represented by community need. The integrated approach was focused on long-term utilization of land for urban development and land use planning (Izakoviˇcová et al., 2018).

Land use conflict identification strategy (LUCIS) model was designed using GIS model builder tool for comprehensive planning. In LUCIS model, suitability maps were generated from MCE-AHP process for land use categories then transformed into preference maps through normalize process. The preferences land use were compared with each preference map and ortho-image through spatial overlay operation in close consultation with the stakeholders and local people as public. In the overlay operation, conflict situation were raised as more than one land use categories occurred in the same preference value on the same location. LUCIS model was collapsed land use category class into the best land use class by comparing with land use preferences in decision making process through qualitative analysis for preparing land use plan (Tims, 2009). In planning process, LUCIS model was also used to show alternative land use scenarios based on priorities and conflicts arisen among stakeholders with the applicable decisions highlighted by showing spatial importance of the land use conflict (Gormus et al., 2017).

Morales (2013) comprehensive land use plan *(CLUP)* was prepared in proactive approach with both qualitative and quantitative techniques with population characteristics, physical resources, economic activities with income and service in Saint Bernard, Philippines. CLUP was assessed on integrated information planning system for disaster risk assessment and analyzed the relation with existing land use plan. The prepared CLUP was assessed through SWOT (strength, weakness, opportunity and threat) analysis for improvement and implementation of plan through interaction of stakeholder's and participation in decision making process (Morales, 2013). Planning support system (PSS) model was developed to support sustainable land use planning in urban renewal projects in the mixed qualitative and quantitative techniques. The qualitative technique was applied for data collection and validation of PSS at case study and experimental study while quantitative technique was used within PSS in decision making process for land suitability analysis and allocation of land use. PSS applied to solve land use conflicts with alternative by adjusting the relative importance raised by multi-stakeholders on the basis of preference and avoidance guidelines. PSS system facilitated to conduct the agreement between contending stakeholder in transparent and explicit way for competing land uses in transparent and explicit way (Hao, 2013).

As discussed above, GIS based MCE, MCE with FAO guideline and multivariate participatory decision making process were applied in preparing land use plan that fit local realities and aspirations with the involvement of local people and stakeholders. Likewise, CA, LSS based simulation tools were used for urban-rural land use and irrigated agriculture practices in planning process. These mathematical and statistical based tools were used in quantitative tools and spatial overlay process in decision making, whereas IAS and SMCA approach were used in land use planning as optimization process involving qualitative and quantitative tools. Similarly, LUCIS is model-builder using MCE-GIS model and used in comprehensive approach in land use planning. CLUP and PSS decision based tools are used in land use planning for allocation of land use using both qualitative and quantitative techniques to solve land use conflicts with alternative by adjusting the relative importance raised by multi-stakeholders on the basis of preference and avoidance guidelines. In this research, land use planning was conducted based on the CA simulation with MCE-GIS based model builder tool with integration of developing infrastructure and risk layers in comprehensive way using both qualitative and quantitative techniques. Also, refinements of land use plan were carried out by SWOT evaluation process with the involvement of local people and stakeholder, incorporating the raised weakness and threat in developed integrated land use plan that make plan more feasible, reliable and acceptance of local people.

2.2.5 Land Use Planning in Nepal

Nepal has not practiced land use planning for the country as a whole (Aacharya, 2011). In Nepalese context, there is initiation of land use planning programs at different level. However, several attempts were made for balanced use of country's existing natural resources in the past through different policies and national planning efforts. Nepal has only regional level data base on land utilization, geology, land system, soil and land capability produced by Land Resource Mapping Project (LRMP), that provided the basis for land resource planning in the country. These maps and information were generated from aerial photographs at the scale 1: 50000 acquired in 1978/79 with intensive field verification in 1982 (LRMP, 1986a; 1986b; 1986c; 1986d).

Risk-sensitive land use plan, Kathmandu Valley was prepared with the consideration of multi-hazard and climate change under the support of Kathmandu Valley Development Authority (KVDA) and United Nations Development Programme (UNDP) in 2010 (KMC, 2010). The envisioned risk sensitive land use plan (RSLUP) proposed mainstreaming of risk reduction strategies and their implementation procedures by two levels; mainly KVDA; and local level. RSLUP takes strategic approaches essentially to decrease the exposure and vulnerabilities to risks through non-structural approaches that identifies the safest locations for prioritizing investments in urban and infrastructure development and the plans are implemented not only to lessen the risks but also for optimum economic use of land through a combination of regulations and incentives for private sector and communities. RSLUP developed comprehensive set of spatial information and analyzed on land use change trends and its driving factors, multi-hazard scenarios and vulnerabilities, future land use projections along with the review of existing bye-laws of Kathmandu Valley to contribute the risk resilience (KMC, 2010).

Ministry of Land Reform and Management of Government of Nepal established the National Land Use Project (NLUP) in 2001 for preparing the land resources databases for the whole country. Previously, land use planning was conducted based on land capability analysis at three broad levels: national, district and local level. In the first phase, the National Land Use Project prepared district level land resource maps. Then, NLUP started for preparation of land resource maps at village development committee (VDC) level and completed in the most part of the Tarai region except municipality area, 10 districts (Illam, Dhankutta, Kavrepalanchok, Tanahu, Kaski, Syanja, Palpa, Gulmi, Arghakhanchi and Surkhet) of hilly region and some portion of Kathmandu Valley (NLUP, 2016) using procedural theory as technocratic planning process. After the formation of Nepalese Constitution (2015) and Land Use Act (2019), land use planning was conducted at national, provincial and local level, which required the basic information about the land, people and services. This information include present land use, geology, land system, soil, land capability, disaster risk zone identification, land use zoning, cadastral layers, and local level (municipality and rural municipality) profile with bio-physical and socio-economic status (NLUP, 2018). The local level land resource data and map of entire country was completed in 2020, but not implemented at any local level. Recently, Birgunj Metropolitan city and Illam municipality prepared land use plan in 2021, but not implemented yet. Madhesh Province started to prepare provincial land use plan in 2022.

2.3 Policy of Government on Land Use Planning

This section provides the review of international and national policy on land use planning for developing land use plan and implementation strategy.

2.3.1 International Policies on Land Use Planning

Different countries have successfully implemented land use planning with clear guidelines and policies. The present section attempts to review international land use planning policies/practices of some selected countries (India, China, Sri Lanka, Malaysia, and South Korea).

India is a federal republic state with two level of governments as national and state, but there are three levels of land use planning organization functioning at national, state and panchayat administrative units. Panchayat (local level) are under the state government. In the Indian Constitution, land and its management are the the subject of the state subject. Also, pertaining to planning of rural areas, the responsibility of preparation of plans for economic development and social justice is entrusted to the Panchayat. At present, India currently lacks a comprehensive and integrated land use planning system, but land use planning has carried out in various forms such as: urban area planning, industrial investment zones planning, eco sensitive zones planning and coastal zone planning. Draft national land utilization policy, 2013 was prepared for land use planning and management. In preparing land use plan that designates land use for rural, urban and industrial development and environmental protection; improving community's physical, economic, and social performance, efficiency and well-being. The six type LUZ has been proposed on the basis of predominant land use as: rural and agricultural areas, areas under transformation, urban areas, industrial areas, ecological areas, landscape conservation and tourism areas, heritage areas; and major hazard vulnerable areas. All the relevant aspects such as legal status according to use of land in the area, land potential, socio-economic needs, pattern of land use changes etc. should be taken into consideration at the time of land use planning. For land management perspectives, Land-use management areas (LMAs) has identified within land utilization zones. LMA has been categorized into protected areas, regulatory areas, reserved areas, and guided development areas (MoLR, 2013).

In China, 'Basic Farmland Regulations' in 1994 regulated the farmland and prohibited the conversion of agriculture land into non-agricultural activities. Land management law (revised in 1998) governs the urban land use. Two major systems occurred relevant with spatial planning as urban planning and land use planning that govern through different laws: land administration law, and urban and rural planning law. Nominally, government is in charge of these two systems; practically land use administration agencies and construction agencies at different level are responsible for overall land use planning and urban planning. There are five level land use planning organizations functioning based on Chinese administrative units (national, provincial, municipal, county and town level) by top-down approach. The local governments' general land use plan must be compatible with their upper-level government's general land use plan (Zhong et al., 2014). Nowadays, the people are involved in planning process as a concept of participatory land use planning (Wei et al., 2015). Six categories of land are used in land use planning process such as: arable land for paddy, arid and leisure land; garden and forest land; constructive land for residential, industry, .mining, and transportation land; water body for water surface, shallow seas and tidelands; grass land for natural meadow, artificial pasture and bare field; and bare land for sand, bare rock and gobi desert (Liu et al., 2016).

In Sri Lanka, land use planning is conducted on the basic of sustainable development goal. The basis of sustainable land use planning is to integrate ecological with socio-economic, and political with ethical principles in land use practices for productive and other functions, to achieve intra and intergenerational equity. The formulation and implementation of land use policies and strategies to collect process and disseminate timely and reliable land use information then utilizes modern land evaluation in sound scientific and technical knowledge. The concept of sustainable land use planning is new approaches on development for proper land management to secure land tenure and its right. In this context, land use planning process has improved and enhanced for the maintenance of biodiversity and natural equilibrium by the combination of knowledge and technique of planner with the relations among users, human and social beings. Therefore, it is necessary to make a new holistic approach having comprehensive, participatory and environmentally sustainable in land use planning. For achieving a sustainable land use planning development; policies and regulations should be based on local realities, traditions and natural resource management strategies considering environmental and socio-economic impacts of such policies and regulations should be assessed before they are implemented (Zahir & Kaleel, 2015).

Malaysia is a federal country with two levels of government: the state and federal level with territories. The governance in Malaysia is divided as the federal government and the state governments, while the federal territories are directly administered by the federal government. Malaysia practices a plan-led development system that consists of national physical plan, structure plan, local plan and special area plan prepared by different level of planning authority. These plans are cascade with upper level plan to lower level plan as basis of top down approach. The national physical plan concept has introduced as a result of amendments to the Town and Country Planning Act in 2001. National physical plan is developed by collaborative process between the federal and state government. Likewise, structure plans are generated by the state government for formulation of the development activities policy. The state structure plan serve as the framework for spatial planning at the local level and special area plan. The local plan is a detailed land use plan (map) for the development and use of land in the area by local planning authority under the guidance of state authority (Ahmad et al., 2013). The updating schedule of land use information is twice in a year. Malaysian land use system consists of 11 land use classes: residential, commercial, industry, institution and public amenity, vacant land, open space and recreation, transportation, livestock and aquaculture, agriculture, forest and water body (Kassim, 2018).

In South Korea, three levels of government as national government, regional governments and special status. The national government has three primary functions related to land use policies. First, it enacts the framework legislation that structures the planning system. Second, it provides a spatial framework for the country that guides its development. Third, it oversees and approves city master plans and designates the urban planning boundaries in the country. A hierarchical land use planning system occurred involving four plans: national comprehensive plan, metropolitan area plans, provincial comprehensive plan and city master plan in top-down approach in cascading order compatible with their upper-level plan. Furthermore, the national government is the primary actor when it comes to environmental protection, the designation of nature reserves and the protection of forests. Land Use Act, 2002 defines five land use zones: residential, commercial, industrial, agricultural, and open space zones, having nine land use districts: historical districts, floodplain districts, scenic beauty protection districts, public facility protection districts, and so on. Overtime, the ecology of greenbelt areas has been attractively preserved without any harm while rapid urbanization and industrialization has devastated natural environments on outskirts of cities outside greenbelts (Park, 2001). It has started to recognize the worth of greenbelt areas as important natural resources, particularly those in metropolitan areas (Kim & Kim, 2000).

2.3.2 Policies on Land Use Planning in Nepal

In Nepal, there are various legal arrangements available for land policy as well as land use planning. Land Related Act, 1964 is one of the very important legal documents on land use planning. A separate section is dedicated for land use management. Main provisions in this act are formation of a powerful council for land use management, restriction in change of land use type, criteria for land use classification, provision of land consolidation, secured settlements etc. Land Related Act, 1964 (5^{th} amendment) amended in 2012; the provision of land use types were categorized into eleven categories and endorsed different level land use council constituted as per the article 51 Cha for implementing land use program and developing land use implementation strategies within five year (MoLRM, 2012).

Ninth periodic plan (1998) mentioned the formulation of land use policy that laid emphasis to classify the arable land by identifying capability of productivity of land

(NPC, 1998). Town Development Act (1998) guided to land use planning for urban infrastructure development and integrated settlement in land pooling process (MoPDT, 1998). Local Self-governance Act (1999) and regulation (1999) empowered the local bodies (district development committee (DDC), municipalities and VDCs) to formulate and implement land use plans (MoLD, 1999). Government of Nepal endorsed National Urban Policy in 2007 and National Urban Development Strategy (NUDS) in 2016; both called for the development of an integrated land use and transportation plan for towns in order to improve the standards of internalized road networks and to promote urban agriculture land for food, vegetable, and horticultural products (MoUD, 2017).

Government of Nepal introduced National Land Use Policy, 2012 and the provision of land use classes categorized into 7 classes as: agriculture, forest, residential, commercial, industrial, public service and undersigned other classes (NLUP, 2012). National Land Use Operational Guidelines (2012) enforced for land use planning procedure and land use implementation mechanism at local level. After the earthquake 2015, Government of Nepal modified the existing land use policy and introduced Land Use policy, 2015 incorporating the risk layers as additional layer in land resource database and categorized land use into 11 classes as: agriculture, forest, residential, commercial, industrial, public service, riverine and lake area, mining and mineral area, cultural and archeological area, construction material exploration and undersigned other classes (NLUP, 2015). In addition, as per the provision made in the Land Use Policy (2015), NLUP was responsible for bringing land use policy into implementation, building basic infrastructure for preparing land use plans, and facilitating the regulation, monitoring and implementation of land use plans. NLUP was mandated to prepare land resource maps at local level planning through outsourcing modality and all these land use plan of the local level has prepared in expert driven approach (NLUP, 2016).

Country Civil Procedure (Code) Act, 2017 (MoLJPA, 2017) and Local Governance Operation Act (2017), specified the provision for land development and managing land use related information through local level authority (MoFAGA, 2017). Parliament of Nepal, Land Use Act, 2019 was introduced in the parliament mechanism for management of land use and control the land fragmentation to conservation of agricultural land for increase agriculture production towards food security (MoLCPA, 2019a). Land Policy, 2019 is issued by Government of Nepal for monitoring the land which is unplanned development infrastructures as well as housing and apartment construction and taking right of agriculture land but not used in agriculture and left it for other use (MoLCPA, 2019b). At present, Land Use Regulation, 2022 was introduced by government to implement land use zone and land use plan by local level having some provision of land use implementation strategies (MoLCPA, 2022).

2.4 Research Gap

The research works by Weng (2002), Zubair, (2006), Long et al. (2007), Paudel (2008), and Wu et al. (2009) have analyzed LULC change dynamic in urban area using qualitative and quantitative techniques. Likewise, the research works by Khanal (2002), Paul (2013), and Liu et al. (2014) have also analyzed LULC changes to identify the driving forces in watershed for managing cropland and preserving forest land use using robust modeling and statistical quantitative techniques. Similarly, Ziadat and Al-Bakari (2006) has evaluated the LULC change for sustainable agro-ecosystems through comparing the existing and potential land use. In the same way, KC (2015) has established the LULC changes relationship with internal migration and human settlement for land fragmentation for residential use in interdisciplinary approach to land development. Likewise, Chaikaew (2019) has analyzed the LULC changes and its dynamic modeling to identify the potential area for soil erosion. These LULC changes research works are limited to specific land use only and determined the causative driving factors for land use changes. However, the present research has analyzed the relevant factors at local context and used as parameters in land evaluation for allocation of land resources. Likewise, based on the land use change pattern, the present research has also attempted to analyze the past trend of LU conversion and measured the compactness (densification) and dispersions (scatterness) for built-up feature/area.

Similarly, on the issues of land evaluation of suitability of different land use, the research carried out by Dia et al. (2008), Yang et al. (2008), Jafari and Zaredar (2010), Nyeko (2012), Hao (2013), and Karna (2013) analyzed the selection of specific site for developable urban site, agriculture, industrial and forest area using different parameters such as physical, social, economic, environmental and utilities/facilities. The research conducted by Dia et al. (2001), Aly et al. (2005), Yang et al. (2008), and Samranpong (2009) have analyzed land suitability for urban and industrial land use. Similarly, the research by Baja et al. (2002), Burnside et al. (2002), Bobade et al. (2010), and Pramanik (2016) have evaluated the land suitability for agriculture use and landscape restoration. These research works are limited to land evaluation for specific site selection with the variation of parameters depending upon the location of planning area. However, the present study has attempted to identify the parameters for land evaluation process in the context of Nepal and local situation of Shambhunath Municipality. Similarly, no any of the above studies have incorporated associated risk factors such as flood, landslide, soil erosion and fire risk etc. However, the present research has used the risk factors with MCE-AHP and GIS in the suitability evaluation for agriculture, residential, commercial, industrial, and forest land use.

On the issues of optimal land use plan, the research carried out by Trung et al. (2006), Lingjun et al. (2008), Hao (2013), Ullah and Mansourian (2015), and Gormus et al.

(2017) have assessed the urban-rural land use planning using land suitability evaluation and decision making process through MCE-AHP, MCDA and planning support tool. Similarly, the research works carried out by Reginster and Rounsevell (2006), Yu et al. (2011), and Nyeko (2012) have used future land use scenario through land evaluation and applied in decision making process of land use planning. Likewise, the research by Bojorquez-Tapia et al. (2001), Trung et al. (2006), Hessel et al. (2009), and Zolkafli et al. (2017) have used participatory planning process as bottom approach in urban area for feasible development goals. The research carried out by Tims (2009), and Morales (2013) have applied comprehensive planning process in preparation of master plan for future land use based on the concept of LUCIS in urban area. Likewise, the research by Girard and Toro (2007), Nguyen et al. (2008), and Izakoviˇcová et al. (2018) have analyzed for sustainable terrestrial land use planning in integrated approach considering the land use land cover changes in decision making process. But all these research works are lacking to incorporate the risk factors and physical development plan in land use planning process. However, none of the studies have analyzed the land use plan in integrated manner; rather analyzed either qualitative or quantitative ways. The present study have used the strength of the combination qualitative and quantitative techniques with extensive utilization of SMCA and CA based simulation DSS model for the allocation of suitable land use and land use plan. Attempt has also been made to relate developing infrastructures with multi-hazardous risks in land use planning. Finally, the land use plan is interacted with the local people and incorporation of their experience in the prepared plan to make it reliable, feasible and implementable at local level.

Similarly, none of the previous research works have attempted to develop implementation strategy. However, the strong point of the present research is that it has developed implementation strategy to provide the development guidelines for infrastructure construction and to make land use plan implementation easier together with monitoring process.

2.5 Conceptual Framework

A conceptual framework has been designed for the present research work and is shown in Figure 2.9.

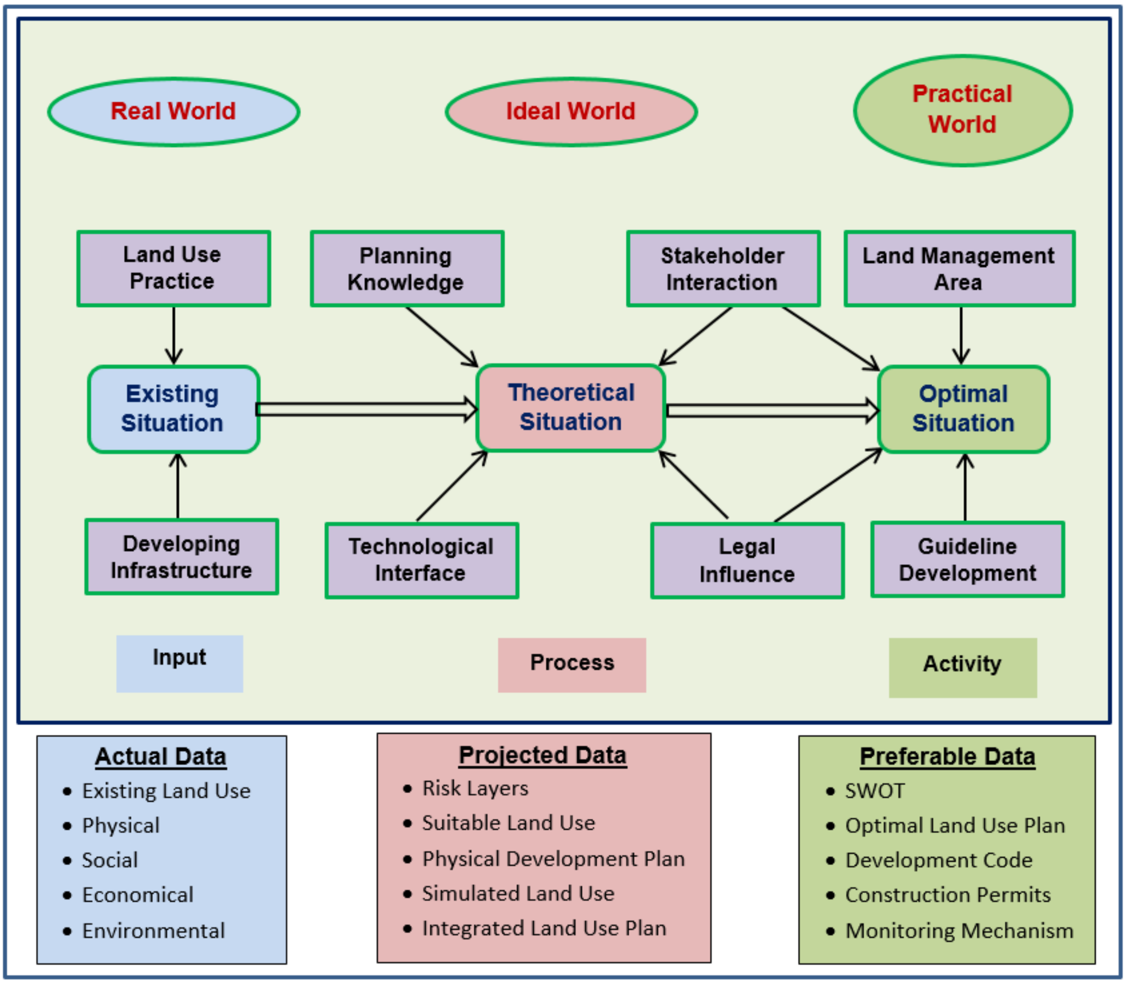


Figure 2.9: Conceptual Framework

The framework is guided with technical procedure on the basis of legally possible (feasible), socially acceptable, economically viable and implementable at ground reality for sustainability. The framework comprises three major components: *existing situation* representing the real world, *theoretical situation* as ideal world and *optimal situation* as practical world. The existing situation covers the real world with functional information of landscape that represent the present status of land. It includes land use and the land qualities: physical condition, utilities/facilities, social infrastructure, ecological, and economic functions for land development. The environmental condition, cultural, historical, and aesthetic value is also considered as constraint for conservation of natural landscape.

The theoretical situation represents the planning information of land and its use that obtained through land use planning process. The planning process is influenced by four components: the *stakeholder interaction* involved in, or affected by, the land units managed; the *legal arrangement* controlled the qualities or limitations of the land units being planned for; the *planning knowledge* considered the available, viable land use options; and *technology interference* described the method of planning technique. Hence, the planning process includes the analysis of risk layers; land suitability analysis for potential land use; develop physical infrastructure activities; projection for simulation land use; and integrated land use plan.

The practical world identified the optimal situation with the preferable land use information for implementation. It includes optimization through qualitative information to support the decision makers to make land use plan more accurate and reasonable based on development priorities and constraints raised by economic, social and political perspectives. SWOT analysis has been made for this purpose. Finally, the optimal land use plan is developed for allocation of land use options which could be reliable and feasible for implementation.

As mentioned above, the existing situation describes the current practices of land use with its land quality in term of physical, social, economic and environment status. The theoretical situation is the assessment land use information based on the methodological process. This theoretical land use information is analysed based on facts and data used in modelling process. These land use information may or may not be matched in ground reality, and acceptance by local people, stakeholders to implement the land use plan at local level. The theoretical land uses are analyzed in close consultation with local people, stakeholders and politician to design applicable, feasible and implementable land use plan at local level with certain limitation with development code. So, the framework is designed technically on the basis of legally possible (feasible), socially acceptable, economically viable and implementable at ground reality for sustainability.

Chapter - 3
METHODOLOGY

Research methodology is a set of rules used in research to select appropriate procedure that properly agreed the argument within the framework of research in sequential order. It deals with tools and techniques used for data collection, processing, and analysis techniques (Koirala, 2006), and its evidence process. The present research intends to adopt methodological framework practically as a general research design and relationally as a key interrelated component of scientific practice for land use planning.

3.1 Research Design

Research design explains the overall methodological development strategy applied in the research. It describes the integration of different components (views, ideas and knowledge) in a coherent and logical way based on conceptual framework of the research (Hao, 2013). Also, it focuses on the various types of tools and techniques used in information collection, processing, organization, analysis and its evidence process. In this research, a conceptual/ methodological framework is designed to explain and solve issues and problem related to real life in sustainability way. The theoretical framework is based on logical positivism with spatial planning approach of urban land use. So, an applied framework is conceptualized, developed, and validated that support in land use planning. The overall methodology is designed in holistic concept for determination, analysis, interpretation, and planning process of six components: analysis of land use pattern, identification of criteria/parameters, spatial modeling for risk layers, land evaluation for land use class, projection of land use, and preparation of optimal land use plan with its implementation strategies.

The research method focuses on integration of descriptive and analytical approach for necessary data synthesis that aims to collect and analyze the data/information. The quantitative technique is used for selection of optimal land use choice from different alternatives and future simulation that supports in land use planning, whereas, qualitative approach is applied to incorporate the social aspects related to land issues as highly subjective nature that reflect the planning goals for developing infrastructure plan, land use plan and its implementation strategy. Initially, the characteristics of land use pattern are analyzed using quantitative technique with spatial analysis and spatial overlay tools for computing precisely in systematic manner. The different variables followed by qualitative evaluation technique are applied in selection criteria with its priority rank and weight using AHP process, and designing basic developing infrastructure based on people's perception and social needs. However, the determination of suitability index of land use categories are obtained from land suitability analysis using MCE method that acts as alternatives land use option for the land allocation. Similarly, the simulation of land use is extracted from CA model for future simulation of land use option based on past pattern of land use, and developed suitability index that utilized in allocation of land use as preferable land use plan in objective nature (quantitative). The integrated land use plan is designed subjectively by integrating the developing infrastructure and risk layers for increasing socio-economic status and society lifestyle, and to control development activities in risk zone that make land use plan more feasible. The developed integrated land use plan may or may not be acceptable by society, so there is need to incorporate people's perception, social requirement in planning process which is highly complex and subjective (qualitative) related with social science. These social aspects are analyzed based on the integrated land use plan through SWOT analysis. These social interests and public perceptions are incorporated in decision making process and land use allocation process through subjective analysis. Finally, optimal land use plan is developed that meet the planning goals interrelated with suitability index maps, infrastructure development plan and consideration of risk sensitive area.

The data collection and analysis procedure used in the research is shown in Table 3.1.

Table 3.1: Data Collection and Analysis Procedure

Key Research Component	**Data Collection**	**Data Generation**	**Analysis tools/methods**	**Results**
Land Use Change Pattern	LU/LC Data, Maps, Satellite Images, GCPs, Collection of LU types, Extensive Field Verification	Visual Image Interpretation, LU Classification Schema, Digitization of LULC from scan map/ images	Calculation LULC area, Spatial Overlay, Spatial Analysis, Entropy Measurement, Trend Analysis	LULC maps (1986, 1996 & 2017) data, Quantification of land use changes, Land use change pattern, Concentration rate and its growth trend
Identification of factors for Risk and Land Suitability Analysis	Physical, Topographical, Environmental, Socio-economic data/maps	Key Informant Interview (KII), Focus group discussion (FGD)	Qualitative Analysis, AHP, FR, Fuzzy logic function	Parameters and constraints layer, Parameter priority with its rank, Parameter weights
Risk Layers Identification	Parameters/factors maps/data Satellite Images	Data compilation and manipulation, Indices, review of past study	MCE, Quantitative and qualitative analysis, descriptive	Flood, landslide, soil erosion, fire
Land Suitability Evaluation				Suitability maps of Land use classes
Developing Infrastructure Development Guidelines	People needs Population data Status of existing infrastructure Economic function, Land Tenure	Review of past study, polices, guideline; RRA/PRA, FGD	Qualitative analysis, spatial overlay, spatial analysis	Planning guideline, Physical development plan
Land Use Planning	Stakeholder Perception People aspiration	Review of polices, laws; FGD	SWOT analysis, CA simulation, Quantitative and qualitative analysis, descriptive	Optimal Land Use Plan
Developing Implementation Strategies	Cadastral Datasets, existing planning reports	Reviews of Building Bye Law, Polices, FGD	Qualitative Analysis Spatial overlay	Development code, Monitoring Guideline

The overall methodology adopted in this research is explained in Figure 3.1.

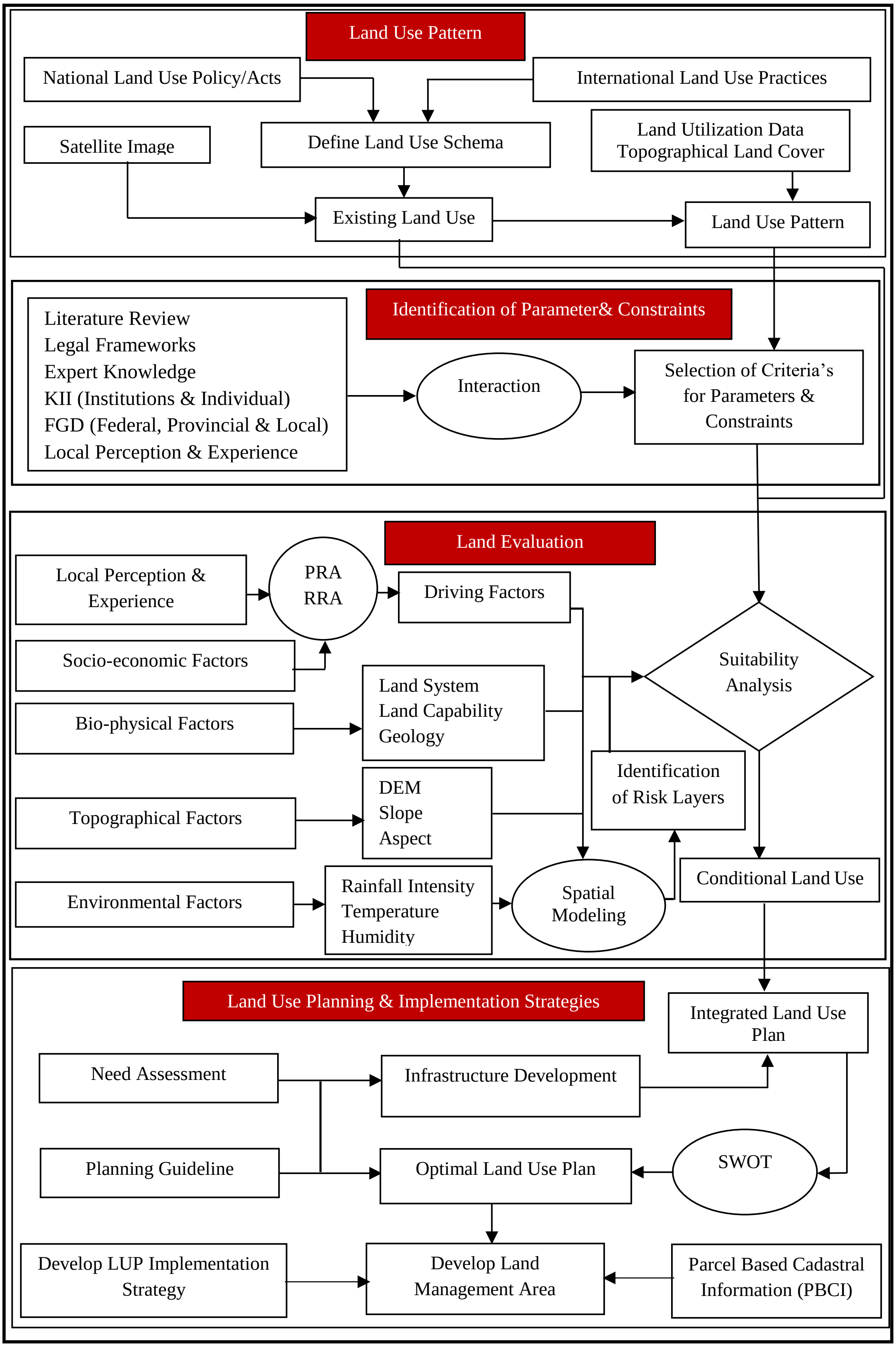


Figure 3.1: Schematic Work Flow Diagram

Initially, LU classification schema is determined through national and international policies, laws, and practices of LU. Based on classification schema, the status of current practices of LU is prepared for year 1986, 1996, and 2017. LU change analysis from 1986 to 2017 is analyzed and quantified through spatial overlay geospatial tools. Also, spatial pattern and past trend of LU of land use are also determined through land change modeler. The compactness of built-up area is analyzed with the measurement of entropy. The evaluation of land suitability uses a total of 27 different criteria, which were identified based on the existing literatures and those criteria were contextualized through the knowledge of the experts and the stakeholders. Generally, risk considerations typically serve as restrictions in land use planning for mitigating potential disaster risks and build the resilience of communities to cope with such risks. Risk factors are evaluated through GIS based spatial modelling, and applied in land use suitability evaluation of specific land use. Land suitability evaluation is carried out with the integration of GIS and MCE tools for suitable site of a particular land use (agricultural, residential, commercial, industrial, and forest) using determined criteria and computation of its weight of criteria through AHP process. Generally, planning guideline is designed on long terms development targets of 15-20 years period (NPC, 1993), that prerequisites to achieve a stable and diversified economy, and social development. Developing infrastructure is allocated for basic physical infrastructure in 2037 A. D. on the basis of land use suitability index map and planning guidelines that meet the needs of local people. For land use data 2037, CA simulation technique is applied for projected land use data for 2037 and used in decision making process of land use planning to allocate land use options. Land use plan is developed based on projected land use incorporating developing infrastructure and risk layers, and qualitatively optimized through SWOT analysis. Land use implementation strategy is developed based on the existing legal situation with reference to the international practice.

3.2 Philosophical Basis for Research Methodology

Philosophy is an abstract of thinking. Any practitioner of an academic discipline undertakes research within a framework provided by a philosophy of that discipline (Johnston, 1984 cited in Koirala, 2006). It describes the fundamental nature of knowledge, reality, and existence. Planning philosophy has commonly embodied a mixture of sociological assumptions about human and social behavior about the nature, purposes, and premises of planning goals (Taylor, 1980). In planning perspective, behaviorism philosophy is applied initially in planning research work (Faludi, 1973), that need to construct idealized system based on a set of principles, the desired states of affairs in the present, and in the future as natural development (Marios, 1979). The principle used in behaviorism is empirical science and theory is *'Theory in Planning'*. The paradigm shift from *'Theory in Planning'* to '*Theory of Planning'* on the planning emphasis due to the identification of planning practice with the advance decision making process in rationality with deduction process as rationalism philosophical thought (Thomas, 1979). These type of research planning works considered the planner's view is a set of methods designed to prepare information in such a way that decision can be made rationally that springs from the development of empirical science and behaviorism. Planning was conducted based on the process of empirical research by gaining and validating knowledge obtained from previous project work in doctrine of positivism/scientism thought of planning (Faludi, 1978) that derived from scientific revolution. The logic and reason becomes the principal pillars as the ideas of planners to understand the real world and better human living conditions experimentally in a scientific and positivistic manner. Also, positivistic thought of social sciences suggested that planning being more '*comprehensive*' beyond the physical dimension and incorporate the social aspects of society in the process of planning (Taylor, 1980).

In planning view, '*comprehensive*' refers to the completeness of the plan, specifying "the detailed courses of action needed to achieve that desired state” based on science, morality and law with the individual interests, and planning goals on Universalism and Humanism thought. Also, comprehensive planning paradigm shifted toward logical positivism considering all kinds of potential for social, cultural, and political intolerances, based on private and putatively superior claims to have access to or create knowledge (Beennett, 2009). In logical positivism, knowledge is constructed and experienced subjectively and socially that recognize the prior experience and existing social contexts. Also, it is related with the ground reality by verification of empirical observations that positively support, as realism position that involves the inductive planning process. In rational comprehensive planning, researches are generally compared with hypothetical deductive in conjunction with inductive process. In such types of planning models, '*alternatives*' can be generated and compared with competing 'hypotheses'; the consequences with the 'predictions' of these hypotheses and the goals; with the facts and figures (Marios, 1979). Marxist with the implicitly or explicitly are influenced by the society and planning practice both having strong relationship with behaviorism (Allmendinger, 2002). Therefore, planning is necessary to facilitate and maintain social control in conflict resolution of land use that includes infrastructure development, land aggregation, land value, and overall development activities in land.

Modernism’s thought is used in planning to consider the significance of humankind and prompted the ascent of Humanism which managed through the critical and rational theory (Taylor, 1998). Planning is always the site of class conflict so far as planners must make decisions on how to allocate the surpluses that are produced among many different classes on the basis of humankind. Planning shifted from modernism to postmodernism on the basis of structural changes occurred in the economy from mass production for a mass society to flexible production for a fragmented society brought about a new interest in the built environment. Planners need to recognize the social aspects, not just in the practice itself but our perception of the society as a whole (Sandercock, 1998). Sustainable development concept has been developed in the conservationist philosophical position influenced by positivism concept and widely adopted in planning practices as a pathway that made for identifying solutions to the problems exposed by the discourse on sustainability (Hector et al., 2014). The central concept of integrity and sustainability of the entire development process is based on ecologism principle by knowing the whole community of life, discover the functions of the entire territory (Partridge, 1984) and reducing environmental degradation in sustainable way (Hector et al., 2014).

Different methodological positions exist within land use planning related to physical and social development, and conservation of nature as a social system for possible future land developments. The scientific, rational method applied in natural science is used for infrastructure development whereas descriptive heuristic methods used for identifying the social aspects of society. In social science, social aspects are generally behaviors, conceptions and decisions, together with interactions with emergent social and institutional structures (Brown et al., 2016). Also, the forms of reasoning in philosophy is made as inductive and deductive reasoning. The key concept in inductive reasoning is based on empirical observation, experience and measurement in which reliable, generalized conclusion is obtained from a set of observed reality. In deductive reasoning, obtained conclusion is logically derived from available facts with testing hypothesis. Even though particular research may look like purely deductive or purely inductive, most social researches involve both inductive and deductive reasoning process at some point (Shrestha, 2014).

The philosophical base of this research is logical positivism with spatial planning concept in sustainable manner using both inductive and deductive reasoning process. The inductive reasoning method is used for acquiring related geographical information, and model development for land suitability analysis and planning process for land use allocation, however deductive reasoning is used to integrate social aspect in the planning process. The holistic concept is applied in designing methodological framework that considered the three basic stands: ontology: that viewing the whole planning system does not exist independently of its constituent parts; epistemology: that viewing to perceive the planning knowledge obtained whole by knowing parts of the whole; and guideline ethics as axiology: that understating the well-being of the society and its needs for land use planning. So, the designed methodological framework is reflected sustainable land development and management using sustainability planning theory in land use planning process. Land use planning is carried out meeting with the general demands of local people and living environment sustainabily. From the perspectives of people's needs, internal mechanism (spatial location) and economic dynamics of land use allocation is based on land use functions, land value and land development status for economic sustainability. Ultimately, people are the principal concern in land use planning to improve the lifestyle, living condition, and social status of vulnerable group (minority races, women, indigenous and elderly people). In land use planning, social impact is analyzed through population trend, household structure, community and neighborhood changes and social needs of vulnerable people. The preservation of historical and cultural heritage is one of the greatest concerns. The social sustainability is improved through land use planning with satisfaction of welfare requirements, conservations of resources and its surrounding, creation of harmonious living condition, infrastructure facilities, and recreational features. The environmental sustainability is also conserved incorporating the risk factor in the process of LUP.

3.3 Secondary Data Collection

The secondary data/information are collected from different sources and used in this research (presented in Table 3.2).

Table 3.2: Source of Secondary Data and its Use

Data used	Source	Purpose
High resolution satellite images, 2016	National Land Use Project, Nepal	LULC map 2017
Land utilization map, 1986 and its digital database 2008	National Land Use Project, Nepal	Preparation of LULC map 1986
Topographical map, 1996 and digital databases, 2001	Survey Department, Nepal	Preparation of LULC map 1996, DEM, slope, aspect; and used in land suitability, risk layer analyses as criteria.
VDC level soil inventory data (soil pit and soil polygon), 2018	Survey Department, Nepal	Soil data analysis and used in land suitability, risk layer analyses as criteria.
Land resource map (land system and land capability map) and datasets, 2018	Survey Department, Nepal	Preparation of criterion map used in land suitability evaluation
Geological and lithology map, 1984	Department of Mines and Geology, Nepal	Used in land suitability, risk layer analyses as criteria
Climatic data (temperature, wind speed, rainfall, humidity) from 2003 to 2018	Department of Hydrology and Meteorology, Nepal	Used in land suitability, risk layer analyses as criteria
Road layer, 2018	Department of Road, Nepal	Used in land suitability, risk layer analyses as criteria
Seismic risk map, 1994	Department of Mines and Geology, Nepal	Risk layer
Fire incident data, from 2000 to 2018	https://firms.modaps.eosdis. nasa.gov/download/create. php	Risk layer analyses as criteria
Cadastral maps, 1970	Survey Office, Saptari, Nepal	Developing implementation strategy
Land related policies, laws, regulation, directives, vision papers, etc.	Ministry of Land Management, Cooperatives and Poverty Alleviation; Law Commission, Nepal	Land use planning, developing implementation strategy
Physical Development Guideline, 2013; Basti Bikas Mapdand, 2015	Department of Urban Development and Building Construction, Nepal	Planning guideline, developing construction code
Shambhunath Municipaity, Basti Bikas Mapdand, 2018	Shambhunath Municipaity, Nepal	Planning guideline, developing construction code
Population data, 2021; Economic Survey Report, 2018	Central Bureau of Statistics (CBS), Nepal National Statistics Office (NSO), Nepal	Preparation population growth rate used in land suitability analysis, population growth trend, need assessment, socio-economic analysis
Agricultural production data, 2020/21	Krishi Gyan Kenra, Saptari	Analysis of economic activities, need assessment

3.4 Primary Data Collection

The primary data is collected using field survey techniques: extensive field visit and observation, rapid rural appraisal (RRA) and participatory rural appraisal (PRA), expert interview, and focus group discussion (FGD).

3.4.1 Field Observation and Verification of Land Use

Field visit is a major tool for geographer to collect real information about geographic phenomenon such as its locational information (geographical/projected coordinate), areal extent with extensive field survey and ground survey using surveying techniques. The field survey was conducted for collection of the ground control points (GCPs) from 3rd October, 2017 to 7th October, 2017. Total 16 ground control points (GCPs) having 10 control points and 6 check points were collected from differential global positioning system (DGPS) survey that used in the ortho-rectification process of satellite images. Extensive field surveys were also used for collection of LU types, the functional use of built-up area, determination of agriculture and forest use pattern and practices. The check list for functional LU through field data collection is shown in Appendix-2. Extensive field survey was conducted for collection of function use of land in the study area from 8th October, 2017 to 14th October, 2017. Also, field survey helped in the problematic area in satellite image having poor contrast quality for assigning LU types. LU information obtained from satellite image and extensive field survey from actual ground, delineating and assigning LU classes need to be evaluated through thematic accuracy assessment. For thematic accuracy assessment of LU classes, the common target accuracy is suggested 85 percent confidence level in remote sensing applications (Foody, 2009). Sample size for accuracy assessment is determined with 90 confidence level, 5 percent threshold, and 50 percent probability of occurrence and nonoccurrence of same LU Class, and determined size is 272. The field survey is conducted for collection of LU validation sample points from 22^{th} October, 2017 to 28^{th} October, 2017. So, total 272 sample points were collected for validation process of LU information obtained from satellite images. These sample points were created using random sample techniques which create random point tool for selection of sample spatially in GIS environment.

Generally, field observation is used in the technical research to monitor the community behavior and activities. This technique is used to observe and record geographic phenomena in order to get information that is true and legitimate, reducing and minimizing the possibility of fallacy and inaccurate information. Observed phenomena, records, events, particularly the qualitative information is recorded in the notes on field observation. This technique is also helped to recall the forgotten points in the stage of explanation and analysis. The notes and marginal observation are helpful to check and verify the collected data. In this research, field observation were used to incorporate the missing information from the visually and audio record information of expert interview and stakeholder interaction.

3.4.2 Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA)

Rapid rural appraisal (RRA) tool is carried out to generate land use inventory data and collected from communities and settlements. Generally, RRA tool has been used to collect household data with consultation process from local and indigenous people. In this research, RRA technique is used to collect the basic socio-economic information of household information such as land use pattern, income, privately owned land, landholding size, adaptation of agricultural technology, agricultural production, population structure, distribution of public infrastructures and services, market centers, industrial employment, status of migration both in and out, wage rates, prices of locally produced and occurrence of major risk/hazard. The designed interaction base for local respondent and/or indigenous people is shown in Appendix-3. Sample for RRA process is collected through random sampling technique. Sample size is computed through Raosoft sample size collector tool on the basis of population size (39634), confidence level (90 percent), confidence interval/marginal error (5 percent), and response distribution (50 percent) and determined size is 270. RRA survey is conducted from 8th October, 2017 to 14th October, 2017. Total 276 respondents (at least fifteen local people for different gender inequality group, four politicians, and four non-government organization (NGO)/community based organization (CBO) members for each ward) has involved in close co-operation with the local population in the community areas to obtain the knowledge of land use practice in actual ground reality and mitigation practices of different risk factors.

Participatory rural appraisal (PRA) tool is intended to enable local communities, conduct their own analysis, and to plan and take action. In this PRA technique, participation of stakeholder and local people has involved: not as sources of information, but as partner team members in the planning process for gathering and analyzing information to effectively manage their natural resources (Chambers, 1992). In this research, PRA tool is carried out for interaction process with the land use council and land use implementation committee members and personnel involved in the regular activities of preparation of land use plan, land use zoning and its monitoring process. So, PRA tool is applied to collect the population growth trend, distribution of public service area such as school, college, health post, government offices, recreation area, open space area, security agencies etc. along with historical risk and hazard data through the consultation with stakeholders and local people orally as well as historical documents issued by government. The developed interaction guideline to local stakeholder is shown in Appendix-4. PRA survey is conducted from 22th October, 2017 to 25th October, 2017. Total 32 respondents in which seventeen committee members (two persons from provincial land use council, three persons from local land use council and twelve persons from land use implementation committee) and fifteen local stakeholders (twelve technicians as sub-engineer those involved in infrastructure development activities from different wards and three community members from politicians) have involved in interaction process with sample data for risk sensitive zone identification, land suitability analysis, and land use planning.

3.4.3 Key Informant Interview

Key Informant Interview (KII) technique is used to collect the relevant information through the conversion process in structure and unstructured format for interviewing the respondent. It is conducted in different ways such as face-to-face interview, telephone interview and mail survey. In this research, KII is carried out in face-to-face form and supplemented with telephone or email in-depth interaction based on semi-structure questionnaire (Appendix-5). In KII process, in depth interview with high level government official those involved in federal, provincial and local land use council and conducted regular activities of preparation of land use plan and its monitoring process. KII survey was conducted from 25th October, 2017 to 27th October, 2017. Total nine key land use professionals (two persons from Federal Ministry of Land Management, Co-operatives and Poverty Alleviation, three persons from National Mapping Agency, Survey Department, two persons from Provincial Ministry of Land Management, Agriculture and Co-operative, Madhesh Province, and two persons from Shambhunath Municipality) are involved in interview. Based on the collected information in tabular data from KII, the key factors/criteria with constraints are identified by literature review and document analysis are adjusted and finalized for risk sensitive zone identification, land suitability analysis, developing planning guideline, and construction code as building bye law.

3.4.4 Focus Group Discussion

Meeting for focus group discussion (FGD) meeting is organized for describing and understanding perceptions, interpretations and beliefs of a selected population to gain understanding of a particular issue from the perspective of the group's participants (Hao, 2013). FGD meeting is conducted to acquire in more in-depth information or common perception from the participants for the subjective judgments/ perceptions of respondents. The discussion frame for FGD is shown in Appendix-6. In this research, three separate focus group meeting has conducted for different purposes. One focus group meeting has organized at Rupani Bazar on 6th October, 2017 with the involvement of planning stakeholders as planners (urban planner, architecture, civil engineer, agronomist), developer (land developers, geomatics engineers, and local residents mainly politician involved in planning and land development activities with 47 respondents; aimed to determine the criteria, rank of the criteria and weight of the criteria for pairwise comparison in AHP process and in multi-criteria evaluation. Likewise, FGD meeting held at Arnaha Chowk on 27th October, 2017 with involving planning stakeholders (urban planner, civil engineer, member of local disaster risk committee) and local residents (local indigenous people, CBO's member, politicians) with a total of 51 respondents; mainly focused on the need of development infrastructure and mitigation practice from different risk occurred in the municipality. The risk factors are used as constraints in land suitability evaluation and land use planning, and infrastructure status is used as inventory data in need assessment for developing infrastructure activities. Another FGD meeting was organized at Kathauna Bazar on 12th October, 2018 with involvement of planning stakeholders (the experienced planner as land use planner/urban planner/architecture, infrastructure planning practitioners as civil engineer, professional persons as land developer/geomatics engineer, personnel of local government mainly planning officer/engineer, member of CBO's and local people mainly politicians) with a total of 59 respondents to conduct interaction through SWOT analysis on prepared integrated land use plan in land use planning process. The meeting mainly focused on tools and techniques used in this research and result of the research work through interaction process for providing comments and suggestion on the infrastructure development plan as well as land use plan. The participants provided the subjective perception in the developed plan for its improvement incorporating with community perception.

3.5 Data Generation for Spatial Analysis

The spatial information collected from secondary data are converted and modified in the similar spatial frame and co-ordinate system in Nepal Nagarkot TM 87 that is applied in the eastern part of Nepal. The collected spatial data are also compiled through the integration of other relevant spatial /thematic data and public perception/view collected from primary data collection technique to increase its reliability, truthfulness and completeness. These spatial data are utilized for multiple purposes such as land use type and its pattern; measuring the concentration and compactness of built-up area (residential, commercial, and industrial); selection of different criterion datasets applied in the identification of different risk sensitive zone; land suitability analysis of land use, developing physical infrastructure, and land use planning.

3.5.1 Land Use Types and Change Patterns

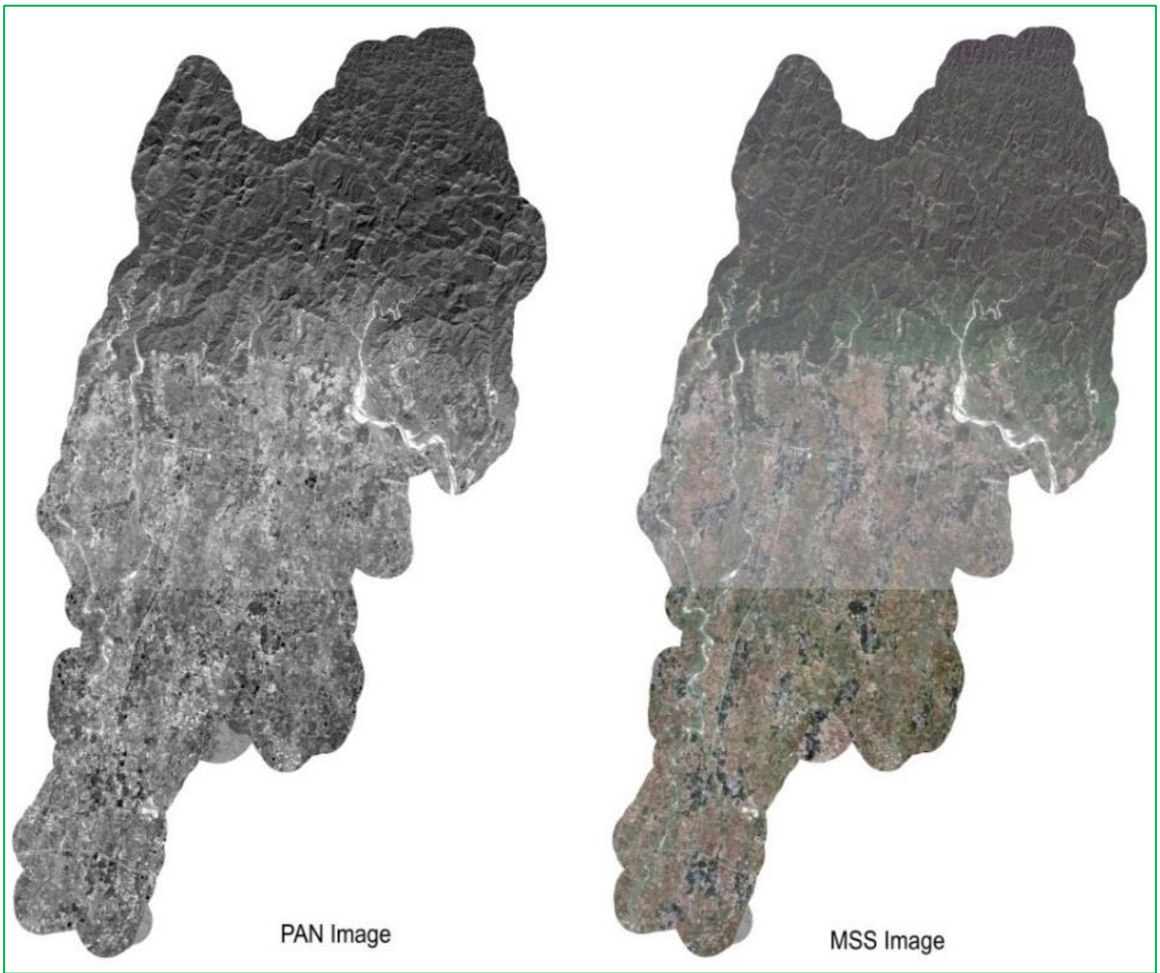
Land use classification scheme describes the systematic arrangement of various classes of land based on certain similar characteristics, mainly to identify and understand their fundamental utilities, intelligently and effectively in satisfying the needs of human society. The land use classification schema is used for organizing and categorization of the land use information that extracted from the different data/information (Jensen, 1996). The best use of land is required in appreciable schema for existing/ present land use that achieved though the proper understanding of land use classes representing all types of land use in concerned regions and area. The developed land use classification schema used in the study is shown in Table 3.3.

Table 3.3: Land Use Classification Schema

S.N.	LU Class	Description
1	Agriculture	Any kind of agriculture land, artificial trees, orchard/nursery and vegetable land.
2	Residential	Any kind of residential area containing villages, settlements, hostel, quarters, infrastructure developed land, residential cluster; other continuous and non-continuous urban fabrics
3	Commercial	Any kind of business and service area containing market area, hotel, utilities, storage, cinema hall, banking house and government offices.
4	Industrial	Any kind of industrial estate, trading complex, special economic zone, construction sites, quarries and gravel pits, mine and mineral exploration area, excavation sites and related other industrial area.
5	Forest	Forests under any legal enactment as forests, whether state-owned or private as National forest, community forest: deciduous, coniferous and mixed, natural bushes, shrubs, trees, palms, herbs and climbers.
6	Public Use	All kind of roads (railway, highway, feeder, district, urban road, street, cart track, and foot trail), open spaces/areas, recreation area facilities (park/public garden, playground, and stadium), school, hospital, security area, airport, archeological place, heritage site, temple, mosque and related other public place.
7	Water body	River and stream channel, permanent open water such as lake, ponds, swimming pool, dams and other water bodies (swamp area), wet land, sand and gravel area along river course.
8	Others	Solid waste landfills, bare exposed rocks, bare ground bare lands, pastures and grazing lands.

In this research work, land use information of 1986 is obtained from digital database of land utilization map of sheet no. $72\frac{J}{10}$ published in 1986 and complied from 1:63360 scale topographical map, associated with 1: 50000 scale aerial photograph acquired in 1978-79 and field verification in 1981-1982. The land use type is determined through integration of land record data, cadastral map/data, and interaction with local people to separate urban area into residential, commercial and industrial use as well as cultural and archeological land use type. The land use type of forest, agriculture and waterbody features is directly determined through digital and hard copy land utilization map. These land use types are used in the preparation of land use data/map for 1986 based on the classification schema in Table 3.3. Similarly, land use database and map for the year 1996 is prepared from the topographical base map and its digital databases of topo sheet no. 2686-07B and 2686-07D with the integration of land record data, cadastral map/data, and local people's perception using reference classification schema in GIS.

Land use data/map for 2017 is prepared from WorldView-2 Satellite Images acquired in December 16, 2016 and extensive field survey in November 11-20, 2017. Both panchromatic (PAN) images of spatial resolution 0.5 m and multi-spectral scanner (MSS) image of spatial resolution 2 m are separately ortho-rectified in bundle block adjustment of these images using rational polynomial co-efficient (rpc) file for interior orientation, 16 ground control points (GCP) collected from differential global positioning system (DGPS) for exterior orientation and refinement of the geometric position of the satellite image and hydro-corrected digital elevation model (DEM) prepared from topographical contours, elevations and hydrographic feature river and stream lines for removing relief displacement in the satellite image. In MSS image, the minimum and maximum residual errors in Easting are ±0.016 m and ± 0.529 m. Similarly, the minimum and maximum residual errors in in Northing are ±0.018 m and ± 0.888m. The overall root mean square error (RMSE) is obtained with ± 0.552 m for geometric correction of satellite image that found within the acceptable limit of 1m i.e. half pixel size of MSS satellite image (Edwards, 2000). The distribution of GCPs is presented in Appendix-7 and also ortho-rectification error assessment is presented in Appendix-8. The ortho-rectified of PAN and MSS image is presented in Figure 3.2.



Source: National Land Use Project

Figure 3.2: Ortho-rectified Satellite Images

The pan-sharpened (resolution merge) images is generated by using Brovey transform for both spatial and spectral high resolution image and increased contrast for visual appearance for image interpretation. Maximum likelihood classifier (MLC) algorithm is used for supervised land use classification. Land use type is determined through image interpretation elements (tone, size, shape, texture, shadow, pattern, site and association), and extensive field survey from pan sharpened satellite image. The thematic accuracy assessment of land type is conducted for verification purpose through ground truth sample point from field survey. In this research, 272 samples points is used for generating confusion matrix for accuracy assessment (presented in Appendix-9).

The summary of error matrix is generated based on the cross-validation of land use. The overall accuracy is found to be 95.59 percent; represents the percentage of correctly classified pixels and achieved by dividing the number of correct observations by the total number of observations. The kappa index of agreement (KIA) is found to be 0.94 addressing the difference between actual agreement and chance agreement for test statistics. After the accuracy assessment, the land use map of the year 2017 is prepared from determined land use classes.

Land use change analysis is carried out using geospatial tools for quantification of changes of land use class in the period 1986, 1996 and 2017. Land use changes are detected through spatial overlay process of land use map and its quantification of change comparison of area. The net changes in each land use types are measured in land change modeler (LCM). The concentration measurement is analyzed for the compactness and dispersion of built-up area proportion in land use/cover and its growth in healthiness or unhealthy insuring Shannon Entropy. The Shannon Entropy is computed by (Yeh & Li, 2001):

$$E_n = \sum_i^n p_i \, log\left(\frac{1}{p_i}\right)/log(n) \qquad (3.1)$$

where, p_i is the density of land development, which equals the amount of built-up land divided by the total amount of land in the i^{th} of n total number of zones, refers as the number of buffers around the municipality. The growth trend of entropy is analyzed through regression analysis for 20 years long term planning period in 2037 A.D.

3.5.2 Analysis of Risk Layers

In land use planning, different risks are considered as constraints for managing land use for safe resilient to housing, economic betterment and easy access to infrastructure and public services. There is necessity to develop land use plans that focus on mitigating potential disaster risks and build the resilience of communities to cope with such risks. In this study, HEC-RAS application tool was used to prepare simulation flood inundation layer with the consideration of discharge for 2 years and 100 years return period in the steady flow environment through wind energy conversion system (WECS) developed by Department of Hydrology and Meteorology, Nepal. Likewise, soil erosion was assessed with RUSLE (Revised Universal Soil Loss Equation) model. Similarly, landslide susceptibility mapping (LSM) was conducted with statistical bivariate analysis and frequency ratio (FR) model. Fire analysis was carried out using MCE and AHP technique of suitability analysis and modeling in GIS environment. Whereas, the seismic risk layer map is prepared from secondary sources. All these five risks factors are considered as constraints and used as criteria in land suitability evaluation of land use, scenario model of land use planning, and preparation of land use plan. The detail description for preparation of risk layers is presented in Appendix-10.

3.5.3 Land Suitability Evaluation for Land Use

Land suitability evaluation is conducted with integration of GIS tools and MCE for suitable site of land use based on the criteria and computing of the weights. In land suitability analysis, multiple factors as criteria's (parameters and constraints) are required having priorities rank and its weight. Identification and selection of criteria is depended on the cause and effect relationship and compatible with local situation in reliability for site selection and very important steps in MCE.

Selection of Factors

The selected influencing factors are used in land suitability evaluation for different land use as agriculture, residential, commercial, industrial, and forest. The influencing factors are considered as parameters in general category while constraints have similar to parameters but allow or block in land evaluation process. The constraints are used hard Boolean operation rule characterized by 0 for restricted area or 1 for limit the expansion of site selection for developing area. The parameter is not hard like constraints; it allows the analyst for determining the suitability categories gradually ranging from unsuitable to highly suitable. The appropriate criteria/factors for land suitability evaluation are identified from the literature review, and modified through interaction with stakeholders and opinion of the planners (expert interview, and focus group discussion). Related spatial data for social and economic infrastructure are derived from related land resource data. Land value information are collected from related land revenue office in association with public interest (RRA and FGD).

Factor Rating

Each factors data are categorized based on their priorities within the criteria as factors. The priority of sub-categories of the criteria are rating through close consultation with expert opinion (mainly land use planner). The priority ranks of each category within the criteria are standardized through the fuzzy membership values with the level of quantification scale in terms of 0 to 9 in the normalized way.

Determination of Weight

AHP integrated with GIS tool is used to identify the importance of competing criteria and to calculate the weight of each criterion with a scale of importance consultation with expert opinion and interaction with local stakeholder. AHP technique is used to compute the influence weight of each influencing criteria considering any subject and problem in a network of criteria, sub-criteria, and options in clusters together. All the elements of a network have established the relationship with each other in pairwise comparison of criteria (in qualitative and quantitative analysis) and to examine consistency in judgments, and flexibility among influencing criteria. In AHP technique, the active participation of decision makers and stakeholders are involved in multi-criteria decision making and multi-objective to reach an agreement rationally for allocating the specific land use on the basis of influencing criteria's. These criteria's are arranged in a hierarchic order and numerical values to subjective judgments based on the relative importance of each criteria. Subsequently these factors are synthesized and each factor is assigned according to their importance. Based on the criteria's, performance matrix is generated by reciprocal pairwise comparison in which each row describes an option and each column describes the performance of the options against each criterion. Each criteria class is ranked by a 9 point rating scale in the entries on the performance matrix as developed by Saaty, 1977 (Table 2.1). By using pairwise comparison AHP technique, the weight assessment of physical criterion is determined in numerical values for suitability factor. The estimating weights are tested as consistency by measuring maximum principal eigenvalue and number of order performance matrix (Alonso & Lamata, 2006).

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (3.2)$$

where, λ_{max} is the largest or principal eigenvalue of the performance matrix and easily calculated from the performance matrix and n is the order of the performance matrix for a good measure of consistency. The number of totally consistent different rating in the performance matrix is required for testing the relation of preference consistency either accepted or not based on the consistency ratio. The consistency ratio (CR) is calculated from the direct calculation of weight using objective comparison with weight distribution and its consequent evaluation in the weighting process (Eastman, 2006). The CR is represented the probability of the judgments that randomly generated in the performance matrix with acceptable level of consistency (Alonso & Lamata, 2006).

$$CR = \frac{CI}{RI} \quad (3.3)$$

Where, RI is the average of the resulting consistency index (CI) for random performance matrices and CI is the consistency index depending on the order of the matrix. If the CR values is greater than 0.1, then AHP model automatically rejected the computed weight in the performance matrix (Shahabi & Hashim, 2015). After testing the consistency ratio within the performance matrix is limited acceptance level, then the weight of factors accepted and maintains the factor weights sum to one, that meet the requirement in using weighted linear combination (WLC) procedure (Eastman, 2006). In the weighting option, numerical weights are assigned to define for each criterion and the relative valuation of a shift between the top and bottom of the chosen scale. The criteria for restricted situation, the numerical weight are used as restricted that available in the weight scaling in GIS.

Computation of Scoring

The suitability evaluation is carried out with the acquired weight from the AHP pairwise comparison and the rating/ranking of the categories of influencing criteria through WLC procedure in GIS application for the flexible combination of map. WLC procedure is used to prepare suitability maps based on the assigning the weights of relative importance to the suitability maps, and then combining the weights and standardized suitability maps to obtain an overall suitability score (Malczewski, 2004). Two critical elements of WLC is the weights assigned to attribute of influencing criteria's and the procedure for deriving commensurate attribute of categories of influencing criterion map. In WLC, the total score is obtained for each alternative through multiplying the importance weight assigned for each attribute factor by the scaled value given to the alternative on that attribute classes of factor, and summing the products over all attributes value (Malczewski, 2004).

$$S = \sum_{j=1}^{n} (W_j \, x F_i \,) \qquad (3.4)$$

where, S is the total suitability score; W_j is the weight of influencing criterion; F_i is the rating map of influencing criteria's and n is the number of the influencing criteria's. Land suitability index (LSI) is the score computing in WLC procedure showing that the highest overall score assigned as highly suitable while least overall score preferred as unsuitable land. Suitability index is divided into two orders (suitable and unsuitable) into a total of five suitability classes (FAO, 1993) and presented in Table 3.4.

Table 3.4: Description of Land Suitability Class

Land Suitability Orders	Land Suitability Classes	Rating Range (1-100)	Definitions of Classes
Suitable	Highly Suitable	90-100	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce benefits.
	Suitable	80-90	Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on highly suitable land.
	Moderate Suitable	60-80	Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits or increase required inputs, that this expenditure will be only marginally justified.
Not Suitable	Marginally (poor) Suitable	40-60	Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.
	Unsuitable	< 40	Land with limitations to sustained use that cannot be overcome.

Source: FAO, 1993

Based on the land suitability evaluation process, the suitability of agriculture, residential, commercial, industrial and forest land use were prepared and used in developing physical infrastructure plan and land use planning.

3.5.4 Land Use Planning for Optimal Land Use Plan

Land use simulation based on CA technique is used in decision making process for allocation of land use. CA-simulation process is conducted on two assumptions: without control by policy, and influenced by policy. In this research, CA-simulation process influenced by policy control in land use planning assumption is applied for allocation of land use. In CA-simulation process, simulation of land use is conducted with existing land use (base policy criteria), transition (conversation) rule (interact process of neighboring cells through criteria suitability map), contiguity filter (simulating the land use from criteria's map) and allocation of land use based on the period interval. Existing land use data is used for describing the current situation land use characteristics in terms of the structure and its spatial pattern for base policy data. Also, existing land use map is used as monitoring human activities interactions with environmental as variation in landscape, ecological conservation services and land development. In this research, land use map 1996 and land use map 2017 has used as base map; in which land use map 1996 has used for model formation and validation purpose while land use map 2017 has used for simulating land use for year 2037.

Transition rule is influenced the conversion of land use through conversion mechanism of policy. The transition rules are mainly included in two parts: local influence and global influence. The local influences are the agglomeration effect of land development through neighborhood effect as stimulation with its surrounding area development. The global influences are included some macro influences as macro location, transportation accessibility and natural constraints in planning policy (Junfing, 2003). In this research, transition rule is designed based on the conversion mechanism of policy and global influences considering the land suitability data/maps and 5x5 contiguity filters. The land use map is nine categories, so there are required nine transition rules from the suitability map of agriculture, residential, commercial, industrial, forest, public use, cultural and archeological, water body, and others as factor. The suitability factors map are converted into continuous form from non-continuous data to represent the degree of suitability in uniform pattern. Therefore, the suitability factor maps are standardized into a continuous scale of suitability from 0 (least suitable) to 255 (most suitable) with the fuzzy membership function considering two reasons. Firstly, all the factor maps are not maintained the same degree of suitability and secondly, all areas in the municipality are not represented the same continuous suitability level. These standardized suitability factor maps are used in simulation process.

In CA simulation process, the transition rule is used as conditional probability matrix for conversion from one LU category into another developable LU category based on the total number of iterations as period interval set by the user (time period for projection). Within each iteration process, each and every LU class is typically converted into one-another LU classes, but some LU class may be only gain from other LU classes. Thus within the consideration of each host within each iteration, claimant classes select land from the host based on the suitability map for the claimant class. The land allocation for each land use class is carried out using a multi-objective allocation (MOLA) based on competition of suitability factors with contiguity filter for specific land use class. The simulation land use map is allocated for the projection of land use in 2017 A.D.

Validation is important in simulation process, though there has no consensus on the factors to assess the performance on simulation model. The validate results are evaluated through Kappa Index having K_{no}, $K_{location}$ and $K_{quantity}$ in order to compare the predicted with the 'real' land use map. In Kappa variations, K_{no}, is shown the proportion classified correctly relative to the expected proportion classified correctly by a simulation without the ability to indicate accurately quantity or location. $K_{location}$, is defined as the success due to a simulation's ability to indicate location divided by the maximum possible success due to a simulation's ability to specify location perfectly. $K_{quantity}$ ($K_{standard}$), is a measure of validation of the simulations to predict quantity accurately (Pontius & Chen, 2006). The validation of projected land use map 2017 is conducted with the existing land use 2017 prepared from satellite image as reference map. The validation of model under sufficient is found then the simulation map for land use allocation for year 2037 is generated.

The planning guideline is developed based on the policies, guideline with demand and needs of local people for minimum requirement of facilities and services. The development physical infrastructures are designed based on the developed planning guideline. The generated land use simulated map is integrated with risk zone layers and physical infrastructure layers are developed to prepare integrated allocation of land use classes in land use decision making process. SWOT analysis is conducted for determining the quality level of integrated land use plan through qualitative evaluation and increases the ownership of plan by local and guarantee the implementation of plan smoothly. SWOT analysis is used for the improvement of integrated land use plan to identify the lacking internal and external coherent condition of planning physical infrastructure in terms of economics, politics, ecological and environment perspectives. In SWOT analysis process, the strength of integrated land use has preserved and increasing the opportunities of developed plan with minimizing the weakness and threat using subjective analysis. The optimal land use plan is developed by incorporating the lacking information in developed integrated land use plan that makes the planning process more reliable and feasible for implementation of land use plan.

3.5.5 Developing Land Use Implementation Strategy

Legal framework is analyzed in Nepalese context to determine the legal situation for land use planning and implementation of land use plan at local level. At the same time, practice of land use plan in international context is reviewed to identify the process and occurring problems in land use plan implementation. Likewise, seamless cadastral datasets is prepared from cadastral maps/databases and ortho-rectified satellite images. Based on the specific zone of each land parcel, the land valuation of each land parcel is determined considering the different factors such as accessibility of public infrastructure, its topography, environment and socio-economic condition. The taxation of each land parcel is determined properly based on the specific land use categories.

Parcel based cadastral Information (PBCI) system is developed using seamless cadastral data and related land records. LUP implementation strategy is developed based on existing rule and regulation in Nepalese context and designed land development code for monitoring process of land use management area (protected, regulatory, reserved and guided development area) in the optimum land use plan. The optimum use plan is interlinked with land development code for its regulation and management of land properly. The developed land management area, PBCI system and optimal integrated land use plan are integrated spatially to explain specific land use categories and its management unit in the proper parcel of land through construction permits by specified institution mention in legal document. The integrated PBCI with specific land use is used to design the implementation strategy of land use plan and land development at local level for sustainable land management.

Chapter - 4

STUDY AREA

The chapter discusses the selection of study area with its location, physical status, the socio-economic situation, cultural, heritage, natural disaster and environments.

4.1 Selection of Study Area

Nepal is extensively diverse in topography. Geographically, the land-orientation covers 17 percent Himalayan Alpine Region to the North, 64 percent Mid-Hill Mountain (Mahabharat Range) in the middle, 6 percent Churia Range (Siwalik Hill) and 13 percent Plain Land of Tarai in the South (Himalayan Mentor, 2017). Land resource mapping project of Nepal classified the country into five broad physiographic regions: Tarai, Siwalik, Middle mountain, High Mountain and High Himalaya (LRMP, 1986). Shanbhunath Municipality lies within the Tarai and Siwalik region. The width of the Tarai region varies from 26 km to 32 km in a nearly continuous belt from east to west (Nepal Outlook, 2020). Out of 753 local administrative units (6 metropolitan cities, 11 sub-metropolitan cities, 276 municipalities and 460 rural municipalities), Shambhunath Municipality is selected for this research. Shambhunath Municipality is situated in both Tarai and Siwalik region having plain land in the middle and South, undulating terrain in the foot of Siwalik hill, and Steep Mountain in the North covers 12 km extent in North-South direction. Population growth rate (12.56 percent) and population density (204 per sq.km) are comparatively higher than national population growth rate and population density of Nepal in 2021 (NSO, 2023). Accessibility and availability of service and facilities are limited along the East West highway crosses in middle part and postal highway crosses in southern part of the municipality. Also, unplanned urbanization, haphazard infrastructure development and high rate of land fragmentation in urban and semi-urban area of the municipality raise land use conflicts that require proper land management and development through land use planning.

4.2 Location of Municipality

Location map of Shambhunath Municipality is prepared and presented in Figure 4.1.

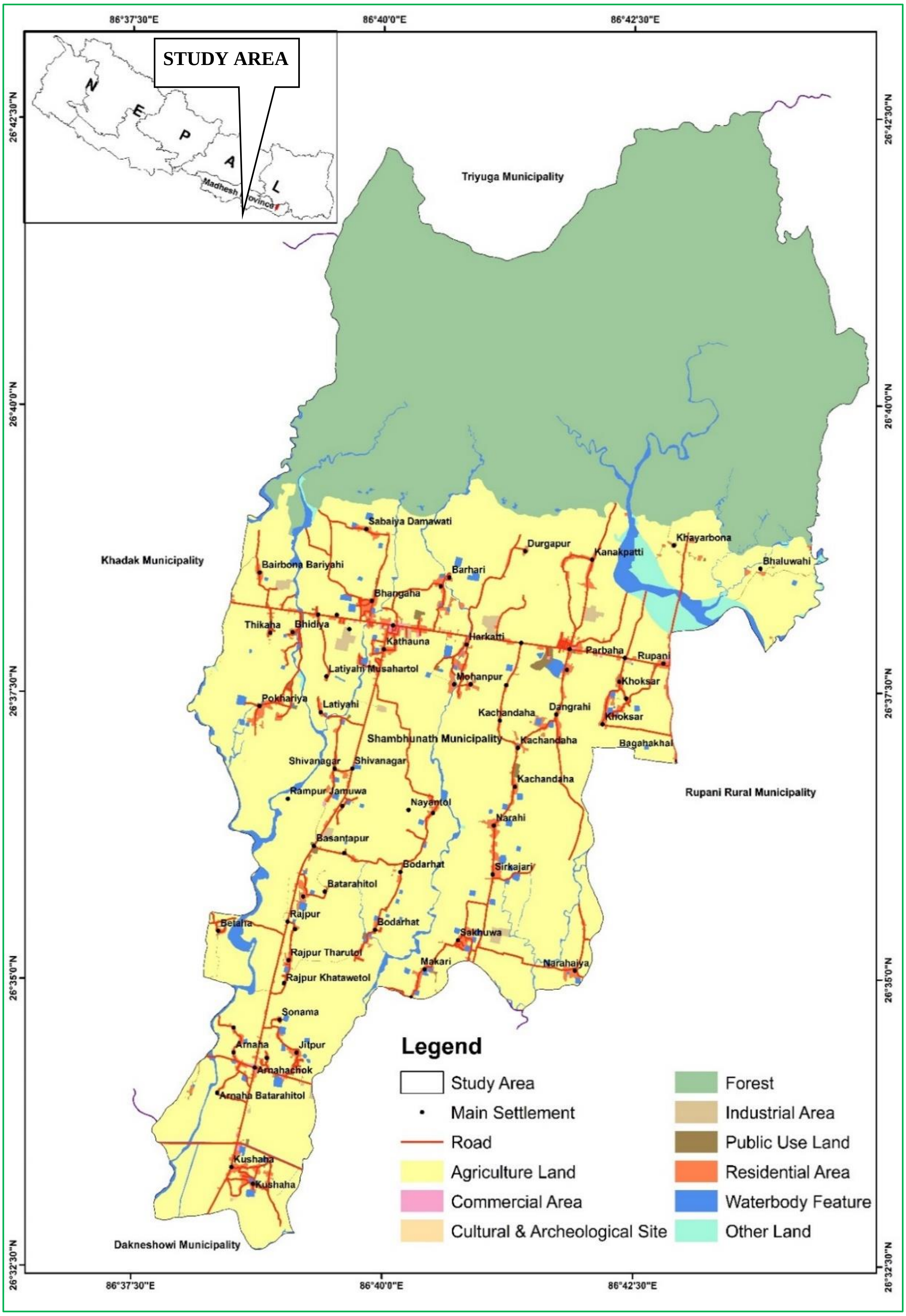


Figure 4.1: Study Area

Shambhunath Municipality was formed on 18th May, 2014 in Sapatari district, Madhesh Pronince with merging of previous village development committee (VDC) of Shambhunath, Bhangha, Khoksar Parbaha, Mohanpur, Basbalpur, Rampur and Jamuwa VDC, and expanded with emerging Arnaha VDC on 11th August, 2017 after formulation of Nepalese Constitution 2072 and reconstructed of local level in Nepal. Sapatari district in Madhesh Pronince. It covers 53 rural settlements and four urban/semi-urban area as market centers. The market centers are located at Kathauna bazar, Rupani bazar, Trarfic chock, and Arnaha chock. The municipality is located between latitude from 26^0 23’ 35” to 26^0 42’ 36” and longitude from 86^0 37’ 39” to 86^0 44’ 54”. The total area of the municipality is 108.46 sq. km having 12 wards as its sub-units. The municipality headquarter’s office is located at Kathauna Bazar. This municipality is bordered with Dakneshwori Municipality in the south, Khadak Municipality and Dakneshwori Municipality in the west, Dakneshwori Municipality, and Rupani Rural Municipality in the east, and Triyuga Municipality of Udaypur district in the north (in Figure 4.1). The famous Hindu regimes of Shambhunath Temple is located within this municipality and naming of the municipality originated as Shambhunath Municipality. In the Baisakh Month of each year local people organized fair for one month at Shambhunath Temple and celebrate here with joy and happiness.

4.3 Physical Setting

Shambhunath Municipality of Nepal covers parts of Tarai as Indo-Gangetic Plain, and Siwalik region as Lower Siwalik (Bhabar) and Upper Siwalik (Chure). Most of 57.78 percent portion of the municipality lies in the Indo-Gangetic Plain in the middle and southern part of the municipality. Whereas, 10.56 percent of the municipality extent is occurred in lower Siwalik region and 31.66 percent in upper Siwalik region. The physiographic map of the municipality is presented in Figure 4.2.

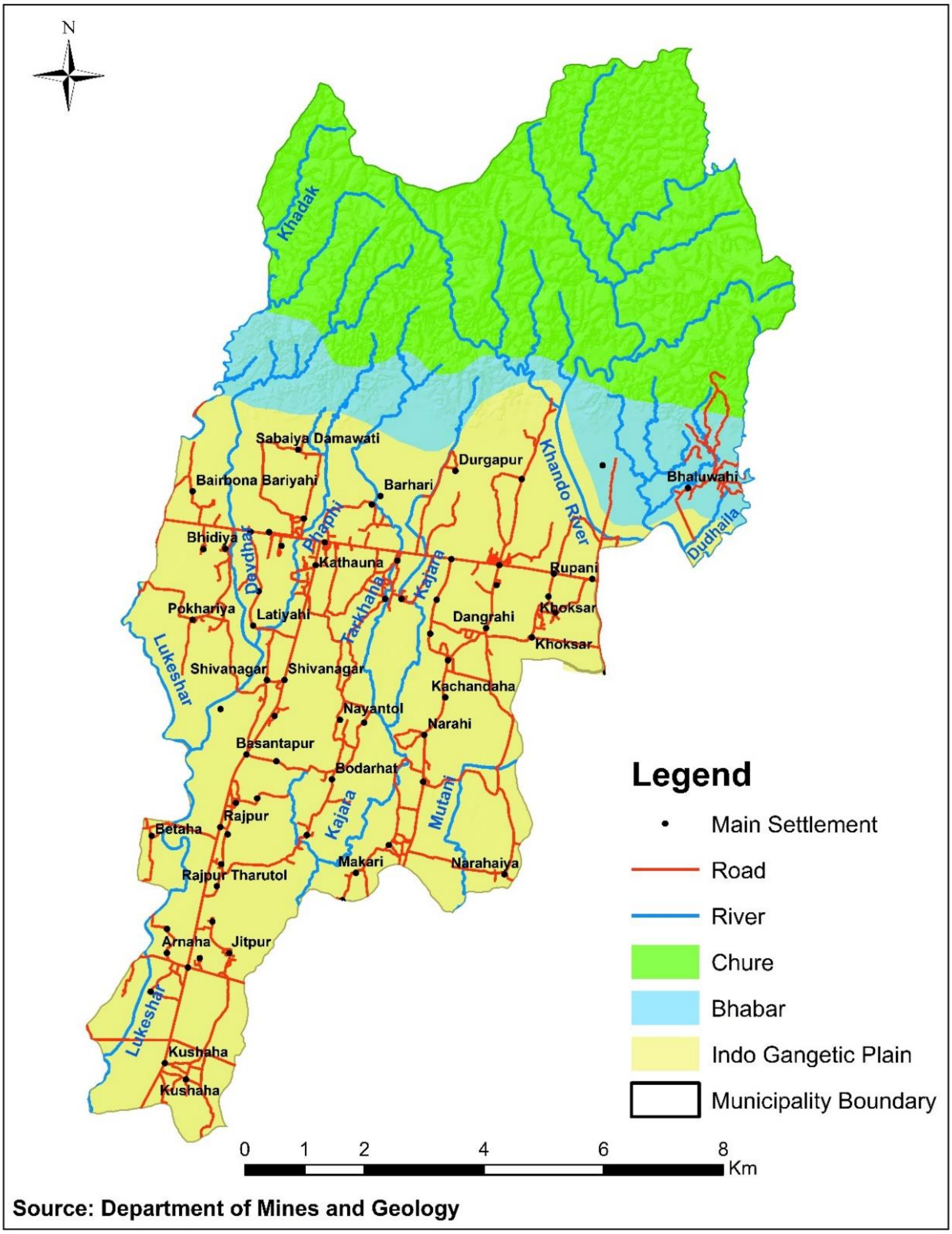


Figure 4.2: Physiography Map of Shambhunath Municipality

4.3.1 Geology

Geologically, Nepal can be divided into five major tectonic zones: Tarai, Siwalik, Lesser Himalaya, Higher Himalaya and Tethys Himalaya, and separated with major Thrusts and Faults (Upreti, 2001). Shambhunath Municipality falls in Tarai and Siwalik zone separated with Main Frontal Thrust (MFT). The formation of sediment is recently

Indo-Gangetic Plain alluvial depositional material in Tarai zone. The rock/sediment of fine to moderate gained particle mainly coaly material and sediments of moderate to course material (sand gravel sediment rock) is dominant occurred in Siwalik zone. The geological map is presented in Figure 4.3.

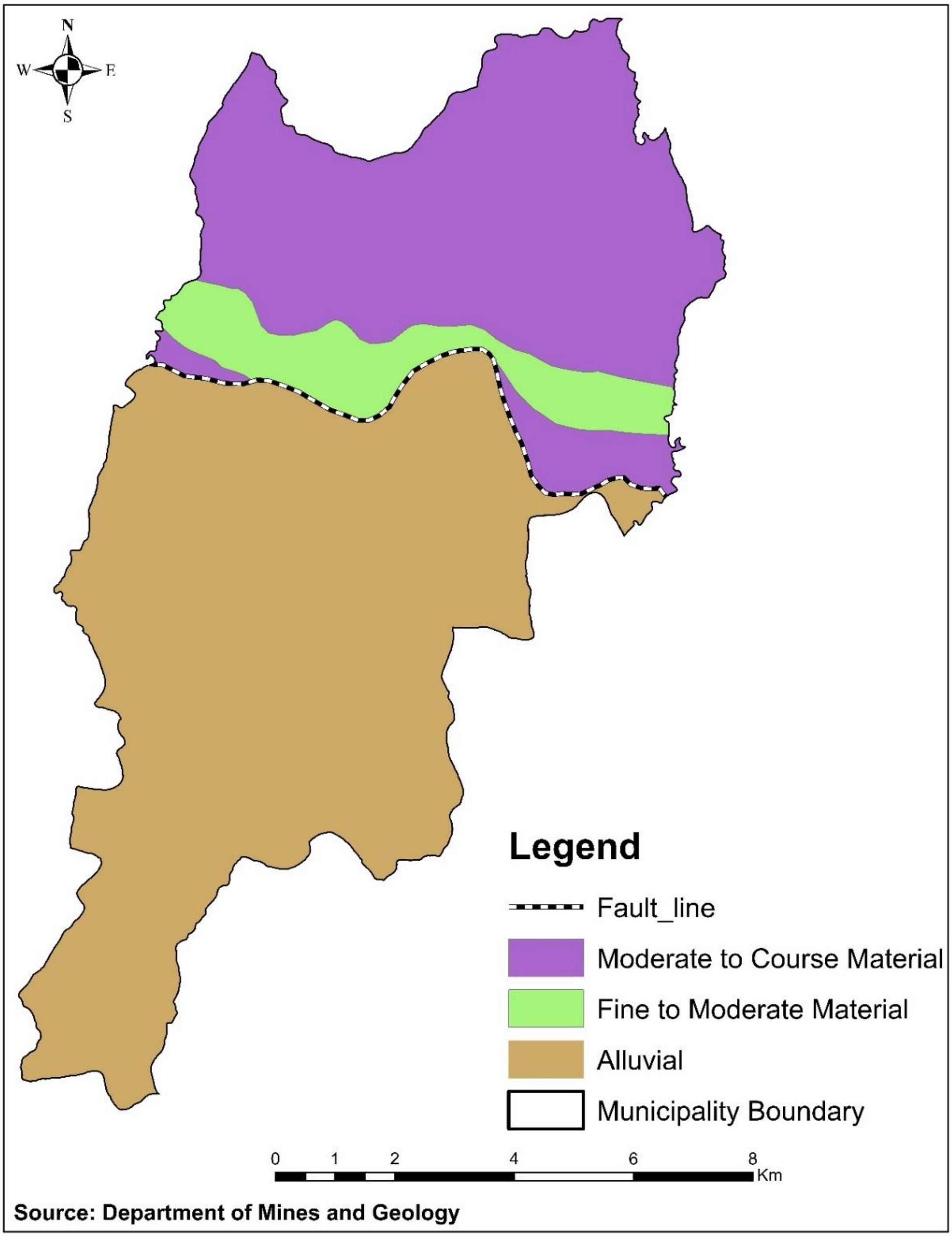


Figure 4.3: Geological Map of Shambhunath Municipality

The Main Frontal Thrust (MFT) separates the loose sediments of the Indo-Gangetic Plain in south and sedimentary rocks of the Siwalik range in North. The Indo-Gangetic plain is developed due to activation of the MFT as evolution before 1 million years ago (NLUP, 2016). The sediments in the southern part of Municipality are represented by the presence of alluvial deposits (mainly silty sand and clays) by active ancient rivers in the past. The sediments of middle northern part are characterized mainly by unconsolidated sands and clays, some sub-rounded to rounded, well sorted cobble and pebble inter-bedded with sands, and silty clay layers deposited from Lesser Himalaya rocks. The northern part appears with gravels of sandstone, mudstone and conglomerate mainly consists of quartzite and slate. The beds are roughly horizontal and show fining upward succession with cobble pebble at base and silty clay at the top (NLUP, 2018).

4.3.2 Geomorphology

Shambhunath Municipality falls under recent formation as alluvium in Indo-Gangetic Plain, depositional basin (Dun) in Bhabhar region and undulating steepness terraces in the Chure region. Topography formed by the distribution of the alluvium sediments is more or less in flat and fineness of the sediments increases towards south of the municipality area (NLUP, 2016). Chure region is characterized by presence of alluvium fans, talus and colluviums. The sediments of the Bhabar zone and Indo-Gangetic Plain in Municipality is developed an alluvial terrace and recent alluvial deposits; and still in formative process through potentially inundated during the high floods. The landscape along the active riverbed is constantly changing as a result of both the annual monsoon flooding and the regular riverbed movement (NLUP, 2018). The geomorphological map is presented in Figure 4.4.

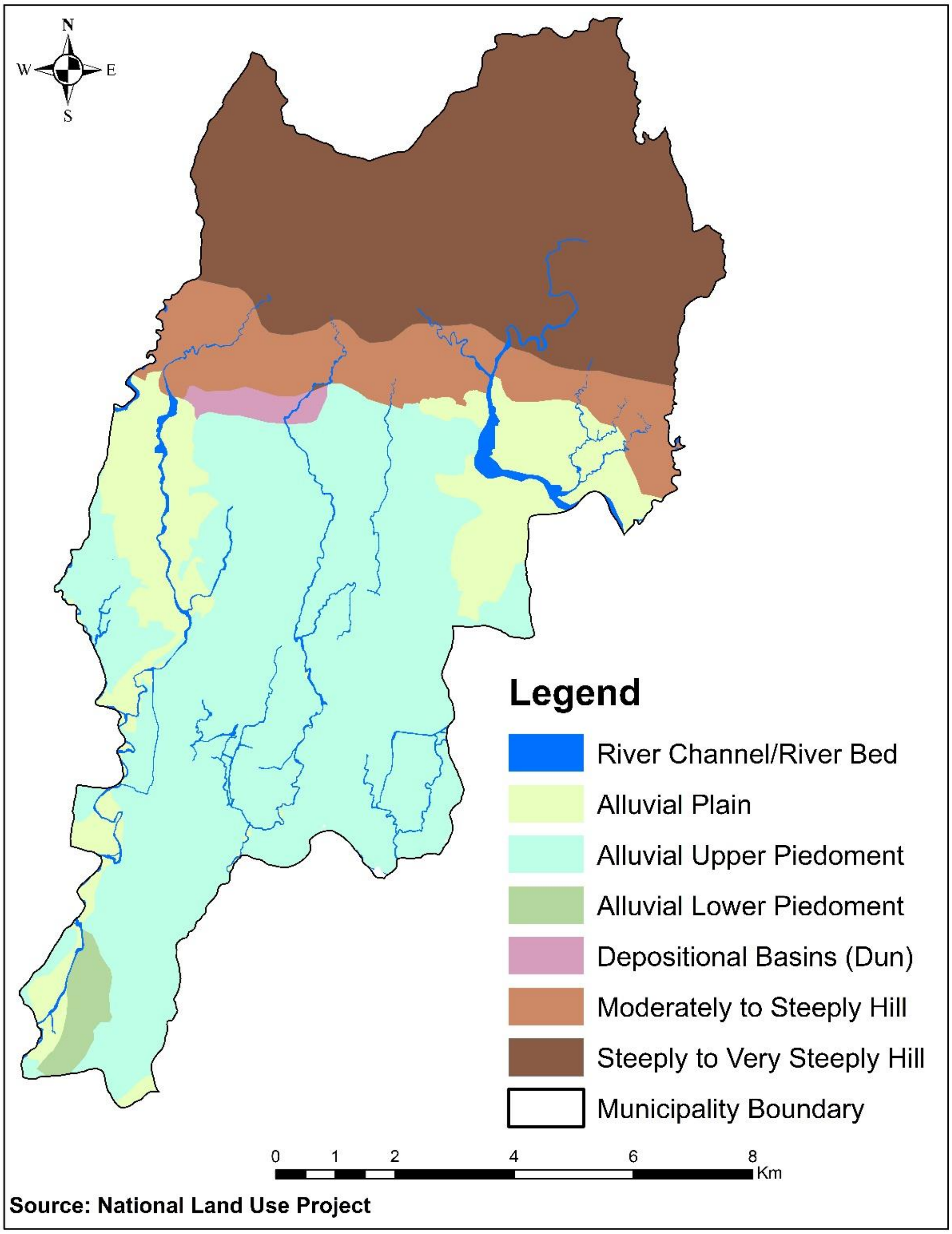


Figure 4.4: Geomorphological Map of Shambhunath Municipality

The river channel and river bed describes the existing river courses containing either water or dry in the Bhabar and Tarai region. Lower alluvial fan consists of recent alluvial plain lower piedmont (depositional and erosional) having steepness less than 1 degree. Upper alluvial fan consists of alluvial fan complex, upper piedmont (erosional) having steepness range between 1 degree to 3 degree. Depositional basin (Dun) having the slope varies from 1 degree to 5 degree. Moderately to steeply sloping hilly area lies in the slope of 5 degree to 15 degree. Hilly rouged terrain includes very steeply slopping terraces in the range greater than 15 degree.

4.3.3 Relief

Shambhunath Municipality lies in the elevation range from 81m to 443m above the Indian mean sea level. The lower elevation has found 81m at south of Kushaha settlement and the highest elevation at top of Siwalik Ridge in the boundary of Saptari and Udayapur districts. DEM overlaid with the Municipality boundary is shown in Figure 4.5.

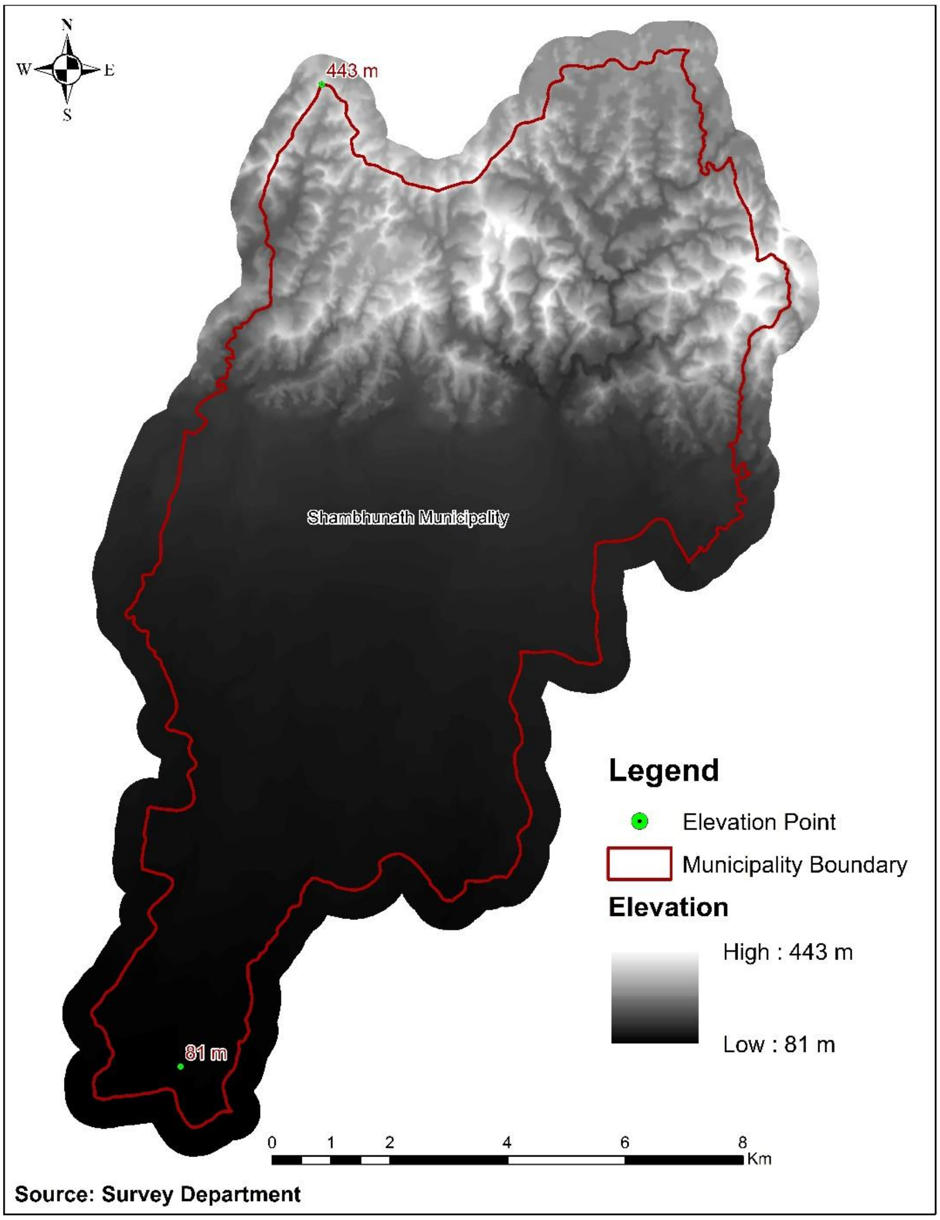


Figure 4.5: Digital Elevation Model of Shambhunath Municipality

The slope map of Shambhunath Municipality is shown in Figure 4.6.

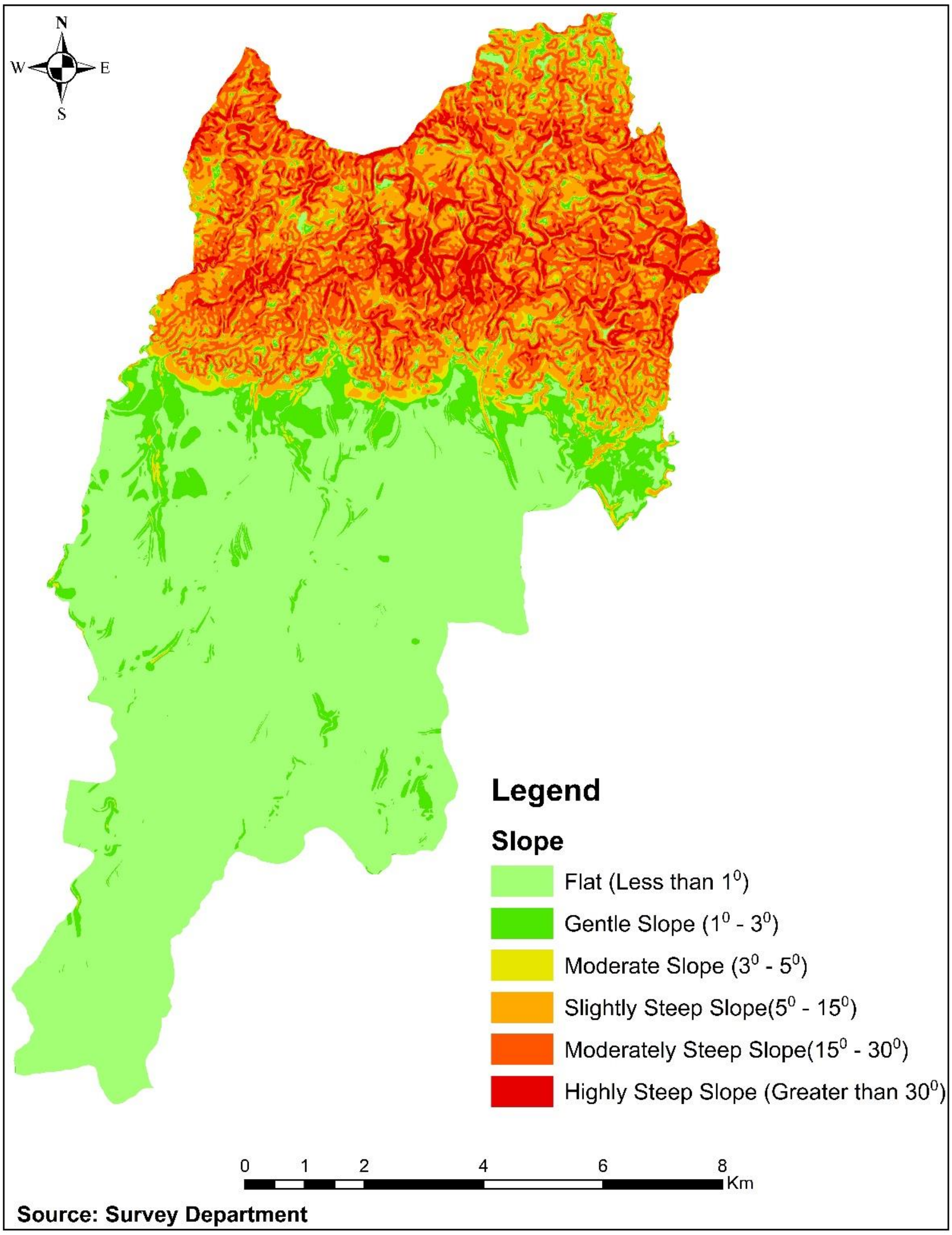


Figure 4.6: Slope Map of Shambhunath Municipality

Flat terrain, the dominant slope in this municipality with 53 Percent, mainly lies in Tarai Indo Gangetic Plain, followed by highly steep slope occurs in Siwalik region of northern portion with 22 percent (24 sq.km.). Likewise, 6 percent (5.74 sq. km) covers in moderate slope area. Similarly, moderately steep slope covers 8 sq. km having 7.72 percent; gentle slope covers 8 sq. km with 7.17 percent, and slightly steep slope covers 6 sq. km with 5.71 percent of municipality extent.

4.3.4 Climate

Shambhunath Municipality lies in the flanks of Tarai plain and Siwalik region; the climate is temperately hot and humid subtropical region along with wet and hot summers; mild and dry winters (NLUP, 2016). The weather station at Rajbiraj, Lahan, Gaighat, Fatepur, Chatara and Barmajhiya are used to depict the climatic situation in the study. Rajbiraj weather station is close to the municipality with 12 km distance. The annual rainfall amount was measured at Rajbiraj weather station from 2003 to 2018 (Table 4.1).

Table 4.1: Annual Rainfall at Rajbiraj Weather Sation

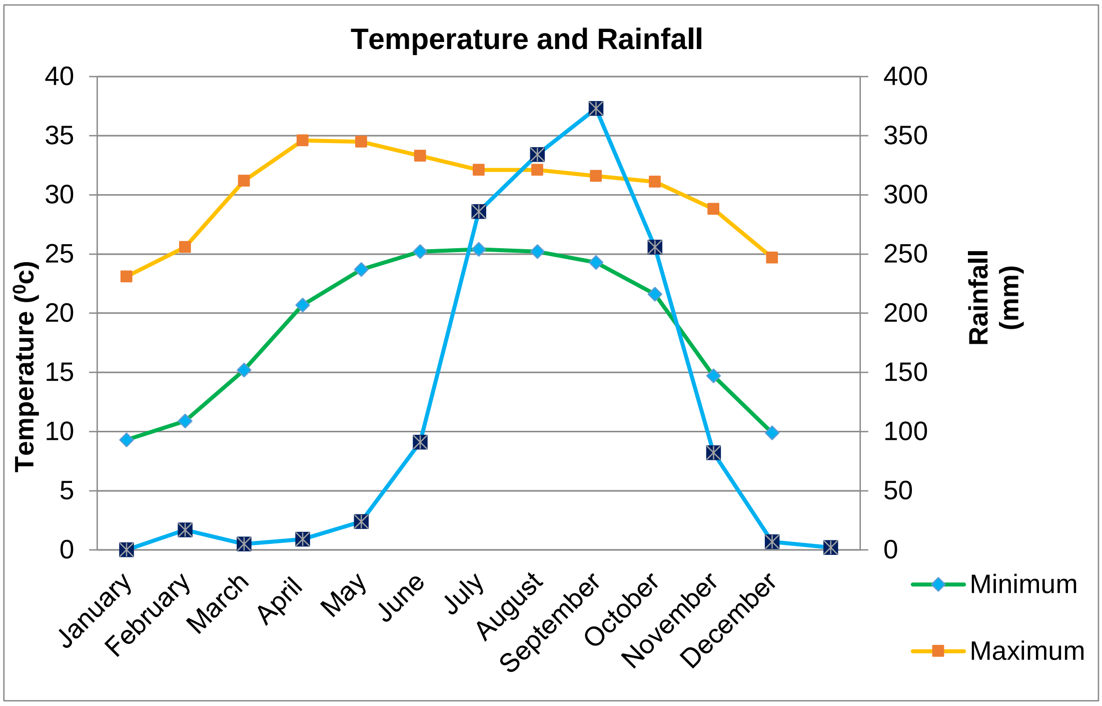
Year	2003	2004	2005	2006	2007	2008	2009	2010
Rainfall (mm)	1763	2185	1230	1114	1009	1212	952	1141
Year	2011	2012	2013	2014	2015	2016	2017	2018
Rainfall (mm)	1680	969	1307	1393	1435	1548	1634	1367

Source: Department of Hydrology and Meteorology

The annual rainfall amount is varied greatly in the last sixteen years. The average rainfall at Rajbiraj weather station falls 1500 mm annually from 2003 to 2018. The minimum amount of rainfall was recorded in 2012 (969 mm) and maximum in 2004 (2185 mm). Likewise, the average monthly rainfall amount increased sharply from April (50 mm), peaked in the month of August (380 mm), and dropped sharply below up to 55 mm in the middle of October. The driest month is December with little to no rainfall.

The average temperature at Rajbiraj weather station is 24.5°C (2003 to 2018). During winter season (November to February), the average monthly maximum and minimum temperatures (2003-2018) was recorded 20^{o}C and 10^{o}C respectively. During April to

September remained fairly hot temperatures peaked at 34°C (maximum) and 25°C (minimum). The average monthly maximum and minimum temperature associated with average monthly rainfall amount data from January to December (2003- 2018) is shown in Figure 4.7.



Source: Departmrnt of Hydrology and Meteorology

Figure 4.7: Average Temperature and Rainfall

4.3.5 Drainage

River, stream and rivulet of the Shambhunath Municipality are originated from Northern part of the Siwalik ridge. Khando River is major river system where as Kajara, Tarkhana, Mutani, Devdhar, Lukeshar and Dudhaila are the minor streams in this municipality. Also, Khadak River is occurred having 0.78 km in the northern west direction. However, numerous smaller streams are also flowing from the Siwalik ridges and other small tributes of streams originate from upper part of Tarai, and become prominent during the rainy season. Flood occurs on these rivers and streams mainly on rainy season, and damages the agriculture land and. The drainage system in the municipality is presented in Figure 4.8.

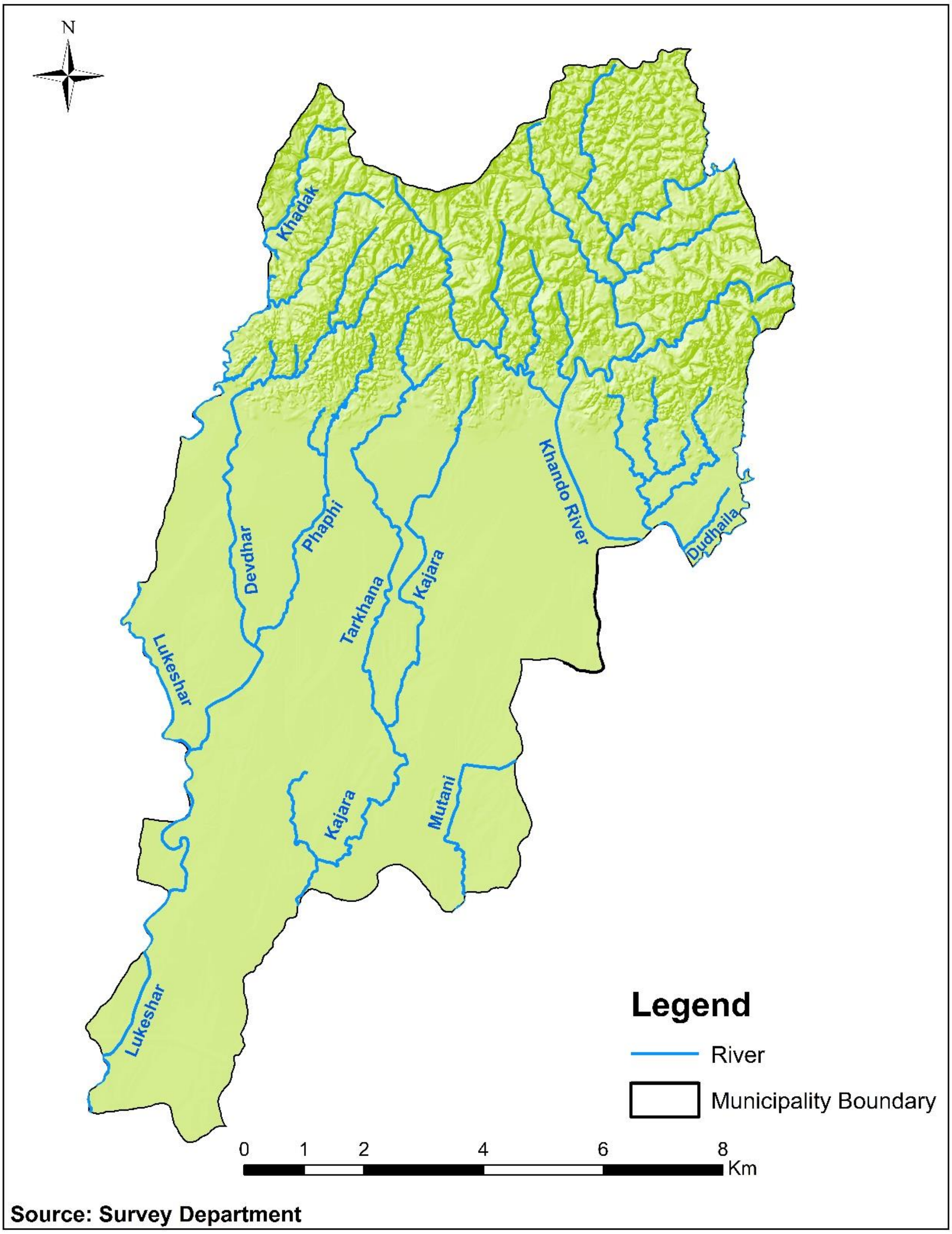


Figure 4.8: Drainage Network of Shambhunath Municipality

4.3.6 Soil

Soil is biologically active, porous medium developed in the uppermost layer of Earth's crust. Shambhunath Municipality has four soil types: entisol, inceptisol, molisol, and alfisol. Entisols soil is developed with limited profile development (horizon) and frequently contains unconsolidated sediment or rock. Inceptisols soil is made up of embryonic soils with a few distinguishing characteristics, and cambic (surface or subsurface) horizons with weather-resistant parent materials such quartzite, silica, clay minerals, metal oxides, and sandstone. Molisol soil is made up of high base saturation, dark soil, argillic or natri horizon of organic matter, and nutrient-rich surface soil. Alfisols soil is produced with high to medium saturation, with an argllic or natric horizon loaded with subsoil of clay, and relatively high fertility native soil (NLUP, 2018). The soil distribution in the Municipality is presented in Figure 4.9.

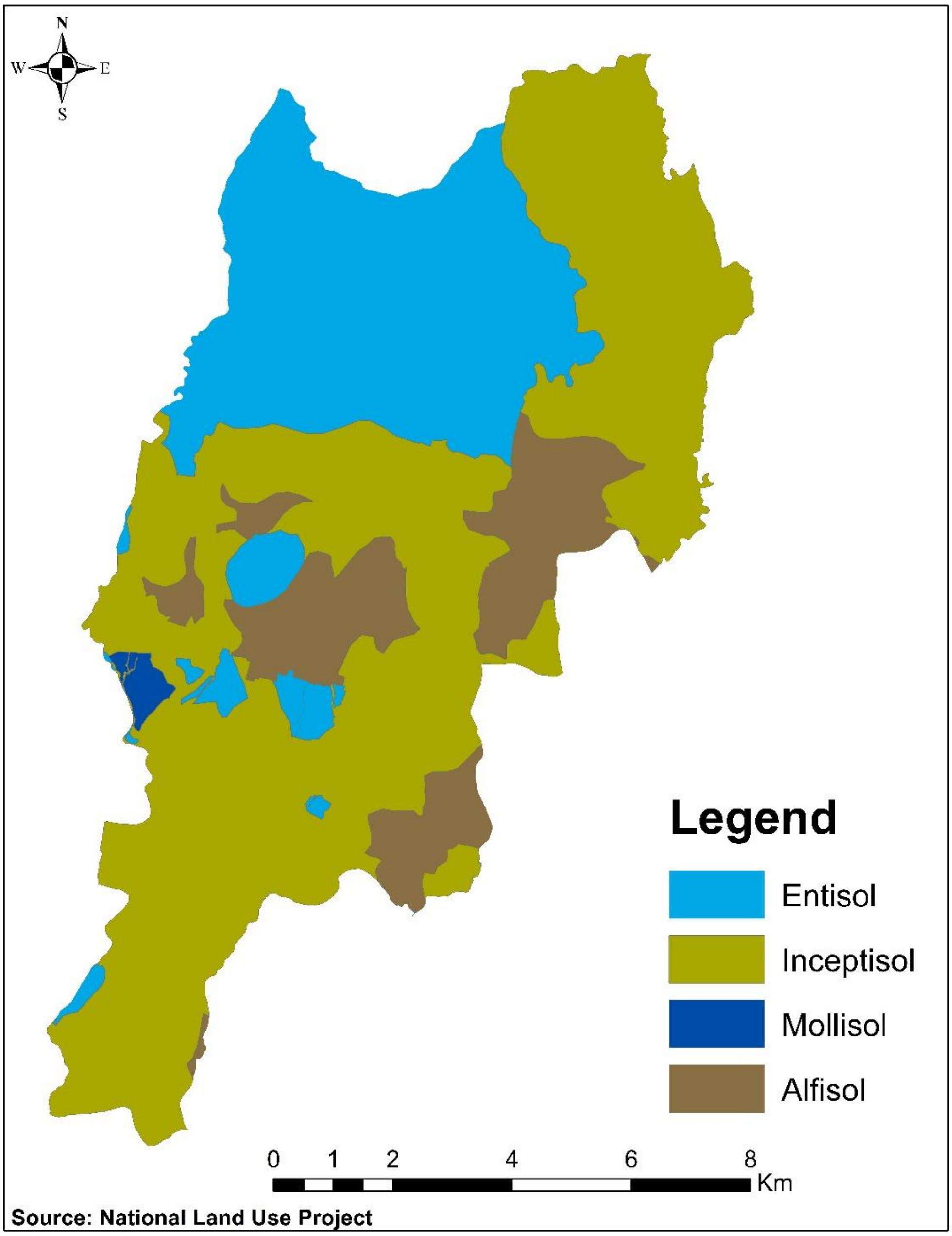


Figure 4.9: Distribution of Soil Types in Shambhunath Municipality

In this municipality, inceptisols soil is the dominant soil type, covering with 63 sq. km (58 percent) and distributed in flat terrain. Entisols soil is the second dominated soil type with 30 sq. km (28 percent) distributed in Siwalik region. Likewise, alfisol soil covers 14 sq.km (13 percent) mainly along the surrounding of Khando River and surrounding to the river junction. Mollisol soil covers only 1 sq. km (0.7 percent) distributed in scattered nature at upland landform and along the river course at Rampur Jamuwa.

4.3.7 Land Capability

Land capability measures the combination of agricultural and conservation practices that permits the most rigorous and proper use of land. Shambhunath Municipality has land capability classes as class I, class II, and class III. Class I land is capable for arable suitability with high fertility rate in the slope less than 1degree and high soil depth 50-100 cm for diversified crop production and forestry use. Class II land is capable for arable suitability with high fertility rate in the slope range varies 1 to 15 degree and high soil depth 50-100 cm for diversified crop production and forestry use. Generally, class III land is capable for arable suitability with medium fertility rate in the slope range varies 3 to 30 degree and high soil depth greater than 20 cm for crop production and forestry use (NLUP, 2018).

In the municipality, land capability class I covers the highest fertile and arable land having 94 sq. km (86.3 percent) land that is used for agriculture practice in Tarai and forestry used in Siwalik region. Land capability class II composes the second dominant fertile land with 15 sq.km (12.5 percent) that is used for moderate arable agriculture production mainly in Tarai along river junction and its surrounding. Land capability class III covers 25 sq. km (1.2 percent) for comparatively less agriculture production mostly found in the foot of Siwalik region (Bhabhar zone) and applied in fruits production. The land capability map in the study area is shown in Figure 4.10.

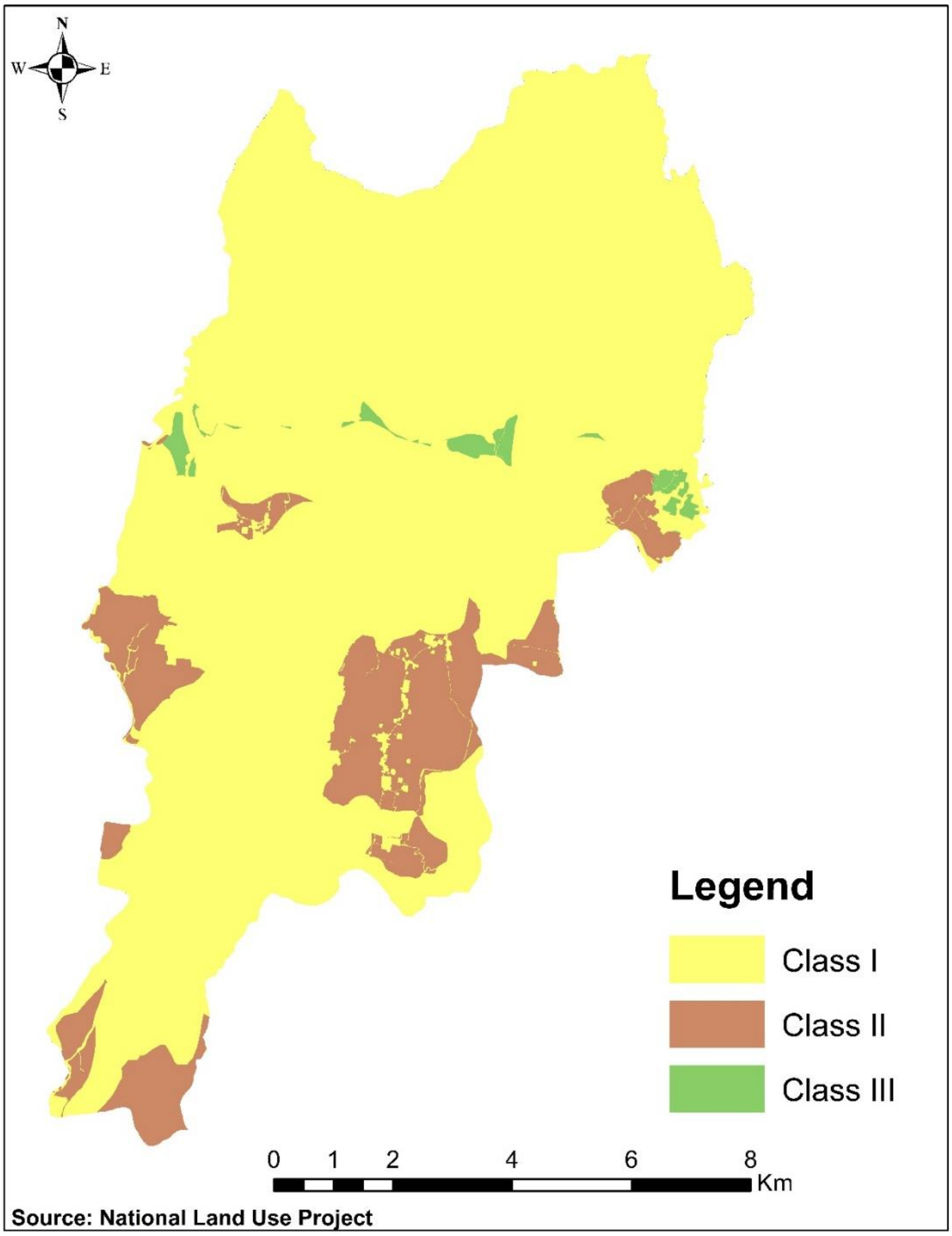


Figure 4.10: Land Capability Map of Shambhunath Municipality

4.3.8 Biodiversity

The biodiversity in Shambhunath Municipality is diversified that broadly characterizes Siwalik and Tarai forest ecosystems. From land use map 2017, almost 41 percent of its area is under vegetation cover community forestry, private forestry and grasslands. About 2 percent of the municipal area is covered with bamboo and orchard. These biological resources in the municipality are important for timber, non-timber and wildlife species; and supports from subsistence livelihood concern to economic development with multiple benefits for the society, community and nation. The major forest cover species are shorea robusta (sal), dalbergia sissoo, albizia lebbeck (sirish), senegalia catechu (khair), rosewood, acacia and grasses in the municipality. Cow, buffalo and goat are the main domestic animals Buffalo is used for draught purpose of agriculture land. Monkey, wild elephants, bears and arnaa (wild buffalo) are major wild animal species randomly observed surrounding to the forest area. The rivers and streams are dried in the winter and summer seasons accept in rainy days. In land use map of 2017, seven small irregular types waterlogging areas (lakes) was observed in Bhabar region. Similarly, one small wetland of 1 ha and 162 number of ponds was accounted in flat terrain.

4.4 Socio-economic Setting

Shambhunath Municipality comprises not only diverse physiography but also diverse caste and ethnic groups with different economic and social backgrounds.

4.4.1 Social Characteristics

Shambhunath Municipality accounts population of 39634 people in which 48 percent of male (19006) and 52 percent of female (20628) having number of houses 8679 and household size 4.57 (NSO, 2023). The ward wise population is presented in Table 4.2.

Table 4.2: Population and Household in Shambhunath Municipality

Ward No.	Household	Male	Female	Total
1	532	1175	1218	2393
2	618	1576	1622	3198
3	1029	2043	2263	4306
4	611	1312	1491	2803
5	545	1051	1154	2205
6	915	1869	1907	3776
7	1034	2392	2608	5000
8	685	1401	1627	3028
9	525	1226	1310	2536
10	393	960	997	1957
11	576	1163	1391	2554
12	1215	2838	3040	5878
Total	**8679**	**19006**	**20628**	**39634**

Source: NSO, 2023

The overall ratio of male to female population in the municipality as per is 0.92 in 2021. There are 63.92 percent (25,335) of independent population ages between 15 and 64 years. The dependent population was 14,299 people (36.08 percent), in which children ages below 15 years population 11,410 people and elderly population aged 65 years and above population 2,899 people (NSO, 2023). The average population density in this municipality is 365 persons per square kilometer. The very high population density occurred in Ward no.5; Kathauna Bazar having 1428 and its surrounding settlement in Ward no. 6 (1293) mainly along East West highway. The least population density is occurred in Ward no. 7 (148) and the Ward no.2 (122) at Siwalik region. The population density map of this municipality is presented in Figure 4.11.

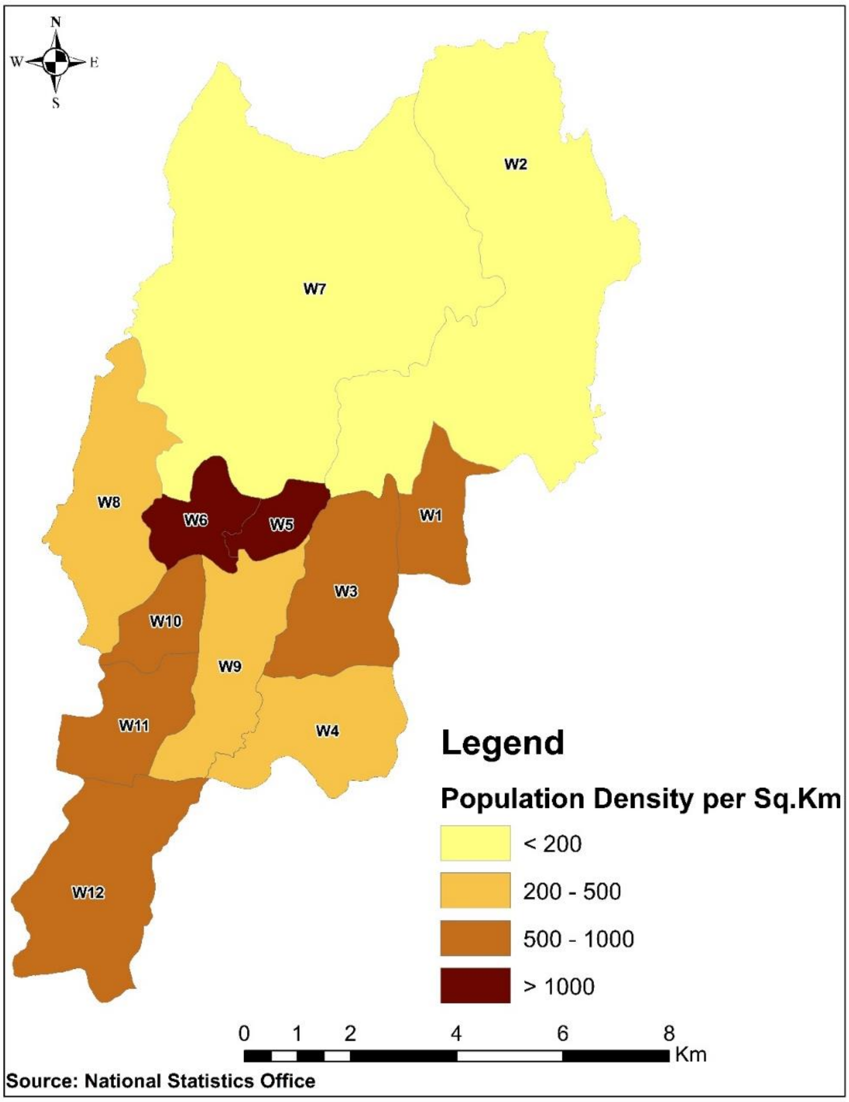


Figure 4.11: Population Density Map of Shambhunath Municipality

The population based on the caste and ethnicity group is presented in Table 4.3.

Table 4.3: Population by Ethnicity in Shambhunath Municipality

S.N.	Caste	Male	Female	Total	Percentage
1	Tharu	5747	6542	12289	31.01
2	Musahar	2133	2293	4426	11.17
3	Teli	1529	1539	3068	7.74
4	Khatwe	1388	1492	2880	7.27
5	Musalman	1323	1464	2787	7.03
6	Bantar/Sardar	1273	1394	2667	6.73
7	Chamar/Harijan/Ram	883	930	1813	4.57
8	Yadav	592	614	1206	3.04
9	Kalwar	563	584	1147	2.89
10	Tatma/Tatwa	511	564	1075	2.71
11	Haluwai	420	437	857	2.16
12	Dhanuk	419	392	811	2.05
13	Dusadh/Pasawan/Pasi	299	319	618	1.56
14	Hajam/Thakur	264	282	546	1.38
15	Bishwokarma	198	233	431	1.09
16	Gaderi/Bhediyar	200	205	405	1.02
17	Mallaha	177	199	376	0.95
18	Kshetri	125	142	267	0.67
19	Kumhar	111	130	241	0.61
20	Rajdhob	108	100	208	0.52
21	Rai	81	81	162	0.41
22	Dom	72	76	148	0.37
23	Kathabaniyan	71	72	143	0.36
24	Magar	66	76	142	0.36
25	Sonar	50	52	102	0.26
26	Foreigner	47	44	91	0.23
27	Badhaee/Badhee	40	38	78	0.20
28	Tamang	39	34	73	0.18
29	Rajput	29	27	56	0.14
30	Others	26	29	55	0.14

31	Pariyar	25	28	53	0.13
32	Kayastha	23	25	48	0.12
33	Amat	19	24	43	0.11
34	Brahman Tarai	20	22	42	0.11
35	Koiri/Kushwaha	19	20	39	0.10
36	Dev	19	17	36	0.09
37	Sundi	14	14	28	0.07
38	Kanu	12	15	27	0.07
39	Mali	10	16	26	0.07
40	Lohar	11	13	24	0.06
41	Danuwar	12	10	22	0.06
42	Kurmi	6	11	17	0.04
43	Newa: (Newar)	9	7	16	0.04
44	Rajbansi	5	8	13	0.03
45	Brahman Hill	8	3	11	0.03
46	Majhi	7	4	11	0.03
47	Gharti/Bhujel	3	7	10	0.03
	Total	**19006**	**20628**	**39634**	**100.00**

Source: NSO, 2023

Social composition of the municipality is comprised with various ethnicity and caste dominated by Tarai communities as Tharu, Mushar (Dalit) and Shah/Yadav (Madhesi). However, other communities such as Brahmin/Chetri, Muslim and Rai/Gurung are also found in large number. Tharu ethnicity community constitute 31 percent population whereas Janjati (Dhanuk, Khatwe, Baatar/Sardar, Kalwar, Tatma/Tatwa, Mallaha, Godari/Bhaidhar, Amat, Magar, Kumal, Rai, Tamang, Suddi, Kumhar, Danuwar, Mewahang Bala, Badhae, Lohar etc.) occupy 28 percent; Dalit (Musahar, Chamar/Harijan/Ram, Dusadha/Paswan/Pasi, Rajdhob, Lhomi, Dom, Damai/Dholi, Mali) occupy 18 percent; Madhesi (Teli, Yadav, Haluwai, Hajam/Thakur, Kaithbaniya, Sonar, Kayastha, Rajput, Maithil Brahman etc.) occupy 15 percent; Musalim occupy 6 percent; Hilly Brahaman and Chhetree occupy 0.70 percent and remaining 1.30 percent are other caste/ethnicity group people in the municipality.

The population based on the religion in the municipality is presented in Table 4.4.

Table 4.4: Population by Religion in Shambhunath Municipality

S.N.	Religion	Male	Female	Population	Percentage
1	Hindu	16391	17731	34122.00	86.09
2	Buddha	1214	1362	2576.00	6.50
3	Islam	1325	1464	2789.00	7.04
4	Kirat	72	68	140.00	0.35
5	Christian	4	3	7.00	0.02
Total		**19006**	**20628**	**39634**	**100.00**

Source: NSO, 2023

In religious composition; Hindu population is about 86 percent, Islam 7 percent, Budda 6.5 percent, Kirat 0.35 percent and Christian 0.02 percent (NSO, 2023). The population based on literacy status in the municipality is presented in Table 4.5.

Table 4.5: Literacy Status in Shambhunath Municipality

Ward No.	Can read & write	Can read only	Can't read & write	Not Stated	Literacy Rate
1	1486	2	653	0	69.41
2	1804	3	1103	0	61.99
3	2657	26	1235	0	67.82
4	1695	3	781	0	68.37
5	1270	2	705	0	64.24
6	2522	1	936	0	72.91
7	3248	29	1258	1	71.60
8	1803	25	884	0	66.48
9	1432	1	854	0	62.61
10	1006	1	740	0	57.58
11	1434	2	841	0	62.98
12	3602	13	1637	3	68.54
Total	**23959**	**108**	**11627**	**4**	**67.10**

Source: NSO, 2023

Literacy rate in the municipality is 67.1 percent with male 77.7 percent and female 57.7 percent. There are only 26,594 people fully literate while 23959 people are able to read and write both, 108 people able to read but not write, 2527 people beginners, and 11631 people illiterate. The literacy ratio between male and female population is 1.35.

4.4.2 Economic Activities

People are engaged in a wide range of economic activities to maintain their life style and livings standard in this municipality. Some small and minor agriculture based micro industries as mills (agriculture and cottage) and moderate industries as brick factory are found in this municipality. According to 2018 Economic Census, there are total 961 establishments that involved in various commercial and economic activities. In those establishments, total 2,186 persons are engaged as a self-employed with total male 1,458 and female 728. In every business, the averages of 2.28 people engaged in which males 1.52 and females 0.76 having the ratio of male to female engagement is 2.00 (CBS, 2018). Out of total population, age more than 10 years 32030 persons in which male (14669) and female (17061) are engaged in economic activities having work duration less than three months 10.8 percent, three to six months 15.7 percent, more than six months 39.9 percent and remaining 33.6 percent people did not work (student, household work/chore, aged, disable, pensioner, social worker, and others) in the municipality. The population based on economic activities performance is presented in Table 4.6.

Table 4.6: Status of Economically Active Population

Sex	Economically Active			Not Economically Active	Economic Activity Not Stated	Population
	Usually Active		Not Usually Active			
	Employed	Unemployed				
Male	7303	609	2978	4061	18	14969
Female	5953	489	4726	5845	48	17061
Total	**13256**	**1098**	**7704**	**9906**	**66**	**32030**

Source: NSO, 2023

Total 22058 persons are found economically active (68.9 percent) and 9906 persons (38.9 percent) not economically active in the municipality. Among economically active people, 13256 persons are typically full time, 1098 persons employed seasonally, and 7704 persons employed occasionally for employment and occupational job. Total 9972 persons are not involved in any active economical activities. The major performing occupation and employment in the municipality is presented in Table 4.7.

Table 4.7: Major Occupation and Employment

S.N.	Occupation/Employment	Population	Percentage
1	Skilled agriculture, forestry and fishery workers	11692	53.01
2	Elementary workers	6134	27.81
3	Crafts and its related trade workers	1501	6.80
4	Service sale workers	883	4.00
5	Professionals	685	3.11
6	Plants and machines operators & assemblers	465	2.11
7	Managers	398	1.80
8	Technicians and associate professionals	199	0.90
9	Office assistants	89	0.40
10	Armed forces	12	0.05
	Total	**22058**	**100.00**

Source: NSO, 2023

In this municipality, agriculture, agroforestry and fishery is dominated occupation having 53 percent skilled worker and 28 percent elementary workers. Likewise, craft workers are involved 6.8 percent, service workers involved 6.8 percent and professional involved 3.11 percent people in this municipality. The activities of people involved for providing employment status is presented in Table 4.8.

Table 4.8: Employment Status

S.N.	Activities	Male	Female	Population	Percentage
1	Own account worker	5123	6749	11867	53.80
2	Employee	4437	2593	7037	31.90
3	Contributing family member	1211	1768	2978	13.50
4	Employer	119	58	176	0.80
	Total	**10890**	**11168**	**22058**	**100.00**

Source: NSO, 2023

More than 53 percent people are involved as self-employed with total 1867 persons in which male 5123 persons and female 6769 persons. 7037 persons acts as employee, 2978 persons supporting own family member whereas 176 persons providing works as employer in this municipality.

Agriculture production is the predominant economic activity in this municipality. Cultivation of cereal crops is the major activities for production of paddy and wheat. Cash crops are mainly vegetables, pulses and oilseeds while horticultural crops products includes mainly mango, litchi, jackfruits, papaya and banana. Fish farming and dairy production are also conducted in massive agriculture production while limited livestock farming also occurred in this municipality. In this study, the crop patterns area are determined through land use map 2017. The production of each crop per ha (yield) is obtained from the statistical information in Nepalese agriculture for Saptari district in year 2020/21 (MolAD, 2022) through Krishi Gyan Kendra (KGK), Saptari. Then agriculture production in the Shambhunath Municipality is estimated with relation to area of yield for each crop production. The production of agriculture activities is shown in Table 4.9.

Table 4.9: Agriculture Production

S.N.	Description	Area (in ha)	Annual Production (MT)	Percentage
1	Paddy	3344.15	12258	45.05
2	Vegetable	459.93	7175	26.37
3	Wheat	1183.40	4118	15.13
4	Mango	217.66	2682	9.86
5	Litchi	63.39	414	1.52
6	Pulses	194.72	242	0.89
7	Oilseeds	105.33	118	0.43
8	Fish	23.06	113	0.42
9	Jackfruits	1.19	26	0.10
10	Fresh Meat	3.56	21	0.08
11	Papaya	2.23	17	0.06
12	Banana	0.54	10	0.04
13	Maize	2.22	7	0.03
14	Dairy Product	2.07	5	0.02
15	Millet	1.58	2	0.01
16	Goat Meat	8.34	1	0.004
	Total	**5613.35**	**27209**	**100.00**

Source: KGK, 2021

The cereal crop is covered with 60.18 percent of agriculture production (paddy and wheat) with quantity 16376 MT in which paddy production conducted two times in summer and rainy seasons, and wheat production conducted one time along the command area of Koshi pump canal in Ward no. 12 (surrounding Kushaha settlement). The northern side of highway up to Churiya foot hills occurs apparently fallow, grazing lands or light and poor "Rabi crops" (oilseed, mustard/rayo, lentil, wheat, etc.) after paddy crop. Some high land area also cultivates with maize (2.22 ha) and millet (1.58 ha). In winter season, little lowland with dry land cultivation in southern side of the East West highway having normal moisture condition cultivates with wheat, lentil, mustard/rayo, oilseed, and vegetables after paddy crop. Livestock (cattle/animal husbandry) rising is remained as an indispensable to the farming system by integrating both farming of agriculture production and livestock practiced. By this system, farmers are able to manage farmland ecology. Both cow and buffalo are used for production of milk, then conversion to diary production. Also, ox and male buffalo are used in tillage practice to take favorable conditions for agriculture use. Poultry farms are managed by locals and some families as chicken; ducks farming system. Likewise, fish farming is being done in all the wards of this municipality. Mango, litchi and jackfruit are the main fruits grown in upland area as horticulture production. Farmers get various products such as fruit, milk, ghee, meat, egg and fish by raising livestock, poultry, fish farming and horticulture products for households use as well as for additional income.

4.5 Culture and Heritage

Heritage is a tradition: property that is or may be inherited; an inheritance, relating to things of historic or cultural value that are worthy of preservation, and valued items, such as historic buildings, that have been passed down from previous generations. So, heritage denotes anything and everything, to suppose rightly or wrongly, handed down from the past. Although heritage is by no means uniformly desirable, it is widely viewed as a precious and irreplaceable resource, crucial to personal and collective identity and necessary for self-respect. There are some temples in this municipality, where the Hindu people perform worship. During religious ceremonies and festivals, people flock the temples to perform puja (worship). Likewise, there are some mosques where Muslim people can carry out their ritual and religious practices.

Culture is the social pattern as well as characteristics and knowledge of a particular group of people, defined by everything from language, religion, cuisine, social habits, music and arts. It also share the patterns of behaviors and interactions, cognitive constructs and understanding that are learned by socialization. It is a social way of life style for an entire society where every aspect of life, food, clothing and even occupations are culturally classified. In this municipality, culture followed by the people is a unique combination of tradition and novelty. The indigenous 'Tharu' culture is unique, besides there have different castes and ethnic groups living in this municipality. These different castes and ethnic groups are their own customs, rites, rituals and traditions. Generally, people following different religions are different cultures. Hindus are the dominant religious group living here. They observe different festivals like Dashain, Tihar, Chhath, Teej, Krishnastami, Janai Purnima, Maghe Sakranti, Holi, and so on. Muslims celebrate Eid, Bakarid, Ramjan. Maghi Sankranti is the greatest festival of indigenous Tharu people and they celebrate it as a new year.

4.6 Natural Hazard and Environment

Floods are a great threat to environmental stability and life in the Tarai region. In Shambhunath Municipality, major flood events occur frequently in almost every 4-5 years and minor floods occur every year in middle and lower portion of the municipality and rivers/streams areas. Rivers/streams like Khando, Kajara, Mutani, Tarkhana and

Lukeshwor are heavily flooded. The recent flood in Khando River occurred in 2014 by heavy rainfall in Siwalik region and it's surrounding (MoFE, 2019). The river bank is destructed the soil dam and its spur through velocity of water flow in river and stream channel by bank cutting. The bank cutting is created probability of entering flood eastern part of Kanakpatti settlement frequently. Many agricultural lands was been converted to river plain due to bank cutting. Loss of private and public property including infrastructure are common.

River bank cutting also happened in this municipality along the river and stream channel in the Siwalik region mainly caused by heavy rainfall, massive soil erosion and mass fall. However, certain cases of very small landslides can be seen in the lower Chure hill region. Therefore, land of Shambhunath Municipality is prone to erosion, landslide and mass wasting. The entire municipality area falls under high seismic risk zone (NLUP, 2016). Sometimes, forest fire has also occurred in the Chure hill region. Also, fire risk happens because of poor management of fire and randomly electric circuit malfunction mainly in the house with thatched roof.

Poor solid waste management and poor sewerage system arises the environmental issues in the emerging urban and semi-urban area. Similarly, water pollution happens due to poor sanitation and open drainage system that degraded the quality of environment as well as agent of water borne disease. Major problem along the East West highway is noise pollution because of the heavy trucks and buses. Excluding indoor air pollution sources, there are no other major sources of air pollutant but brick-chimney creates some air pollution in this municipality.

Chapter – 5

LAND USE ISSUES, PATTERN AND SPATIAL TREND

The chapter discusses the existing land use practices, land use change, spatial pattern of land use, and spatial concentration and trend analysis of built-up area.

5.1 Issues on Land Use Practices

Land use map for 1986, 1996 and 2017 are prepared and quantified to represent existing practices of LU. The issues of land use practice are determined through land use change detection analysis and its quantification.

5.1.1 Land Use Map 1986

Land use map for year 1986 was prepared from the land utilization map with the help of GIS tools in digital environment and presented in Figure 5.1.

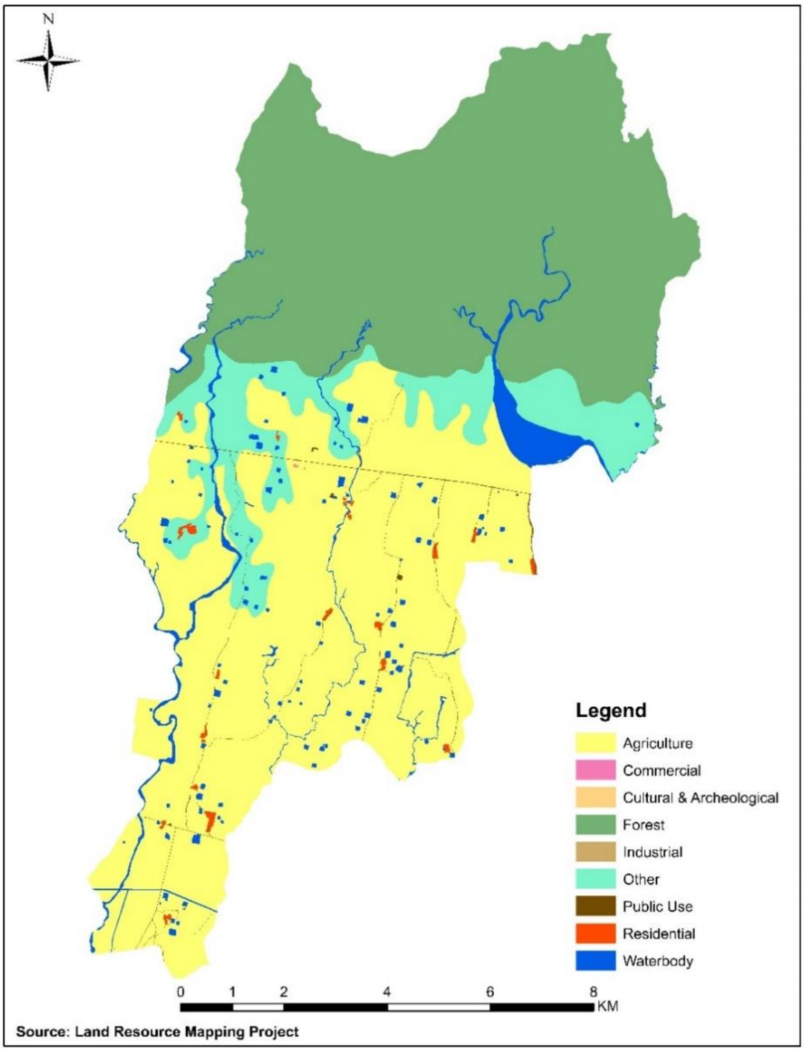


Figure 5.1: Land Use Pattern of Shambhunath Municipality in 1986

Land use categories was analyzed with computation of area from generated land use data for year 1986 in this municipality (Table 5.1).

Table 5.1: Different Types of Land Use in 1986

S.N.	Land Use Classes	Area (ha)	Percentage
1	Agriculture	4767.21	43.90
2	Forest	4538.14	41.79
3	Other	1090.98	10.05
4	Water body	394.16	3.63
5	Residential	34.94	0.32
6	Public Use	34.03	0.31
7	Commercial	0.51	0.005
8	Cultural & Archeological	0.28	0.003
9	Industrial	0.13	0.001
	Total	**10860.39**	**100.00**

Source: Land Use Database, 1986

In 1986, the agriculture use has been found as dominant land use type in this municipality with 44 percent extent having 4767 ha. Forest use has been the second dominant land use type having 42 percent with 4538 ha. At the foot of Chure hill and along the Khando River course, other land use classes occurred having 10 percent of the municipality extent. The residential and public use land have occupied minimum extent about less than half percent. The cultural and archeological and industrial area have comparatively negligible extent in the municipality.

5.1.2 Land Use Map 1996

Land use map for year 1996 was prepared from topographical map for the year 1996 with the help of GIS tools in digital environment and presented in Figure 5.2.

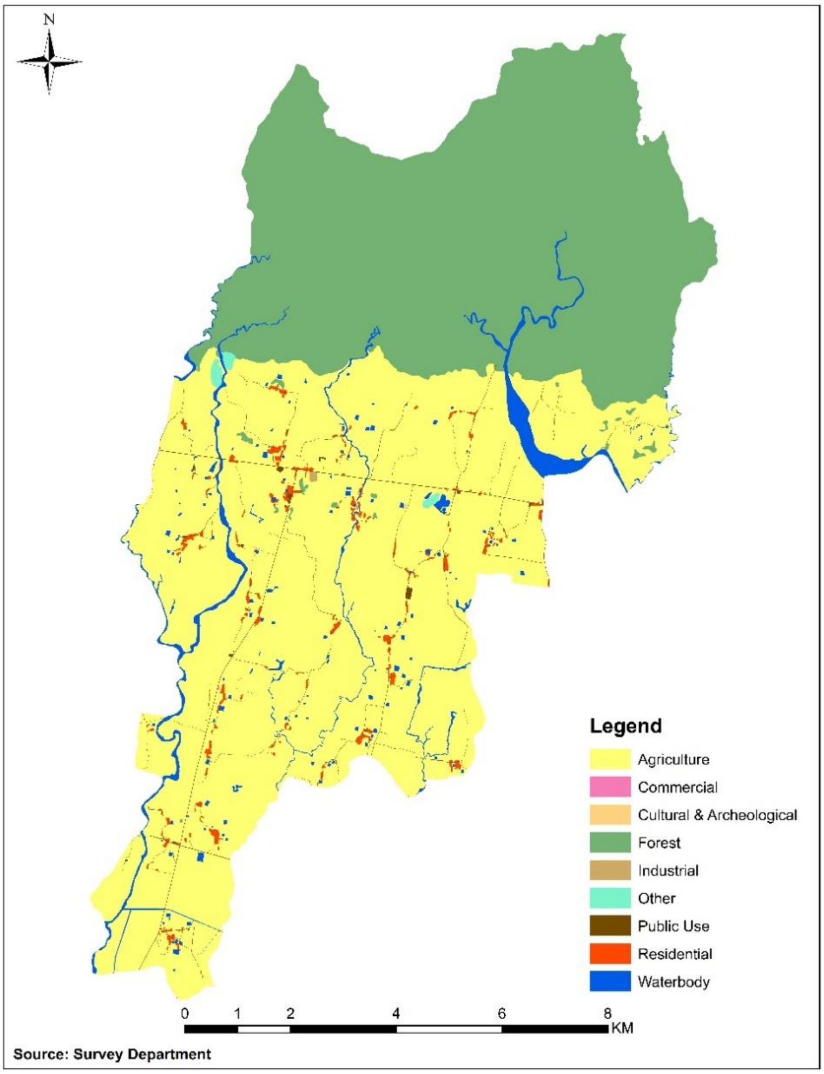


Figure 5.2: Land Use Pattern of Shambhunath Municipality in 1996

The distribution of land use categories was analyzed with computation of area from the prepared database for year 1996 in this municipality (Table 5.2).

Table 5.2: Distribution of Land Use in1996

S.N.	Land Use Classes	Area (ha)	Percentage
1	Agriculture	5960.41	54.88
2	Forest	4396.31	40.48
3	Water body	318.13	2.93
4	Residential	90.81	0.84
5	Public Use	70.33	0.65
6	Other	20.40	0.19
7	Commercial	2.48	0.02
8	Cultural & Archeological	1.14	0.01
9	Industrial	0.37	0.003
	Total	**10860.39**	**100.00**

Source: Land Use Database, 1996

In 1996, the agriculture land had dominant land use with 55 percent extent of the municipality having 5960 ha. Forest land had the second dominant land use having 40 percent with 4396 ha followed by water body area with 3 percent. Likewise, the residential and public use land occupied with minimum extent less than one percent. Furthermore, commercial, cultural and archeological and industrial area have found comparatively negligible extent.

5.1.3 Land Use Map 2017

Land use map for year 2017 was prepared from the classified WorldView-2 satellite image verified with extensive field survey in digital environment (Figure 5.3).

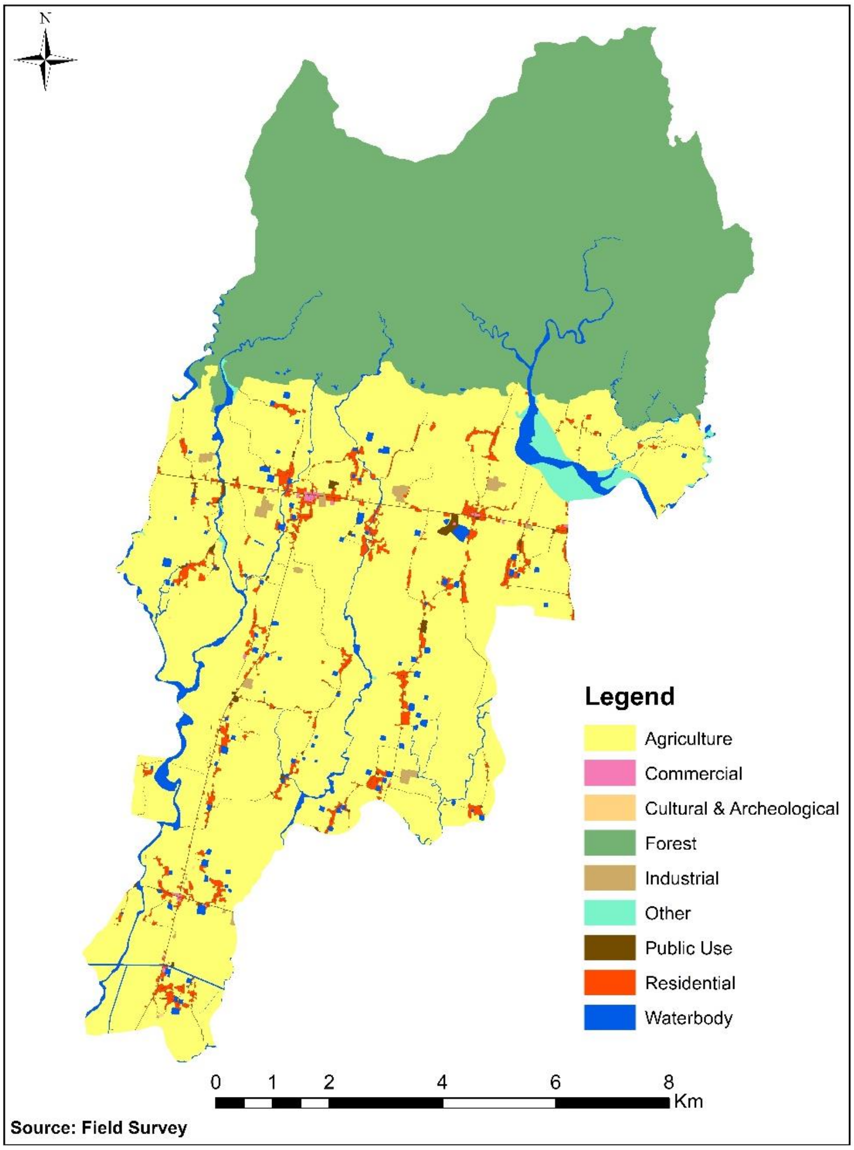


Figure 5.3: Land Use Pattern of Shambhunath Municipality in 2017

The distribution of land use categories was analyzed with computation from prepared land use database for year 2017 in this municipality (Table 5.3).

Table 5.3: Distribution of Land Use in 2017

S.N.	Land Use Classes	Area (ha)	Percentage
1	Agriculture	5609.35	51.65
2	Forest	4402.78	40.54
3	Water body	353.09	3.25
4	Residential	250.53	2.31
5	Other	100.98	0.93
6	Public Use	92.05	0.85
7	Industrial	40.09	0.37
8	Commercial	9.01	0.08
9	Cultural & Archeological	2.52	0.02
	Total	**10860.39**	**100.00**

Source: Field Survey, 2017

In 2017, the agriculture land was found dominant land use with 52 percent of the municipality extent having 5609 ha. Forest land was the second dominant land use having 41 percent with 4403 ha followed by the hydrographic feature mainly water body, sand and gravel area covered with 3.25 percent. Residential area covered with 2.31 percent. The undersigned other, public use, industrial area, and commercial area occurred nearly one percent of the municipal extent. Cultural and archeological area has found about 2.5 ha.

5.1.4 Land Use Change in Shambhunath Municipality

The land use/cover changes (LUCC) was analyzed through geospatial tools and its quantification for the dynamic representation of land use in space. The quantified amount of land use changes occurred in the municipality from 1986 to 2017 A.D. is shown in Table 5.4.

Table 5.4: Land Use Changes from 1986 to 2017

Land Use Categories	Area Change in Hectares			Area Change in Percentage		
	1986-1996	1996-2017	1986-2017	1986-1996	1996-2017	1986-2017
Agriculture	1193.20	-351.06	842.14	25.03	-5.89	17.67
Forest	-141.83	6.47	-135.36	-3.13	0.15	-2.98
Other	-772.85	34.95	-737.89	-70.84	10.99	-67.64
Water body	-303.34	159.71	-143.63	-76.96	175.87	-36.44
Residential	35.39	30.64	66.03	101.28	43.57	188.97
Public Use	-13.63	71.65	58.02	-40.06	351.28	170.49
Commercial	1.97	37.61	39.58	386.78	1518.65	7779.32
Cultural and Archeological	0.86	7.87	8.72	303.59	690.14	3088.90
Industrial	0.23	2.15	2.39	173.28	584.95	1771.80

The changes in LULC showed that residential, commercial, industrial, and public use land expanded tremendously while undersigned other and water body shrank abruptly. Likewise, the forest land use also rapidly decreased with 135 ha from 1986 to 2017A.D. Also, land change modeler (LCM) tool was used for quantification of land use changes from one land use class to another to provide a better understanding the land use pattern. The land use changes were quantified from one land use class to another in the temporal period 1986 to 1996 and shown in Table 5.5.

Table 5.5: Quantification of Land Use Change from 1986 to 1996

(Area in ha)

LU Classes	Agriculture	Commercial	Cultural & Archeological	Forest	Industrial	Other	Public Use	Residential	Water body
Agriculture	4666.13	2.43	0.55	5.95	0.25	4.99	33.87	36.01	17.09
Commercial	0.46	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cultural and Archeological	0.14	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00
Forest	163.22	0.00	0.00	4370.92	0.00	3.39	0.37	0.00	0.25
Industrial	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00
Other	1017.99	0.00	0.00	19.38	0.00	12.00	13.78	23.88	3.95
Public Use	11.68	0.00	0.04	0.00	0.00	0.00	20.47	1.77	0.07
Residential	6.17	0.00	0.00	0.00	0.00	0.00	1.10	27.68	0.00
Water body	94.69	0.00	0.40	0.07	0.00	0.02	0.74	1.47	296.77

The quantification of land use change from 1986 to 1996 is presented graphically in Figure 5.4.

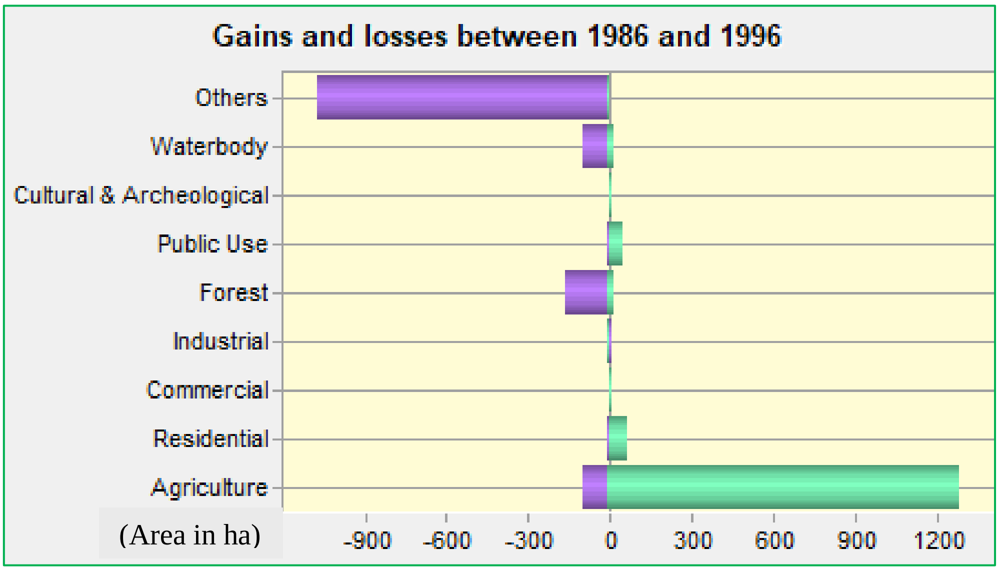


Figure 5.4: Gains and Losses of Land Use between 1986 and 1996

From the Table 5.5, the result showed that the agriculture land has increased in overall 1193 ha in which expansion from deforestation and encroachment of barren and bushes area with 1294 ha, and conversion into built-up area (mainly residential use) and construction of road and public use building with 101 ha. Residential land has increased in overall 56 ha in which 63 ha expanded mainly from agriculture land and decreased with 7 ha converting into commercial and the right of way (ROW) of road. Public use land has increased in overall 37 ha with increasing 50 ha by construction of road infrastructure and public building, and decreased with 13 ha by encroached for agriculture practices and residential use. Water body has decreased in overall 75 ha in which 95 ha land decreased for agriculture practice along river surrounding in low land and increased with 22 ha through bank cutting of agriculture and forest land use. The other land use area has decreased by 1071 ha in overall in which decreased in by 1079 ha for agriculture use and increased by 8 ha for barren cultivation land.

The spatial location of land use changes from one land use class to another for year 1986 and 1996 is represented in Figure 5.5.

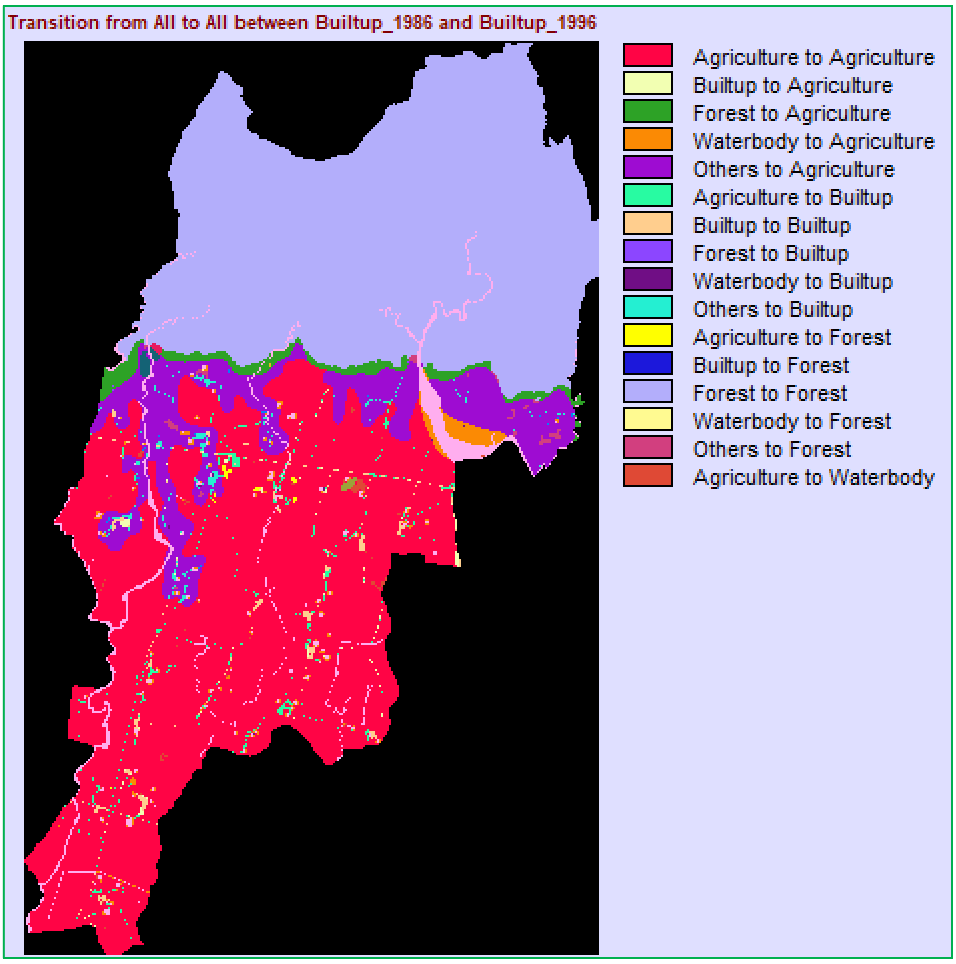


Figure 5.5: Changes of Land Use from 1986 to 1996

In the same way, the land use changes were quantified from one land use class to another in the temporal period 1996 to 2017 and shown in Table 5.6.

Table 5.6: Quantification of Land Use Change from1996 to 2017

(Area in ha)

LU Classes	Agriculture	Commercial	Cultural and Archeological	Forest	Industrial	Other	Public Use	Residential	Water body
Agriculture	5491.73	4.06	1.95	26.58	39.44	36.40	18.64	173.24	167.92
Commercial	0.00	2.38	0.00	0.00	0.00	0.00	0.05	0.05	0.00
Cultural and Archeological	0.37	0.00	0.47	0.00	0.00	0.00	0.01	0.00	0.29
Forest	28.91	0.00	0.00	4335.22	0.00	1.29	0.00	1.19	29.69
Industrial	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00
Other	0.48	0.25	0.00	14.46	0.00	0.78	4.23	0.02	0.18
Public Use	2.18	0.19	0.00	0.00	0.00	0.00	66.05	1.44	0.47
Residential	13.85	2.02	0.10	0.00	0.26	0.03	1.21	71.58	1.75
Water body	71.54	0.11	0.00	26.52	0.01	62.47	2.27	2.29	152.93

The quantification of land use change from 1996 to 2017 is presented graphically in Figure 5.6.

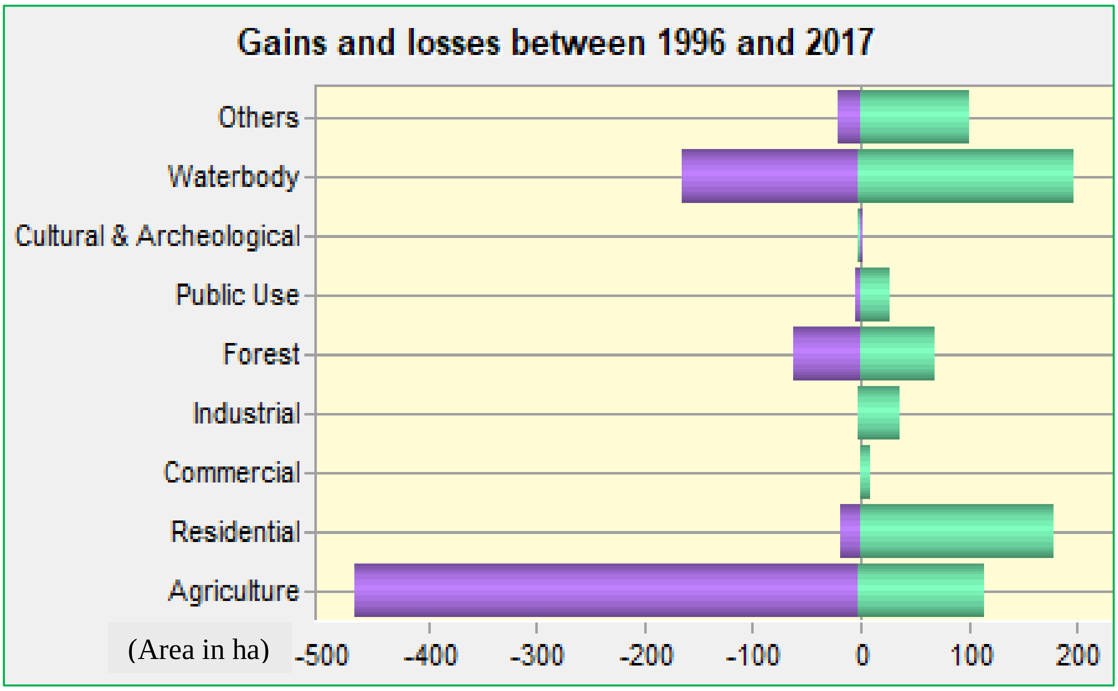


Figure 5.6: Gains and Losses of Land Use between 1996 and 2017

From the Table 5.4, the result showed that the agriculture land has decreased in overall 351 ha in which deduction of agriculture land with 469 ha for construction of residential, commercial and industrial building with the road and expansion with 118 ha through encroachment of forest land and open space area. Residential land has increased in overall 160 ha in which 179 ha increased from agriculture land mainly and decreased with 19 ha converting into commercial and expansion of road's ROW. Forest land has increased in overall 7 ha in which about 68 ha increased from plantation along water body and barren cultivation land, and decreased 61 ha for agriculture practice through encroachment. Public use land has increased in overall 21 ha in which 26 ha increased through construction of road and public service building, and decreased with 5 ha by encroached for residential use. Water body has increased in overall 35 ha in which increased by 200 ha from agriculture land through bank cutting along river channel and decreased by 165 ha for agriculture and forest uses. The undesignated other area (mainly open space) has increased from barren and as bushes and shrub by 80 ha. The spatial location of LULC changes were also analyzed through cross-tabulation in LCM from land use maps of year 1996 and 2017 and represented in Figure 5.7.

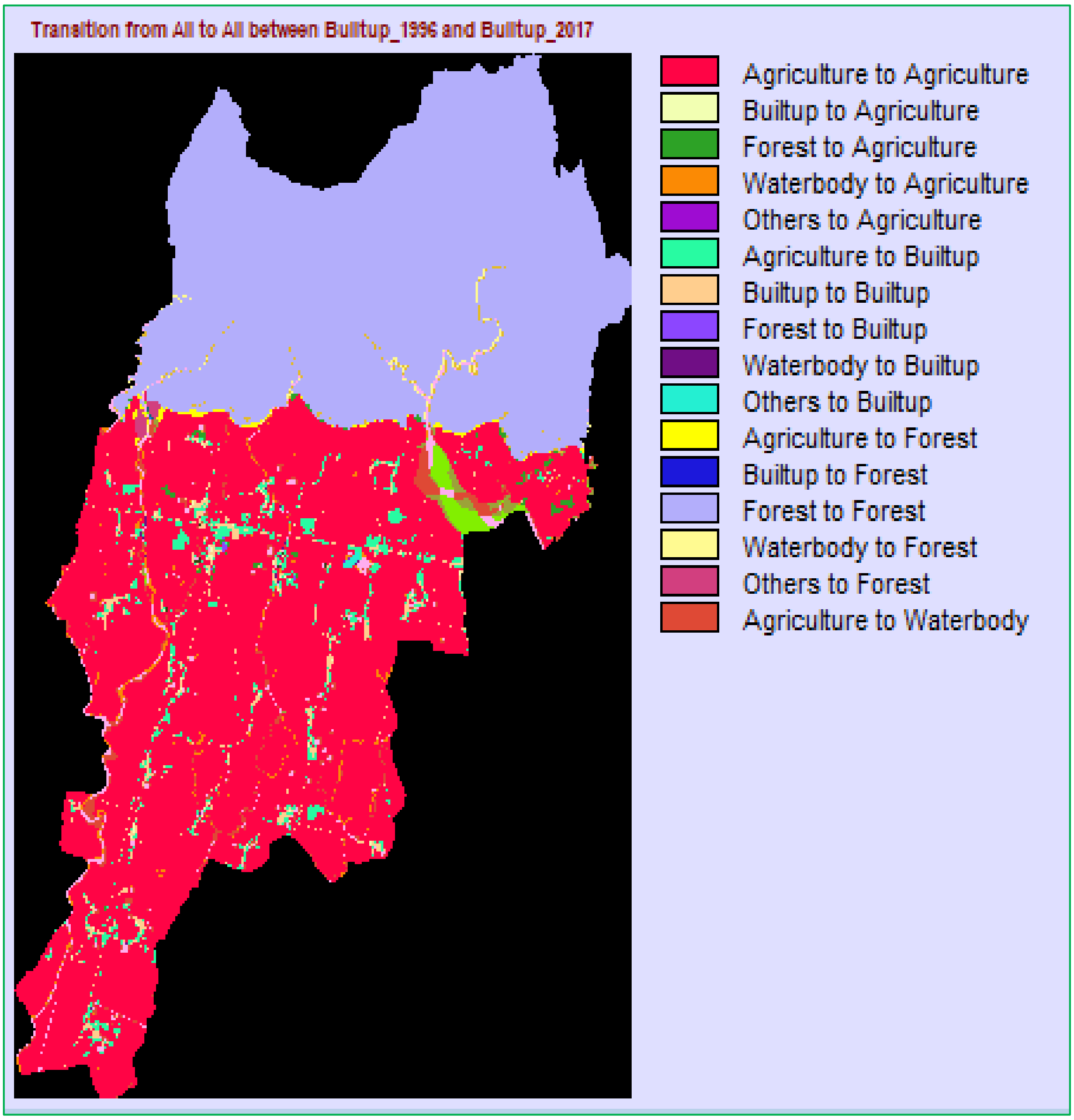


Figure 5.7 : Changes of Land Use from 1996 to 2017

Similarly, the overall change in land use during last three decades was analyzed and quantification of LUCC from one class to another from 1986 to 2017 and shown in the Table 5.7.

Table 5.7: Quantification of Land Use Change from1986 to 2017

(Area in ha)

LU Classes	Agriculture	Commercial	Cultural & Archeological	Forest	Industrial	Other	Public Use	Residential	Water body
Agriculture	4428.52	7.85	1.70	0.00	39.19	2.07	51.93	156.37	80.02
Commercial	0.00	0.35	0.00	0.00	0.00	0.00	0.16	0.00	0.00
Cultural & Archeological	0.00	0.04	0.24	0.00	0.00	0.00	0.00	0.00	0.00
Forest	142.40	0.00	0.00	4357.92	0.00	4.09	0.37	0.40	32.97
Industrial	0.01	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00
Other	954.32	0.73	0.11	18.35	0.60	9.80	15.47	61.63	29.97
Public Use	8.36	0.34	0.19	0.00	0.07	0.00	21.22	3.56	0.29
Residential	7.43	0.00	0.00	0.00	0.00	0.03	1.24	26.24	0.01
Water body	68.20	0.19	0.30	26.52	0.00	84.98	2.07	1.74	210.17

The quantification of land use change from 1986 to 2017 is presented graphically in Figure 5.8

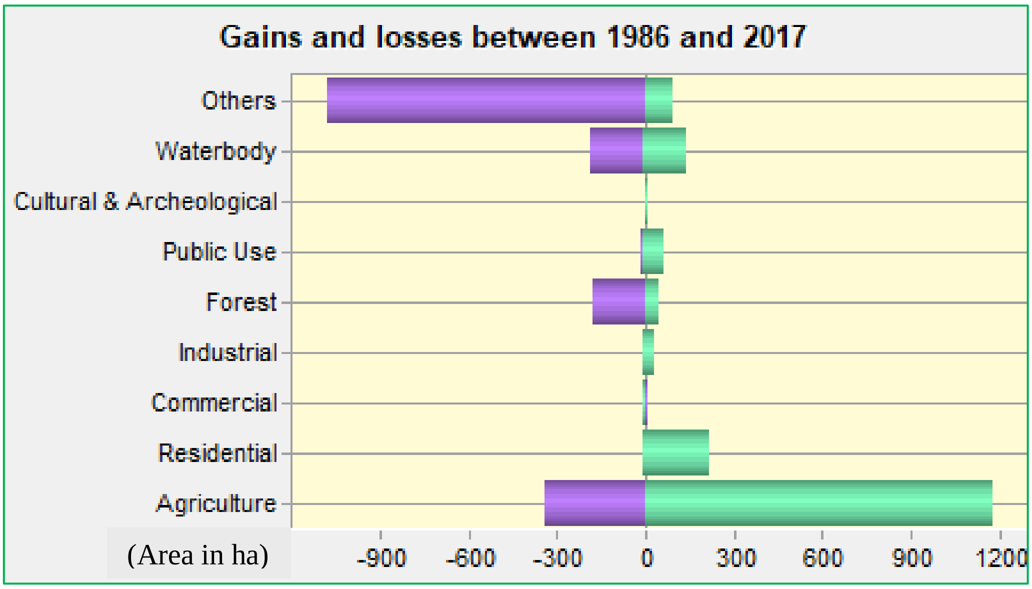


Figure 5.8: Gains and Losses of Land Use between 1986 and 2017

From the Table 5.4, the result showed that the agriculture land has increased in overall with 842 ha in which expansion from deforestation and encroachment of barren and bushes area with 1193 ha and construction for residential use, commercial, industrial and public use with 351 ha. Forest land has decreased in overall 135 ha in which 180 ha decreased for agriculture practice through encroachment and 45 ha increased from plantation along water body. Residential land has increased in overall about 215 ha in which 224 ha increased from agriculture land and decreased with about 9 ha converting into commercial and ROW of road. Public use land has increased in overall 58 ha in which 71 ha increased through construction of road infrastructure and public building, and decreased with 13 ha by encroached for agriculture practices and residential use. Water body has decreased in overall 41 ha in which 184 ha land decreased for agriculture practice and increased with 143 ha through bank cutting of agriculture and forest land. The other land use area has decreased by 990 ha in overall in which decreased in by 1081 ha for agriculture practice and increased by 91 ha for barren cultivation.

The spatial location of LULC changes was also analyzed in LCM through cross-tabulation of the land use maps for year 1986 and 2017 (Figure 5.9).

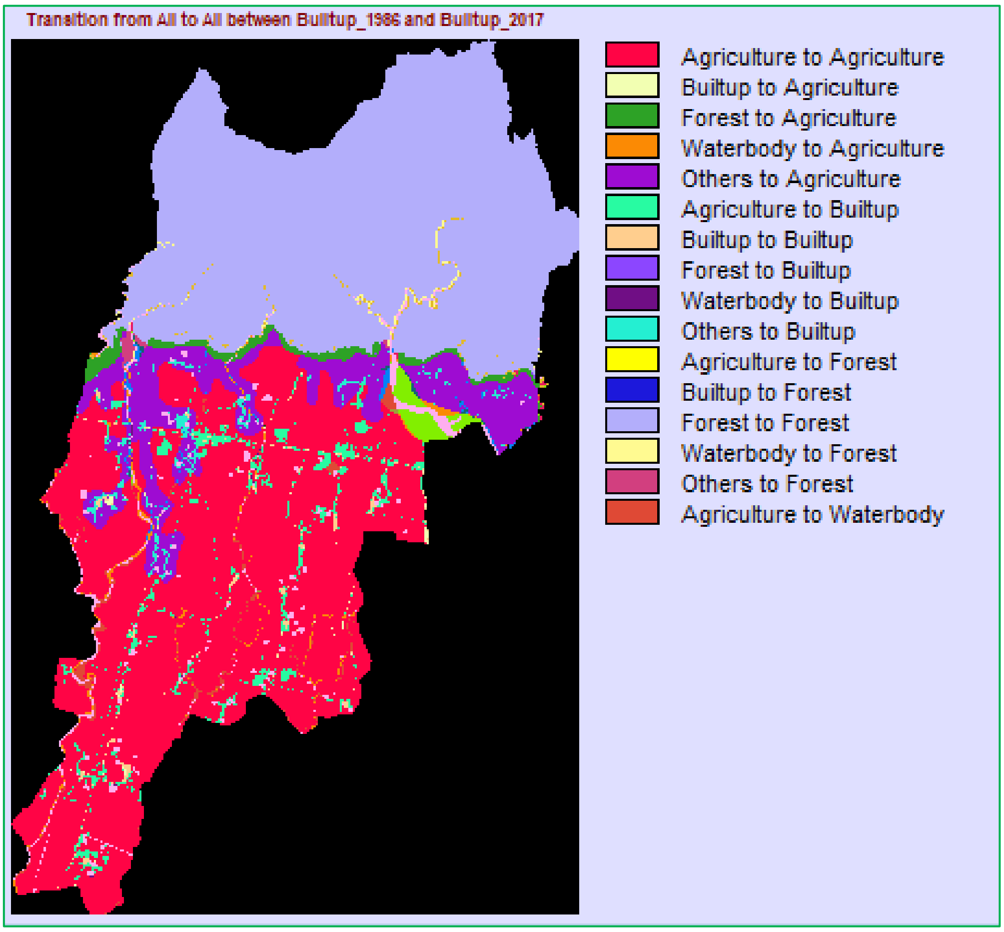


Figure 5.9: Changes of Land Use from 1986 to 2017

5.2 Spatial Pattern of Land Use Change

From Table 5.4, the land use changes occurred from 1986 to 1996 showed that the agriculture land was increased by 1193 ha from forest and undersigned other land use (barren and bushes area). The increased in agriculture land was mainly occurred in the north of East West highway through deforestation of forest of 142 ha and encroachment of barren and bushes area. The water body area was decreased mainly by construction of embankment and expansion of agriculture practices in the low land surrounding to the Khando River. Residential land was increased by 35 ha rapidly along East West highway, and Kathauna to Pato feeder road. Likewise, the commercial was increased with 2 ha surrounding to Kathauna bazar and develop commercial area at Traffic Chock along East West highway after construction of traffic police post. Similarly, the industrial are is increased with 0.23 ha mainly construction of rice mill at Kathauna bazar along East West highway. The cultural and archeological land was increased with 0.86 ha through construction of temples distributed in all twelve wards of this municipality. The public use land was decreased in area but not in total length. The public use land has encroached with agriculture practices along road corridor and residential use surrounding to the area. The undesignated other area (mainly open space) was encroached by different community for construction of community building.

Similarly, the land use changes occurred from 1996 to 2017 showed that the agriculture land was decreased 351 ha by increasing in the built-up area (residential, commercial and industrial) mainly along road connectivity, and increased in forest area from agriculture barren land and bush area. The residential area was increased 31 ha mainly surrounding to the settlement area and along road network. Similarly, the commercial area was increased with 38 ha mainly at Kathauna Bazar, Traffic Chock and Arnaha

Bazar. Likewise, industrial area was increased with 2 ha mainly as brick factory access to Hulaki Sadak (postal highway) and Kathauna to Pato feeder road. The public use land was increased 72 ha for construction of road to increase the connectivity from major road network to settlement areas as villages. The water body was increased with 160 ha surrounding to the Khando River by occurring the flood with siltation in the agriculture land. The cultural and archeological land was increased 8 ha for construction of cultural feature as temple, mosque and other religious feature.

Land use changes in past three decades from 1986 to 2017 shows that the rate of change in built-up area (residential, commercial and industrial) is rapidly increased about 108 ha along the strategic road network. Commercial area is increased by 40 ha mainly at the node of junction of road at Kathauna Bazar, Traffic Chock, Rupani and Arnaha, and also increased along the corridor of East West highway, Hulaki Sadak, feeder road, district road and local road network. Industrial area is increased with 2.3 ha at the edge of Kathauna bazar along East West highway, and brick factory operated along postal highway and feeder road. Residential area is rapidly increased with 66 ha surrounding to the existing business area and developed commercial area mainly in urban and suburban area at Kathauna Bazar, Traffic Chock, Rupani and Arnaha. Also, residential area are gradually increased surrounding to the existing settlement in rural area those not connected to major strategic road network. The assumption of Hoyts sector theory of urban land use explains that the major commercial areas are increased surrounding to central business zone where as retail business area and industrial along transportation route, and residential area increased surrounding to central business zone and developed business and industrial area. Therefore, land use change pattern occurred in the municipality flows similar pattern of land use as the assumption of Hoyts sector theory. The agriculture practices are shifting toward mango orchard by lacking irrigation facilities in the middle to northern part up to foot of Siwalik hill. The agriculture land is increased in the north of East West highway through deforestation and encroachment of barren and bushes area with 842 ha. Water body feature area is decreased mainly by construction of embankment and expansion of agriculture practices in the low land surrounding to the Khando River having 144 ha. Likewise, public use land is increased with 58 ha for construction of road to increase the connectivity from major road network to settlement areas as villages. Cultural and archeological land is increased with 9 ha for construction of cultural feature as temple, mosque and other religious feature.

5.3 Spatial Influencing Factor for Land Use Change

Based on spatial pattern of land use change, the residential area has grown significantly along the East West highway, feeder road, and other local roads. Similarly, residential areas have been expanded surrounding to the current settlement at a compatible with the rate of population growth. Kathauna Bazar has assumed the principal commercial area in the municipality after completion of Kathauna-Pato feeder road that connected East West highway to Indian border, and provided the accessibility to the southern villagers. Kathauna Bazar acts as the major commercial area in the municipality after the completion of the Kathauna-Pato feeder road which connected the East West highway to India boarder and providing the accessibility to the southern settlement. The development of physical infrastructures and service facilities has significantly strengthened the economic influence at Kathauna Bazar. Similarly, the economic activities at Arnaha Chock has also expanded after upgrading Hulaki Sadak and serves as business service center in the southern part of the municipality. Arnaha Chock is the road junction of Kathauna-Pato feeder road and Hulaki Sadak. Likewise, the construction of Traffic Chock-Pathergadha-Hulaki Sadak district road, socio-economic activities at Traffic Chock has gradually increased after construction of Traffic Chock-Pathergadha- Hulaki Sadak district road which lead to land use change in Dangrahi and Narahi. Also, the socio-economic activities at Rupani Bazar has rapidly due to connectivity node to East West highway and Saptari district headquarter Rajbiraj. Therefore, road junction, service center, proximity to settlement, transportation facilities are the causal influencing factor for land use change and land development.

5.4 Trend Analysis of Built-up Area

The term concentration refers to the amount of a substance in a defined space, and used for its density measurement. In land use perspective, density of substance/object is mainly related with residential, commercial and industrial building as built-up area. In this research, the concentration of built-up area is used for measuring urban sprawl (expansion of urban patches in the urban and sub-urban area) with its growing trend.

5.4.1 Spatial Pattern of Built-up Area

Spatial pattern of built-up area is visualized through a sequences of temporal built-up area in LU map in each time period. In order to visualize the spatial pattern of built up areas during the three time periods: 1986, 1996 and 2017. So, LULC maps of 1986, 1996 and 2017 were reclassified into built-up area and non-built-up area. The built-up area included the residential, commercial, industrial, cultural and archeological, and institutional building (public use buildings) along with the road networks with bridges. Non-built up area included the forest, agriculture, waterbody features and public land as barren land, open area, open space and recreational facilities area. The spatio-temporal change of the built-up area is visualized through spatial overlay function in GIS environment to display the pictorial view of the spatial pattern of built-up areas during the study periods and presented in Figure 5.10.

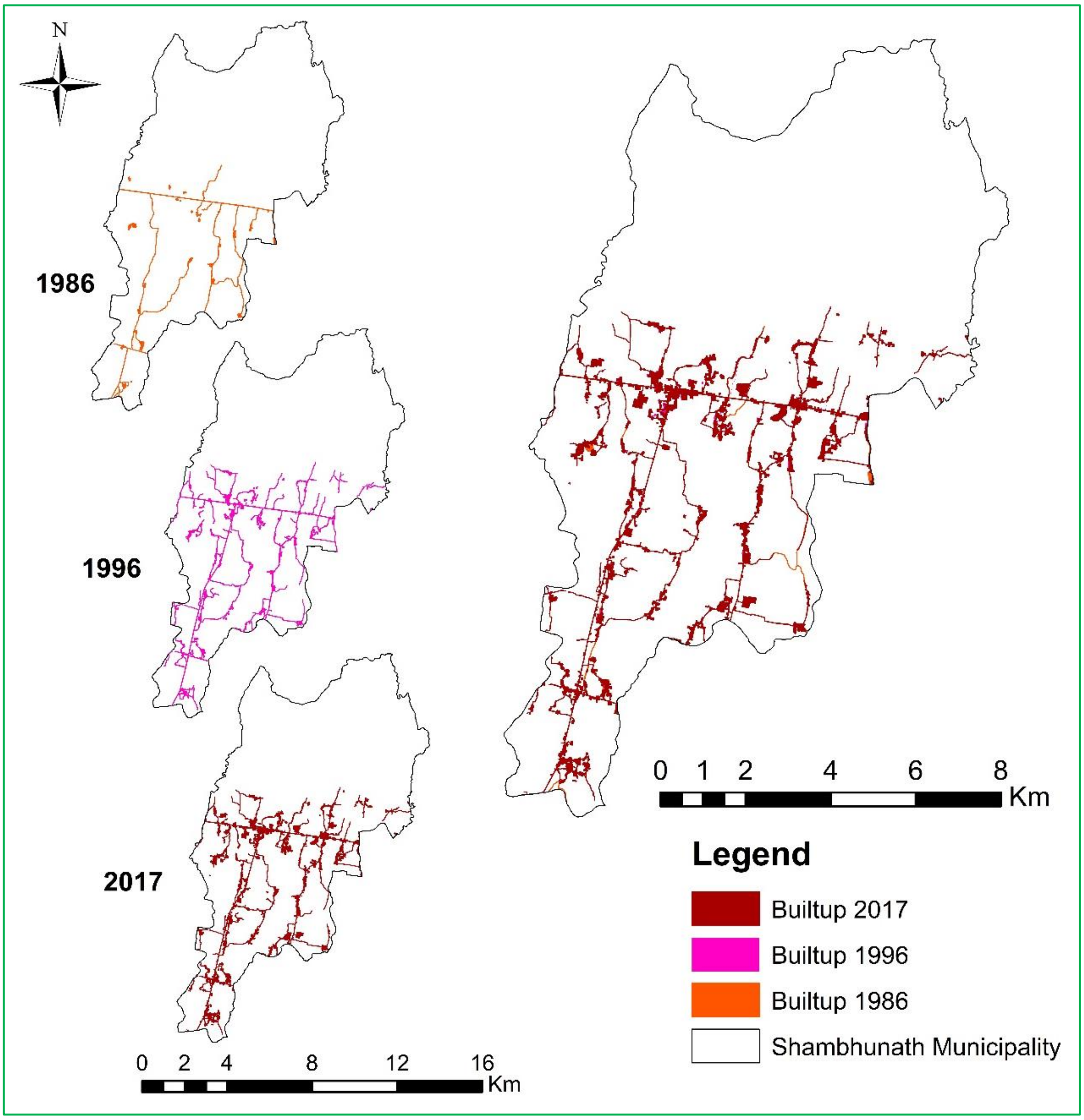


Figure 5.10: Spatial Expansion of Built-up Areas in 1986, 1996 and 2017

The quantification of built-up area and non-built-up area from land use maps of 1986, 1996 and 2017 in the municipality is presented in Table 5.8

Table 5.8: Built-up Proportion in Shambhunath Municipality

Land Use Classes	**1986**		**1996**		**2017**	
	Area (ha)	**Area in %**	**Area (ha)**	**Area in %**	**Area (ha)**	**Area in %**
Built-up	69.90	0.64	165.13	1.52	394.19	3.63
Non Built-up	10790.49	99.36	10695.26	98.48	10466.20	96.37
Total (ha)	**10860.39**	**100.00**	**10860.39**	**100.00**	**10860.39**	**100.00**

The built-up areas proportion is occupied only 0.64 percent in 1986. The proportion of built-up area is gradually increased to 1.52 percent in 1996 and 3.63 percent in 2017.

The temporal dynamics patterns of land use is increased in west middle portion of municipality at Kathauna Bazar having major business area and dense settlement area. The trend of land use is showed that increasing pattern of built-up area towards the east direction along Rupani Bazar in East West highway and also increased towards south west direction along Kathauna-Pato feeder road. The major commercial area is increased along the crossing with Hulaki Sadak at Arnaha Bazar. The residential area is increased in the surrounding of older settlement area (villages) in south east direction. The growth pattern of built-up area was analyzed with the 3rd order cubic polynomial surface modeling function of change to best fit the interpolated result with the input images. The spatial pattern of change in built-up area from 1986 to 1996, from 1996 to 2017 and 1986 to 2017 are presented in Appendix-11. The spatial trend of growth of built up area is occurred in west middle portion (Kathauna Bazar) and increased towards east direction (Rupani Bazar) along East West highway as well as also increased towards south west direction (Arnaha) along Kathauna-Pato feeder road.

5.4.2 Concentration Measurement and Spatial Trend of Built-up

Built-up area took in unlimited outward expansion in unplanned and uneven pattern of growth, driven by processes and leading to inefficient resource utilization. Concentration measurement has been used to analyze the compactness (density of the built-up area) and dispersion (scattered of built-up area) in spatial arrangement with its growth pattern in healthiness or unhealthiness. In this research, Shannon's entropy is used to measure the degree of spatial concentration and dispersion of built-up area with the consideration of growth pattern in built-up area, quantified compactness and its degree of urban sprawling from temporal land use data/maps. Shannon's entropy values and difference of entropy has computed from temporal land use maps of 1986, 1996 and 2017, and presented in Table 5.9 .

Table 5.9: Shannon's Entropy Values and Difference of Entropy

En(Entropy during the 3 Study Period)			ΔEn (Difference of Entropy)		
1986	1996	2017	1986-1996	1996-2017	1986-2017
0.14	0.24	0.45	0.10	0.21	0.31

The entropy values indicate that there are fewer sprawls in the year 1986, it stated to increase in 1996, and substantial internal variation in the patterns of urban feature growth measured in 2017. The measurement of the difference on entropy is indicated the temporal change in the degree of concentration (densification) of built-up area and used in land development (Karna et al., 2013). The growth trend of built-up area particularly occurred surrounding to the settlement area in agricultural land. The proportion entropy in built-up areas is rapidly increased 14 percent in 1986, 24 percent in 1996 and 45 percent in 2017 (31 years). Also, the trend of concentration and dispersion of built-up area was generated from the computed entropy of temporal land use with twenty-year projection (2017-2037) using linear function (Figure 5.11).

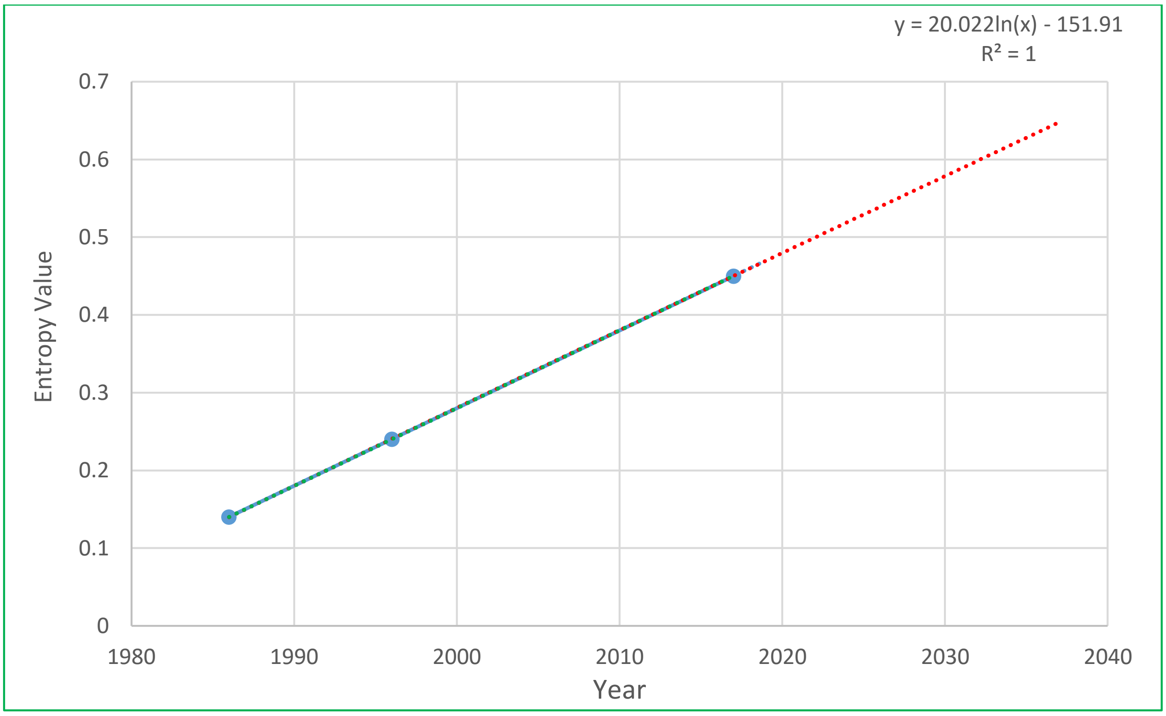


Figure 5.11: Trend of Built-up Area Concentration

In general, built-up increased throughout temporal periods of three decade and occurred the fragmented type of built-up growth along strategic roads. The fragmentation type land use change caused the loss of biodiversity, environmentally fragile lands, and loss of agriculture land as well as economic cost for construction of minimum living service facilities infrastructure. The measurement of the entropy and difference in entropy between time periods got increased gradually from 1986 until 2017. Entropy value 0.45 indicates that the growth of the built-up area has particularly moderately compact settlement fringe in the municipality. The projected entropy in built-up areas was found 63 percent in 2037. So, there is a need of land use plan and its implementation to ensure proper land management and sustainable land development.

Chapter – 6
LAND SUITABILITY EVALUATION

The chapter discusses the preparation of risk zone evaluation. This chapter also discusses the selection of criteria and land suitability evaluation for agriculture, residential, commercial, industrial, and forest land use.

6.1 Risk Zone Evaluation

Risk management is conducted to reduce the uncertainties of an action taken through planning, organizing and controlling of both human and financial capital. The risk management is essential in land use planning process to reduce the risk factors associated with the land use plan that identifies the spatial location of risk and its degree of severity effectively through risk assessment. Generally, risk assessment is used to measure the probability and severity of an adverse effect to health, property and the environment and estimated through the product of probability of a phenomenon of a given magnitude in time with the consequences in non-product. It is used to reduce the vulnerability of people and infrastructure identifying appropriate and safe locations for settlement, open space and construction infrastructure as public utility services and enhancing the economic activities (ADPC, 2015). It is also applied for reducing the spatial exposure of hazard, vulnerability and risk as poor construction, poor transportation and road access, lack of evacuation routes and escape locations/sites, poor drainage systems and waterways etc. In this research work, the risks including flood, soil erosion, landslide, seismic and fire are conducted for the analysis of risk management.

6.1.1 Flood Risk

The catchment area mainly represented with watershed contributes to the flow of water to a common outlet in the concentrated drainage system (water basin). The outlet point, the lowest point within a watershed's boundary, serves as a reference for the catchment area, which is represented as the sub-watershed inside the watershed. In Shambhunath Municipality, the minor six catchment areas have occurred mainly Khando, Kajara, Lukeshar, Mutani, Khadak and Dudhaila (Figure 6.1)

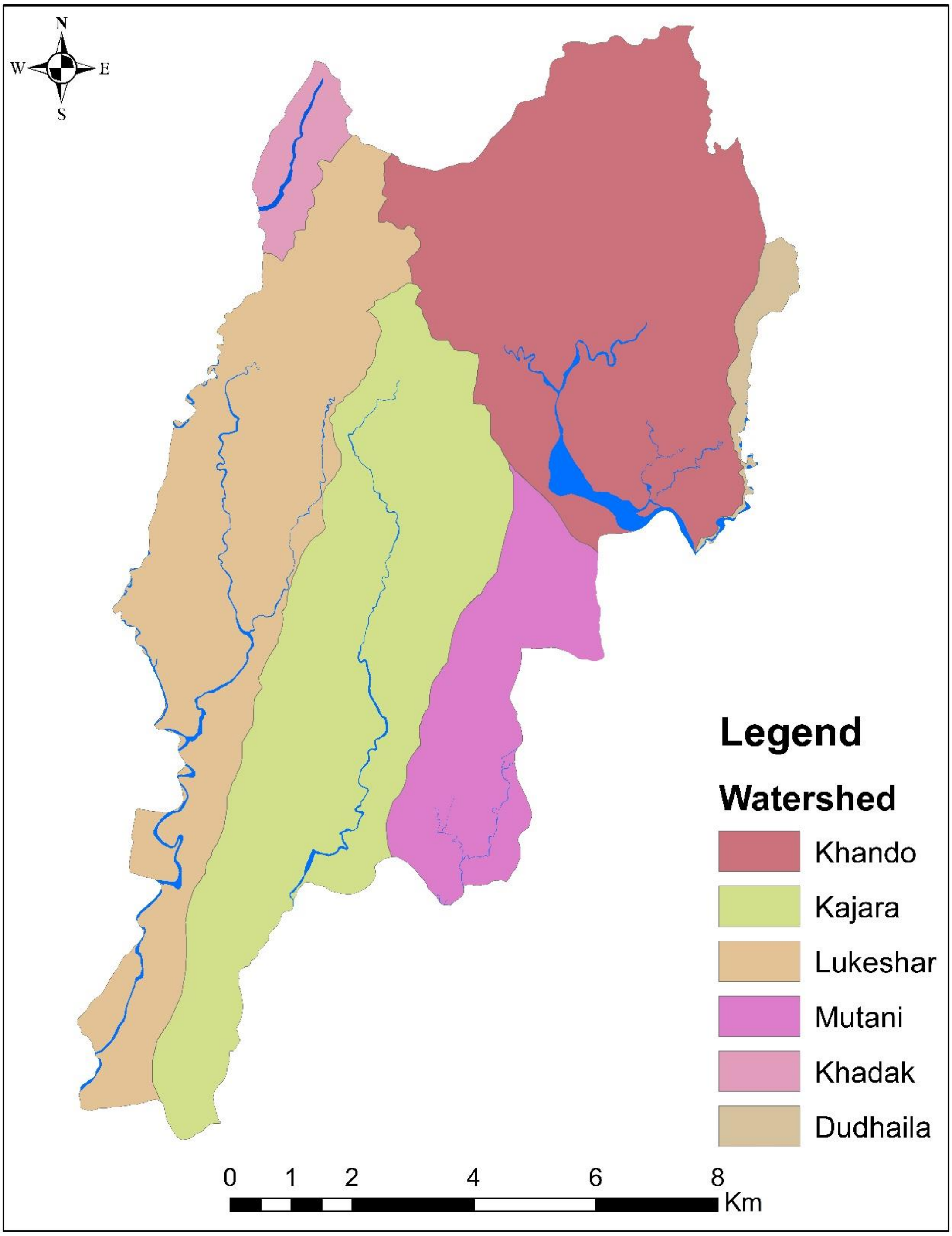


Figure 6.1: Catchment Area in Shambhunath Municipality

The discharge has described the flow of water volume in the channel of river system and represented the volume of water per sec from the certain location. In the study area, all river networks were seasonal river channel. The measurement of discharge has randomly measured in the municipality extent at Khando River at East West highway. The computation of flow discharge for the given catchment area for 2 years and 100 years return period were computed and presented in Table 6.1.

Table 6.1: Discharge Calculation for Given Return Periods

S.N.	River	Flow Length(km)	Catchment Area (km^2)	2 years Discharge (m^3/s)	100 years Discharge(m^3/s)
1	Khando	15.31	35.67	44.39	206.08
2	Kajara	20.00	30.23	38.55	183.16
3	Lukeshwor	23.24	28.04	36.17	173.64
4	Mutani	6.25	11.29	17.00	92.35
5	Khadak	3.04	2.76	6.01	38.71
6	Dudhaila	0.78	1.61	4.36	29.61

Kajara, Lukeshar, Khadak and Dudhaila rivers originated from Siwalik Hill for drains exclusively, but there is some seasonal flooding during the rainy season. Significant flooding from the Khando River has affected the eastern part of this municipality. The simulation of flood from Khando, Kajara, Lukeshar and Mutani (tributaries of Ghordah River) were carried out for the determination of flood inundation as flood risk. GIS, HEC-GeoRAS and HEC-RAS application was used to prepare simulation flood inundation based on the continuous steady flow of discharge in the river channel. The flood discharges of return periodic 100 years were used in the simulation of flood inundation delineation using water surface profile. The simulation result of flood inundation for 100 year return period is shown in Figure 6.2.

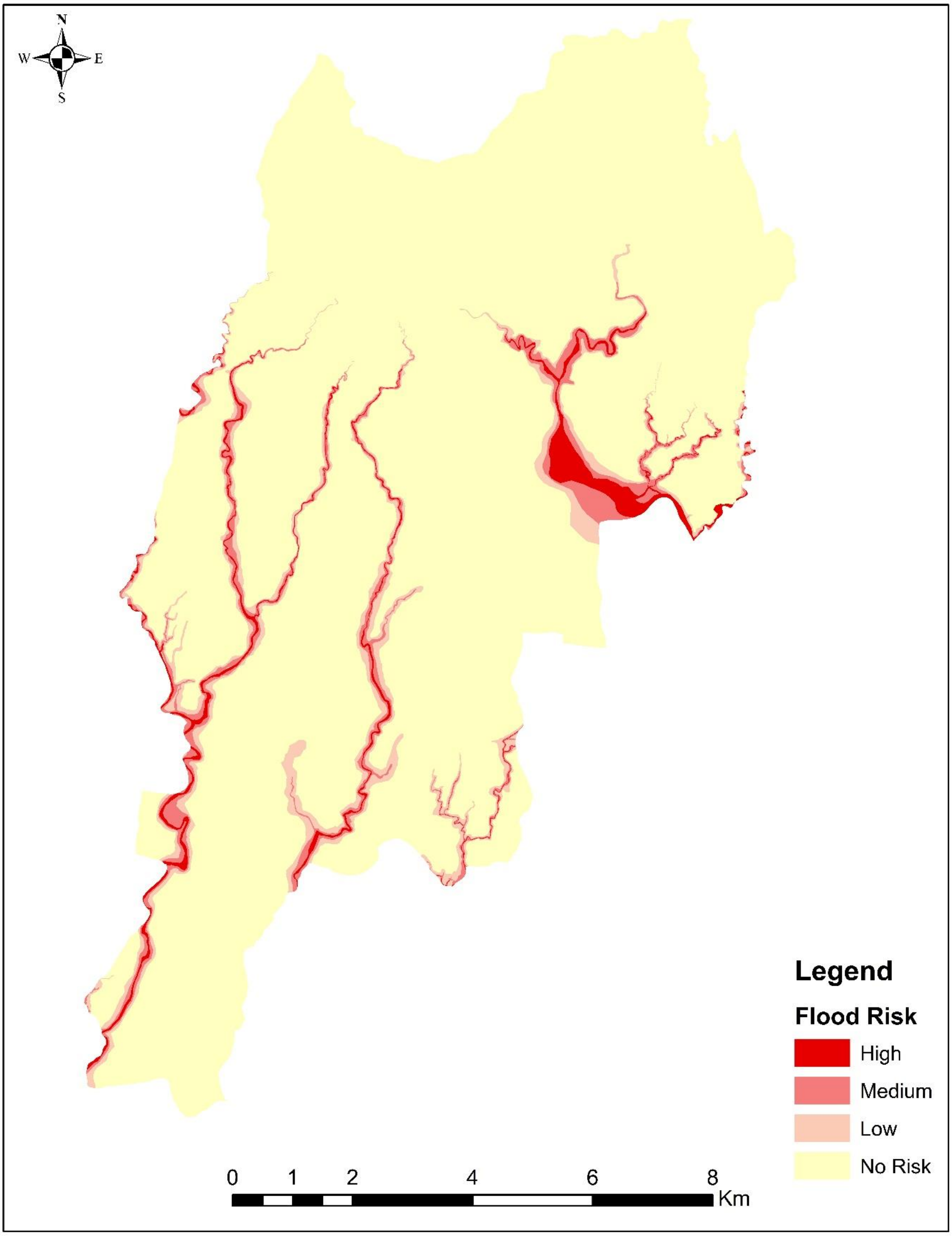


Figure 6.2: Area of Flood Risk in Shambhunath Municipality

The risk of flood is categorized as high risk (inundation depth greater than 1.5 m), low risk (inundation depth less than 0.5 m) causing enormous losses of lives and properties (Thapa et al., 2020). From the flood inundation map, the high risk of flood covers 18 percent, medium risk of flood (inundation depth between 0.5 to 1.5 m) covers

35 percent and low risk of flood covers 47 percent. The high risk flood prone area require proper mitigation activities for safe resilience to people, infrastructure and physical property.

Potential Impact of Flood

The impact of potential flood risk assessment is carried out by the process of spatial overlay operation of flood risk layer into land use layer 2017. The potential flood risk in the land use categories is shown in Table 6.2.

Table 6.2: Flood Risk Impact on Land Use

S. N.	Land Use Type	Area in Land use		Risk Area Based on Land Use (area in ha)					Overall Risk (%)
		(in ha)	%	High	Medium	Low	Total	%	
1	Agriculture	5609.35	51.65	11.22	202.42	430.98	644.62	55.88	11.48
2	Water body	353.09	3.25	167.62	76.45	14.18	258.25	22.39	73.13
3	Forest	4402.78	40.54	0.70	63.51	66.92	131.13	11.37	2.98
4	Other	100.98	0.93	33.05	56.09	10.66	99.80	8.65	98.83
5	Residential	250.53	2.31	0.03	3.33	9.16	12.52	1.08	4.95
6	Public Use	92.05	0.85	0.13	2.65	3.15	5.93	0.51	6.66
7	Industrial	40.09	0.37	0.00	0.11	1.27	1.38	0.12	3.66
8	Commercial	9.01	0.08	0.00	0.00	0.00	0.00	0.00	0.00
9	Cultural and Archeological	2.52	0.02	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**10860.39**	**100.00**	**212.75**	**404.56**	**536.32**	**1153.63**	**100.00**	**10.62**

Among the municipality extent, about 10.62 percent of area is occurred in different form of flood risk prone zone. Total 11.48 percent of land under agriculture is found to be affected by flood. Likewise, threats from flooding have been identified for the following land use types: 6.66 percent for public use, 4.95 percent for residential, 3.66 percent for industrial, and 2.98 percent for forest. Also, some of the residential area near the riverbanks are found in the flood prone risk and pose a threat to the community.

About 9 ha residential land is found with the flood depth less than 0.5 m having inundated and 3 ha residential land in flood depth having up to 1.5 m which dangerous to safe life and property. The flood depth more than 1.5 m inundation level is also affected several hectares of agricultural land, forest, and public and private properties. Therefore, it is necessary for these communities to be relocated in safe zone from flood risk through resettlement plan.

6.1.2 Soil Erosion Risk

Soil loss is related to kinetic energy of rainfall through the detachment power of raindrops striking the soil surface and the entrainment of the detached soil particles by runoff water down slope (Mandal, 2017). Soil erosion with RUSLE model has required rainfall erosivity, soil erodibility, topography, crop management, and conservation practice factors as parameters for estimation of soil loss through rainfall and surface water flow. The rainfall erosivity factor (R) has described the erosivity of rainfall at a particular location based on the rainfall amount and intensity that reflects the effect of rainfall intensity on soil erosion. The rainfall measurement data has essential for preparing R-factor. So, the rainfall intensity data for 50 years was collected from Department of Hydrology and Metrology at the period of 1970 to 2019 for the near and surrounding six metrological stations (Rajbiraj, Lahan, Gaighat, Fatepur, Chatara and Barmajhiya). The average annual rainfall of these metrological stations were computed and prepared rainfall map through spatial interpolation technique using Kriging (Appendix-12). Then, R-factor map is derived from the created rainfall map Morgan's relationship. The average rainfall erosivity range was varied between 561 and 580 mm per year having highest in north-western part and the lower values in the southern part of the municipality (Figure 6.3).

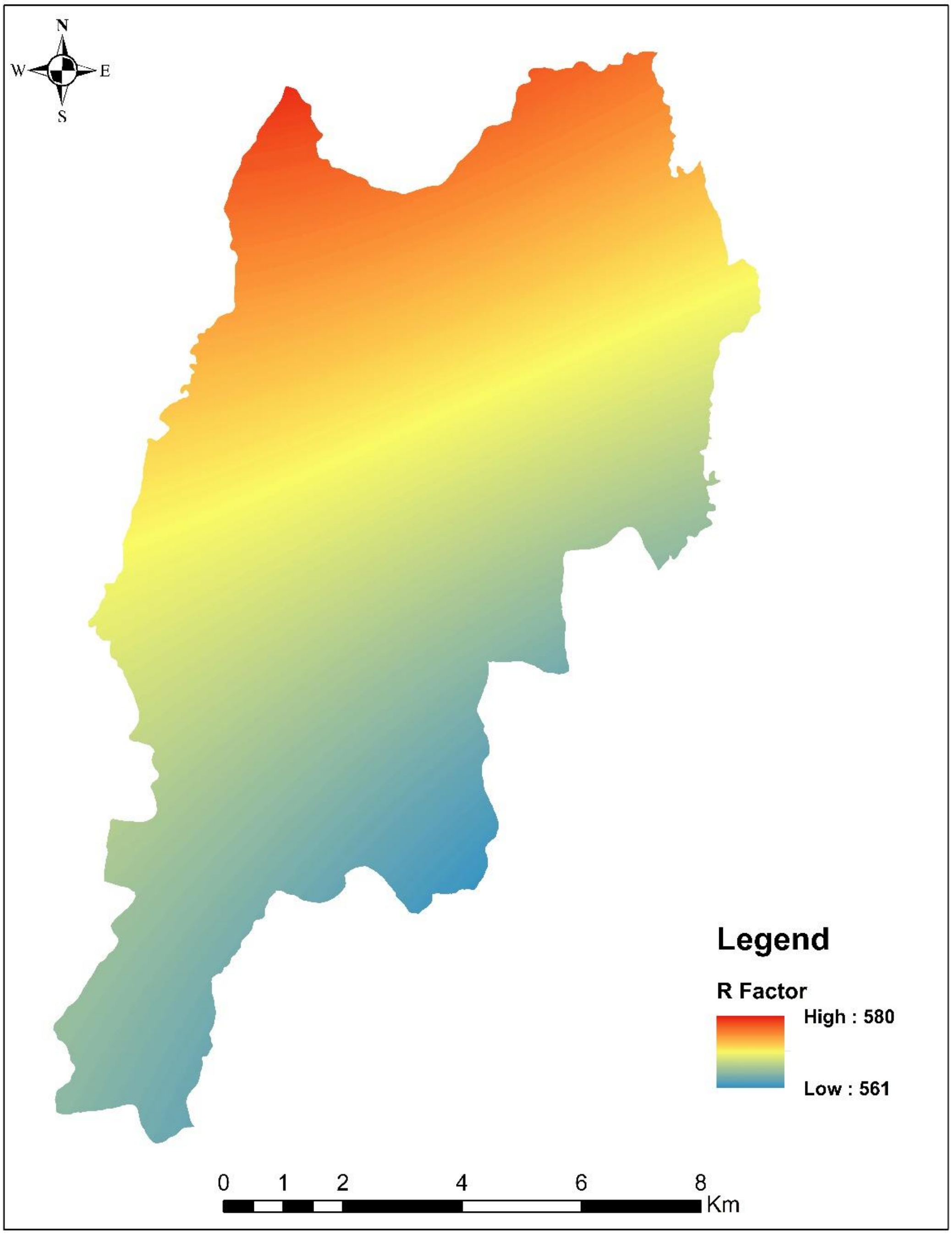


Figure 6.3: Rainfall Erosivity Factor Map of Shambhunath Municipality

Soil erodibility factor (K) has been used for representing the quantitative description of the inherent erodibility component of a particular soil type; based on the susceptibility of soil particles to detachment and transport by rainfall and runoff. Based on the collected soil sample data; sand, silt, clay and organic matter maps were generated and presented in Appendix-13. The K-factor map was produced using soil particles (soil texture and organic contains) and presented in Figure 6.4.

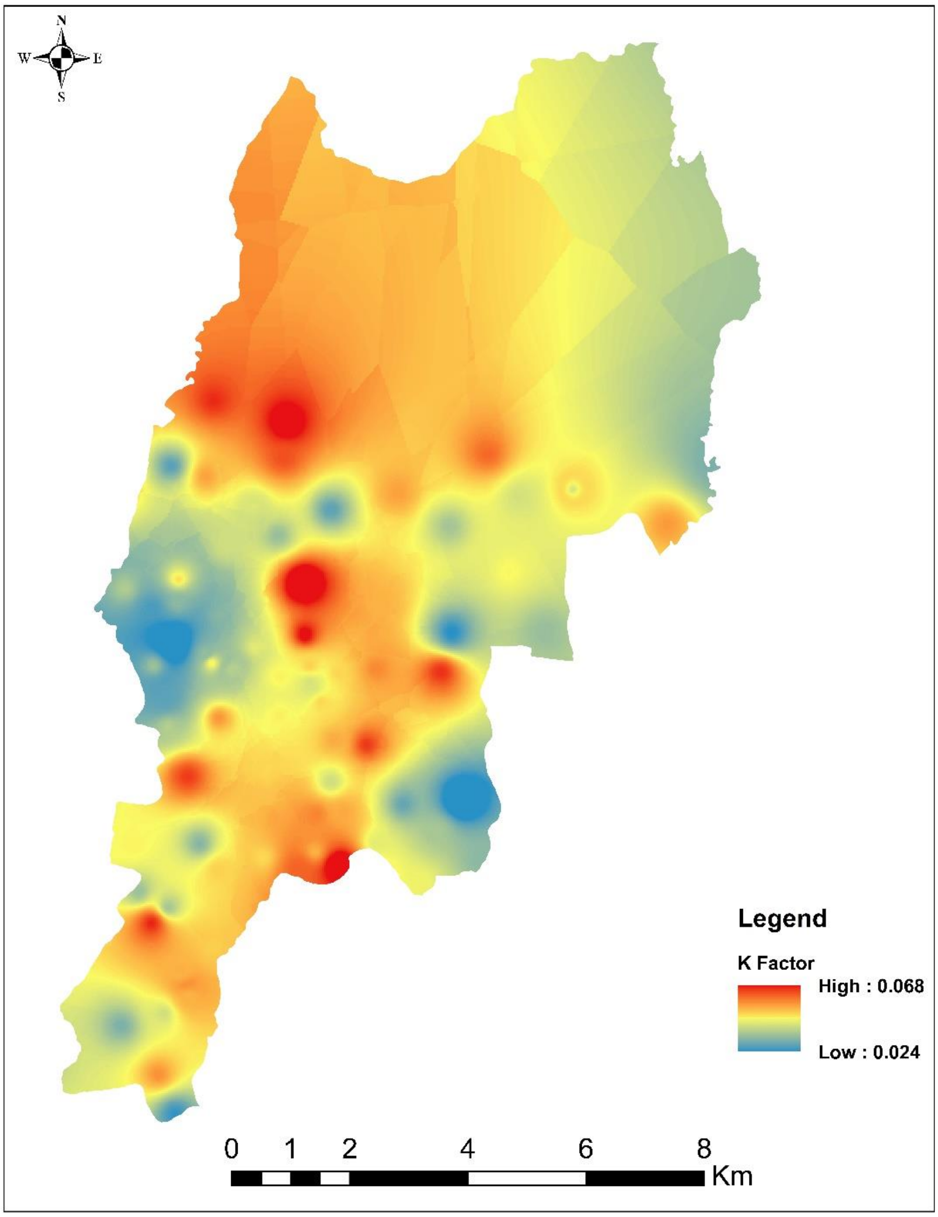


Figure 6.4: Soil Erodibility Factor Map of Shambhunath Municipality

The soil erodibility range varied from 0.024 to 0.068 in Figure 6.4. The distribution of K-factor is found in the scattered nature on the soil texture properties within the municipality.

Topographical factor (LS) was based on the slope length and steepness. The slope length (L-factor) and steepness (S-factor) were used for calculating the transport capacity of overland flow (surface runoff). For generating L-factor, required flow accumulation map that was derived from DEM which is shown in Appendix-14. So, the flow accumulation map was applied for generating the L-factor map (Figure 6.5).

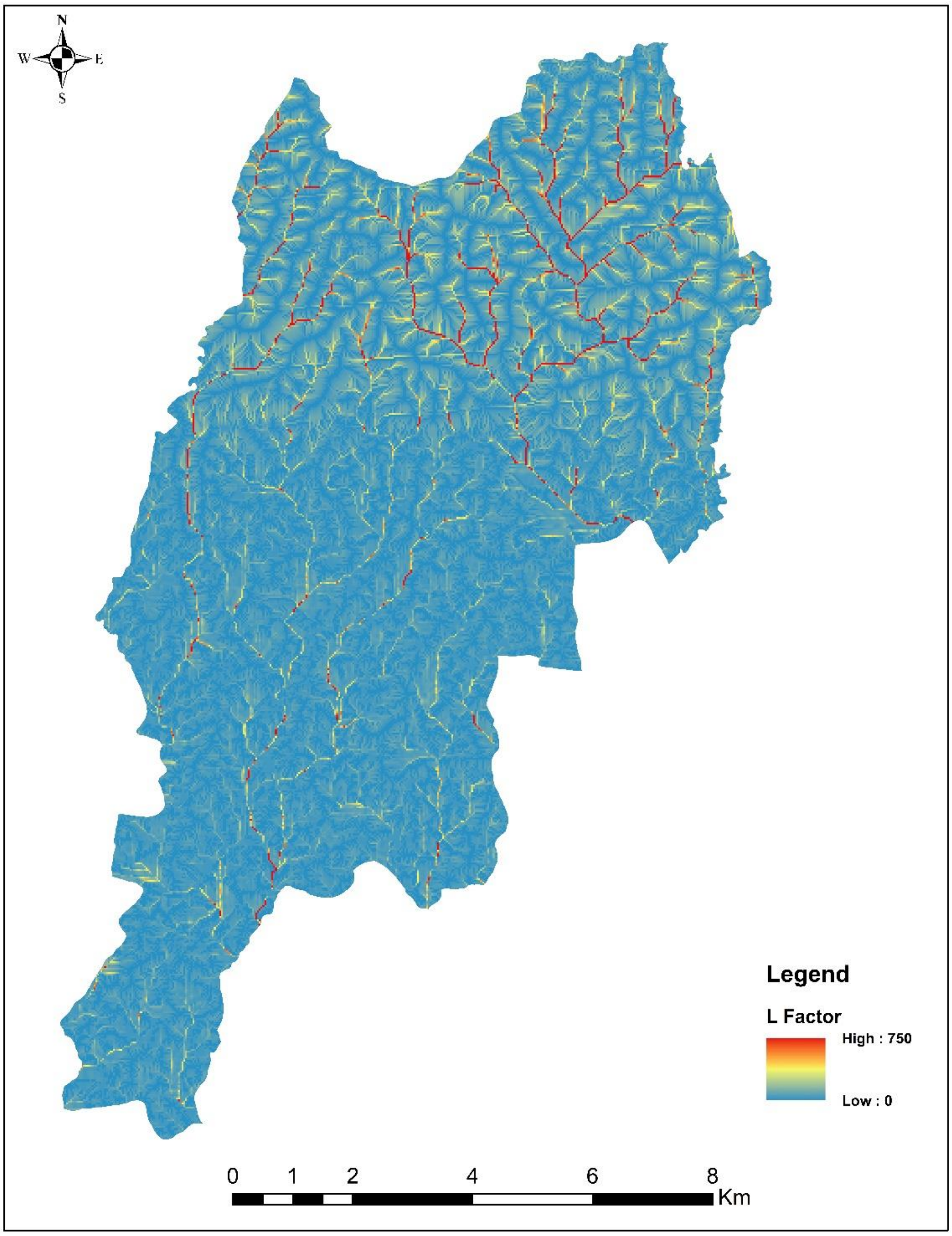


Figure 6.5: Distribution of Slope Length in Shambhunath Municipality

From the slope length factor (L) showed that the L-factor value ranges from 0 to 750 depending upon the terrain condition and water runoff. The run off rate is high in Siwalik region having higher value of slope length and less in southern portion of the municipality with lesser value of slope length. Similarly, the effects of slope steepness factor (S) have a greater impact on soil loss than slope length having relation steeper the slope, greater the probability of occurring erosion. The S-factor map was generated in Figure 6.6.

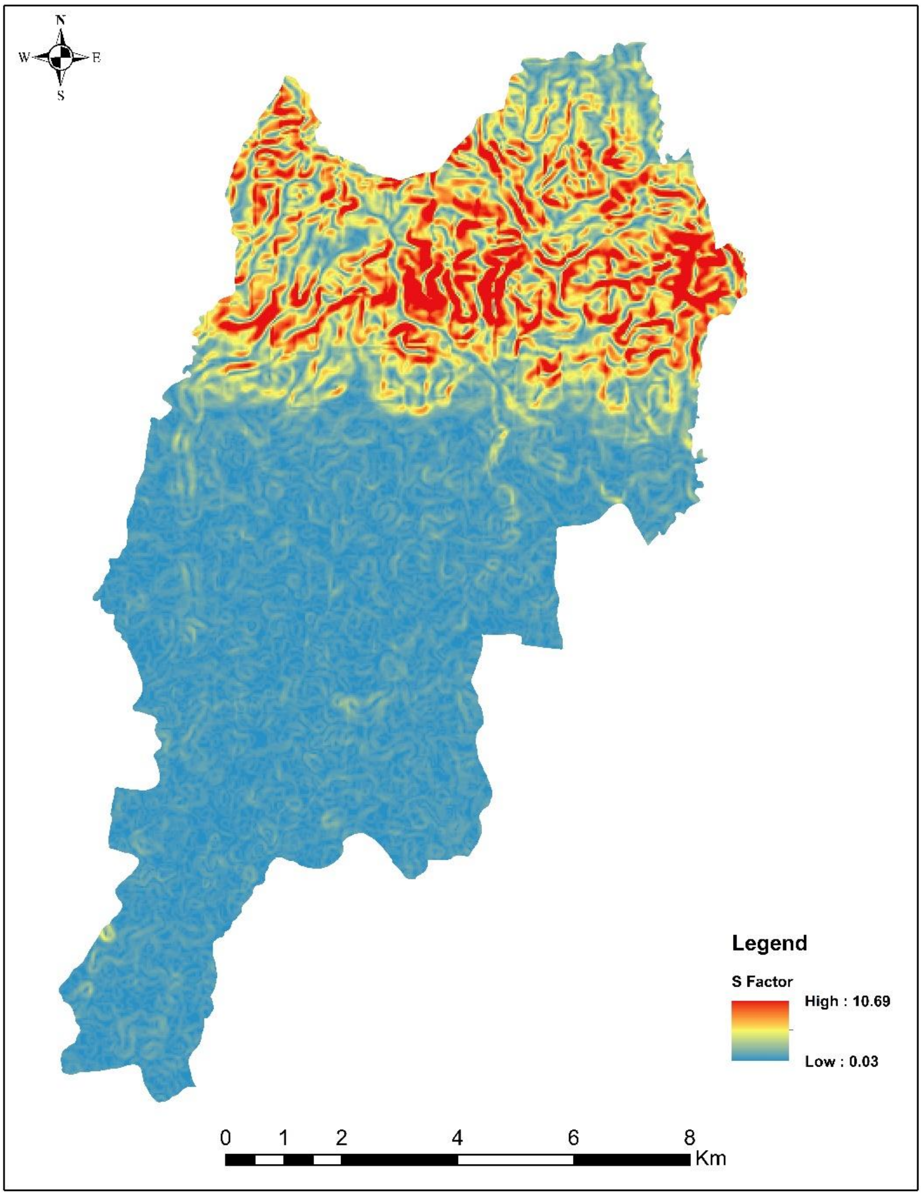


Figure 6.6: Distribution of Slope Steepness in Shambhunath Municipality

From the slope steepness (S-factor) map showed that the S-factor value ranges from 0.03 to 10.69 having high in the northern part (Siwalik hill) with steepness of terrain and lesser in southern part of the municipality.

The topographical factor (LS) has represented the combined effect of slope length and steepness relative to a standard unit plot. The LS-factor has increased through increase in hill slope length and steepness. The combined effect of slope length and slope steepness were computed from L-factor and S-factor (Figure 6.7).

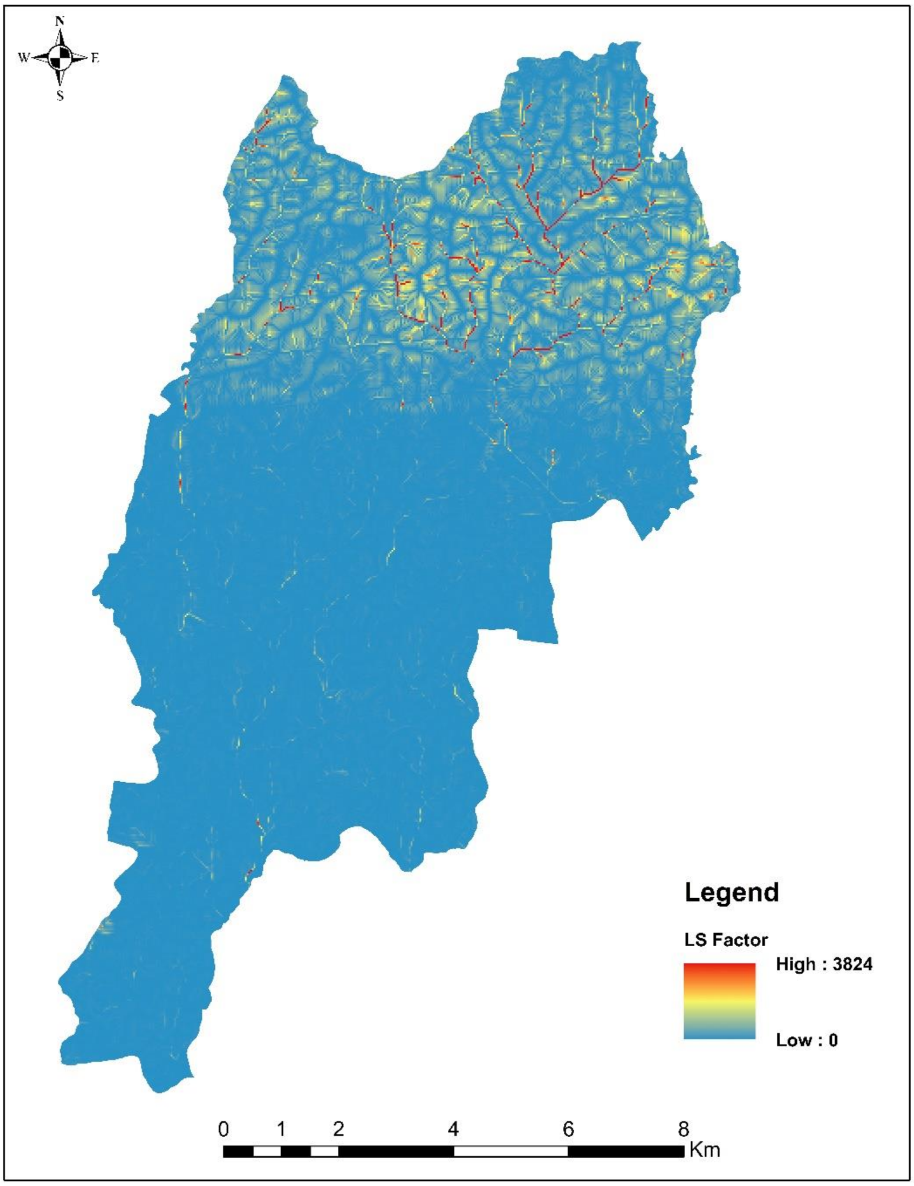


Figure 6.7: Topographical Factor Map of Shambhunath Municipality

LS-factor ranges were obtained from 0 to 3824 showing that the incidence of erosion is high in the northern section at Siwalik hill and less incidence of erosion in the southern part of the municipality due to flat terrain intensity. The chance of occurring erosion remains higher in barren land and open area along the river's banks.

Erosion control practice factor (P) described the ratio of soil loss resulting from agricultural activities in sloppy terrain. So, P-factor has considered as the control practices by affecting drainage patterns, runoff concentration, and runoff velocity on slope terrain. P-factor map was generated based on agriculture practices associated with different slope regimes and shown in Figure 6.8.

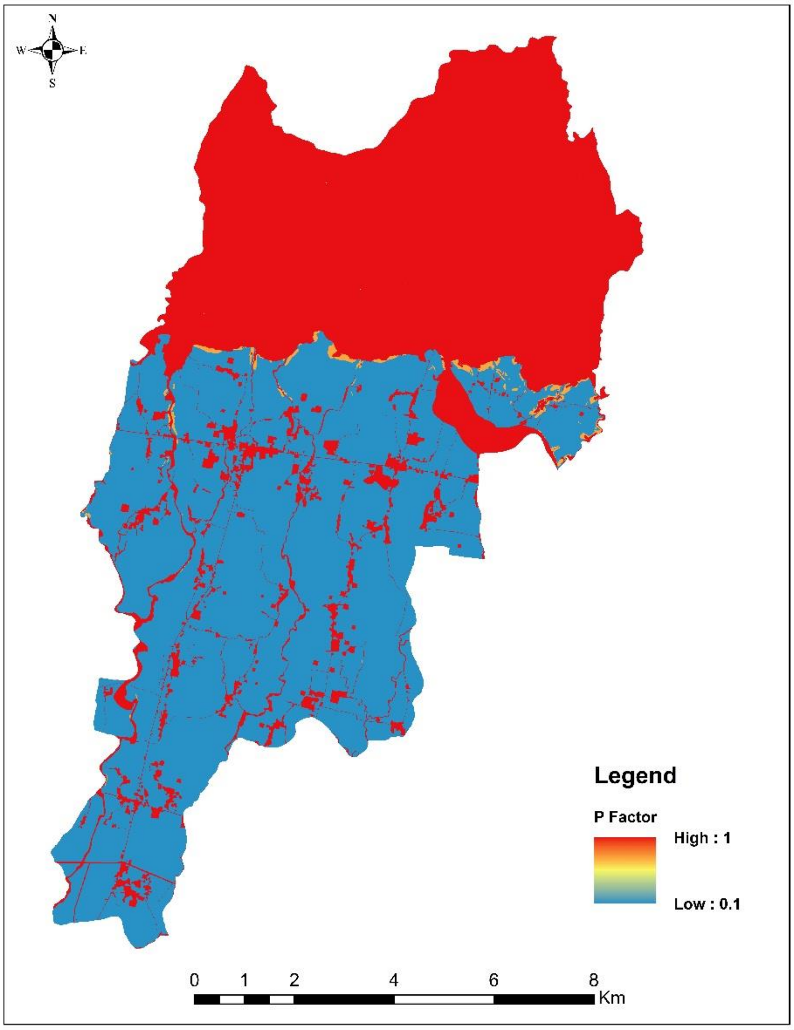


Figure 6.8: Erosion Control Practice Factor Map of Shambhunath Municipality

The P-factor value lies between 0.01 to 1 where the value less than 0.1 indicates good conservation practice and the value near 1 describes as poor conservation practice for agriculture activities. In this municipality, the majority of P-factor value are found less than 0.01 that represents the most of agriculture activities conducted in slope less than 5 degree, The P-factor value are found greater than 0.1 in Bhabar region (the foot of Siwalik hill) where agriculture activities carried out in slope between 5 to 20 degree. The sloppy terrain greater than 20 degree is used for non-agriculture practice mainly for forest use having P-factor value less than 0.21.

The cover-management factor (C) has been used to minimize the effect of cropping and other management practices on erosion rates. Vegetation cover has the second most important factor next to topography that controls soil erosion risk. Also, land cover intercepts rainfall, increases infiltration, and reduces rainfall erosional energy. So, the C-factor map was generated based on the land use practice and associated C-factor value based on cropping pattern for the analysis of land cover management activities (Figure 6.9).

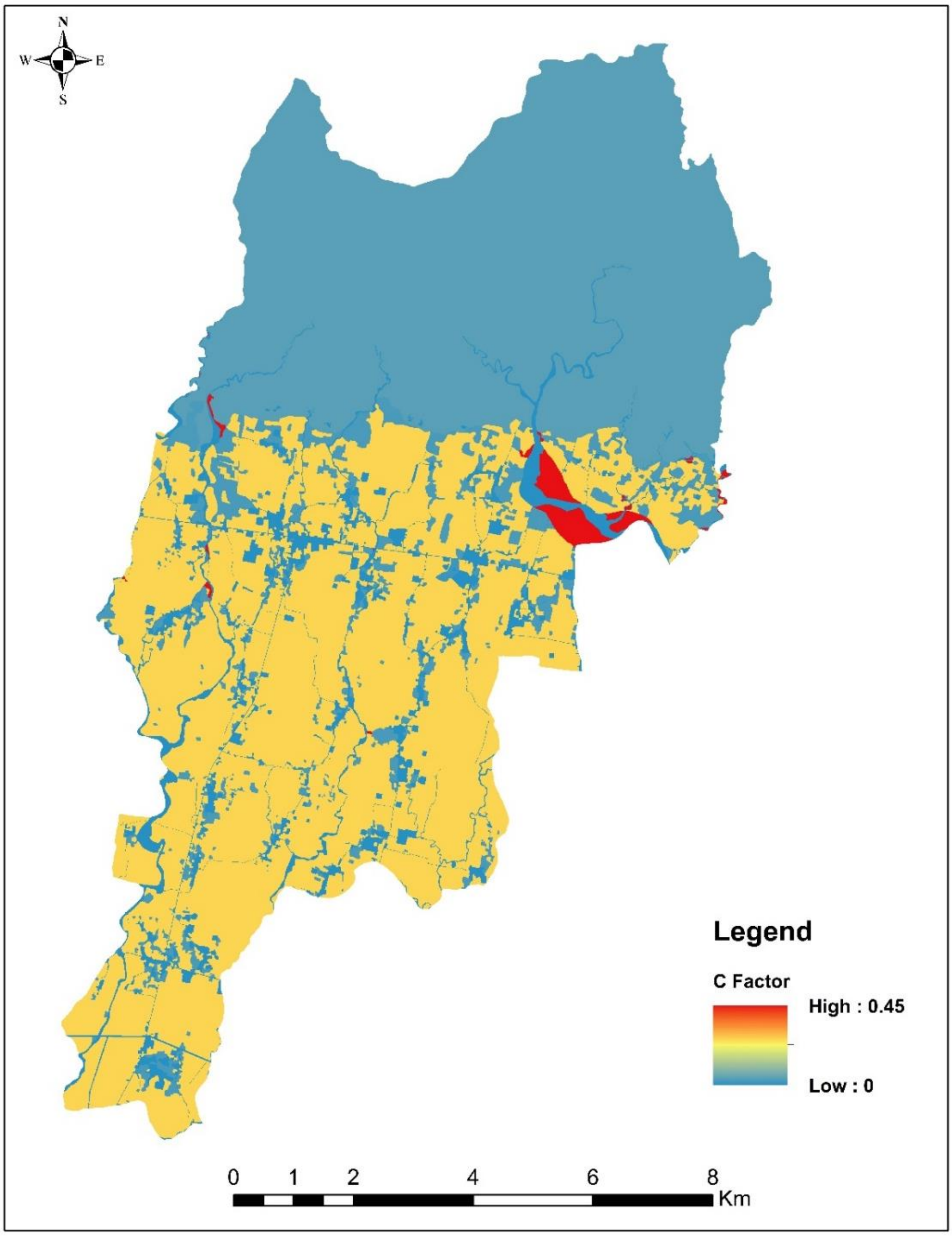


Figure 6.9: Cover Management Factor Map of Shambhunath Municipality

The C-factor value ranges from 0 to approximately 0.45, where higher values indicate no cover effect and soil loss comparable to that from a tilled bare fallow, while lower value of C means a very strong cover effect resulting almost no erosion.

The potential soil erosion map was produced from rainfall erosivity factor (R), soil erodibility factor (K), topographical factor (LS), Erosion control practice factor (P) and cover-management factor (C) map in ArcGIS by the raster multiplication through map algebra as the function used in RUSLE model (Figure 6.10).

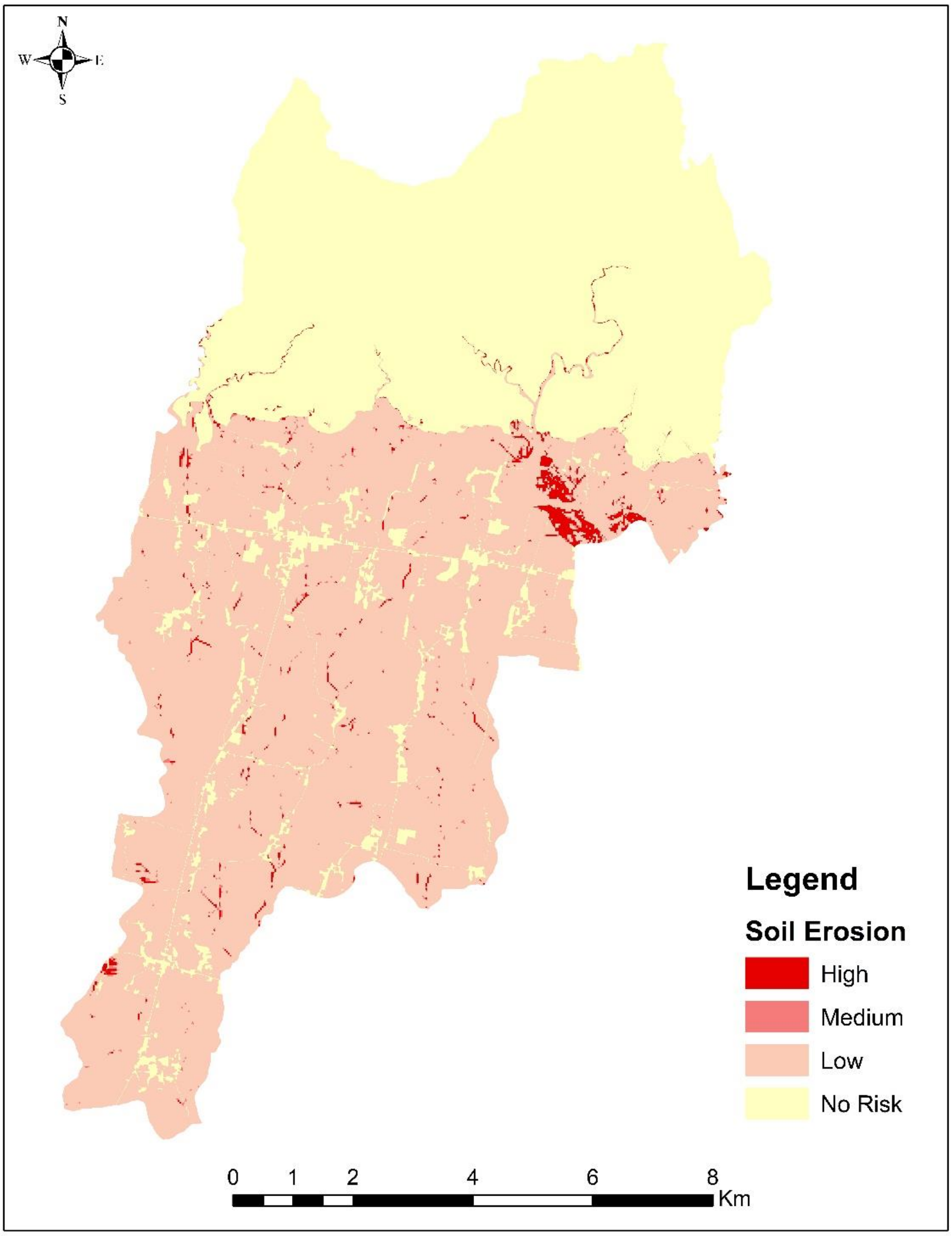


Figure 6.10: Soil Erosion Map of Shambhunath Municipality

The soil erosion ranges values were found from 0 to 50.38 t ha^{-1} yr^{-1} in terms of soil loss per year in the municipality then categorized into 6 classes based on conservation priority: low as less than 5 t ha^{-1} yr^{-1}, moderate as 5-10 t ha^{-1} yr^{-1}, high as 10-20 t ha^{-1} yr^{-1}, very high as 20-40 t ha^{-1} yr^{-1}, serve as 40-80 t ha^{-1} yr^{-1} and very serve as greater than 80 t ha^{-1} yr^{-1} (Koirala et al., 2019). The soil erosion results showed that the distribution of the low risk of soil erosion (slightly erosion) area with 54 percent, medium risk of soil erosion area with 0.5 percent, and the high risk of soil erosion (high, very high, serve and very serve erosion) with 1 percent having soil erosion rate greater than 10 t ha^{-1} yr^{-1}. In the municipality, there is essentially no soil erosion in the built-up area, road, agriculture land mainly orchard and forest areas. Likewise, the other land mainly open space, playground are causal rate of soil loss about 12 tons/ha per year within the municipality. Less soil erosion risk exists on agricultural land on flat terrain. Moderate soil erosion occurs on agricultural land in undulating terrain. High soil erosion risk exists in the lower terrace land, which is primarily an erosion and deposition area along river courses. Mostly high soil erosion risk area occupied in Khando River catchment area then in the longest course of Lukeshwor River and followed by Kajaria River.

Potential Impact of Soil Erosion

The impact of potential soil risk assessment has been carried out by the process of spatial overlay operation using zonal statistics of soil erosion potential layer to land use layer. The potential soil losses in each land use types are estimated through comparison of soil risk layer with references to land use data 2017 in the municipality. The potential effect of soil erosion rate in the term of maximum, average and total soil loss with relation to the land use types is shown in Table 6.3.

Table 6.3: Soil Erosion Impact on Land Use

S.N.	Land Use/Land Cover			Potential Soil Loss (tons/ha)			
	Description	**Area(in ha)**	**%**	**Max**	**Average**	**Total**	**%**
1	Agriculture	5609.35	51.65	50.38	0.26	16048.77	4.42
2	Forest	4402.78	40.54	2.64	0.01	332.36	0.09
3	Water body	353.09	3.25	1.07	0.00	4.46	0.00
4	Residential	250.53	2.31	0.01	0.00	0.63	0.00
5	Other	100.98	0.93	0.57	0.01	11.55	0.00
6	Public Use	92.05	0.85	0.09	0.00	1.09	0.00
7	Industrial	40.09	0.37	0.01	0.00	0.07	0.00
8	Commercial	9.01	0.08	0.01	0.00	0.04	0.00
9	Cultural and Archeological	2.52	0.02	0.01	0.00	0.02	0.00
	Total	10860.39	100.00			16398.99	4.51

Soil erosion rates are found highly correlated with increasing exposure of land surface in foot of the Chure range and scattered nature in in Tarai agriculture land. In this municipality, 4.42 percent of the agricultural land has a high risk rate of soil erosion. Similarly, 0.09 percent of forest area has high risk level of soil erosion. Some of the residential village areas near the river banks are found in the flood prone risk that need to be resettled in safe from risk.

6.1.3 Landslide Risk

Landslide has occurred from the movement of a debris, rock or soil mass down the slope (Cruden, 1991) and plays an important role in landform evolution and cause serious destructive natural hazards (Seyedeh et al., 2011). For LSM analysis, the landslide inventory map was prepared from the past landslide occurrences through google images (2000 to 2016) and recent landslide occurrences from satellite images (2017). Total 17 locations of landslide sites were found from 2000-2017. These collected inventory landslide data is divided into two classes for generating training and validation datasets on the proportion of 70/30 (Pourghasemi et al., 2012). Out of total 17 locations of landslide, 12 landslide locations were applied for predicting the future landslides occurrences as the parameter in the bivariate analysis with determined eleven causative factors of landslide. The frequency ratio (FR) technique were used for computing the relative frequency (RF) as priority rank and predictor ratio (PR) as weight of causative factor. The computing FR values, FR ranks, and PR weight is described in Appendix-15 and computing predictor ratio in Table 6.4.

Table 6.4: Influence Weight of Causative Factors

S.N.	Factor	PR Value	PR Weight
1	Dist. to Stream	0.04	4
2	Land Use	0.04	4
3	Lithology	0.06	6
4	Elevation	0.07	7
5	Distance to Road	0.08	8
6	Curvature	0.09	9
7	Soil Erosion	0.10	10
8	Aspect	0.10	10
9	NDVI	0.11	11
10	Distance to Fault line	0.15	15
11	Slope	0.15	15

LSM was generated on basis of the causative factors PR weight derived from frequency ratio technique (Figure 6.11). Landslide susceptibility analysis show that 1 percent of the municipality's extent is at high risk, 33 percent is at medium risk, and 66 percent is at low risk for landslides.

In this study, the performance of LSM were validated through the receiver operating characteristic (ROC) curve and the area under the curve (AUC). In the model evaluation by AUC, there has two evaluation process based on the success rate and the prediction rate. The results for the success rate has been achieved on the basis of training data and attained the prediction rates by a set of validation data. The results of the success rate has represented the fitness of the model for the training data; used in model building and not useful in assessing the predicting power of the model (Nohani et al., 2019).

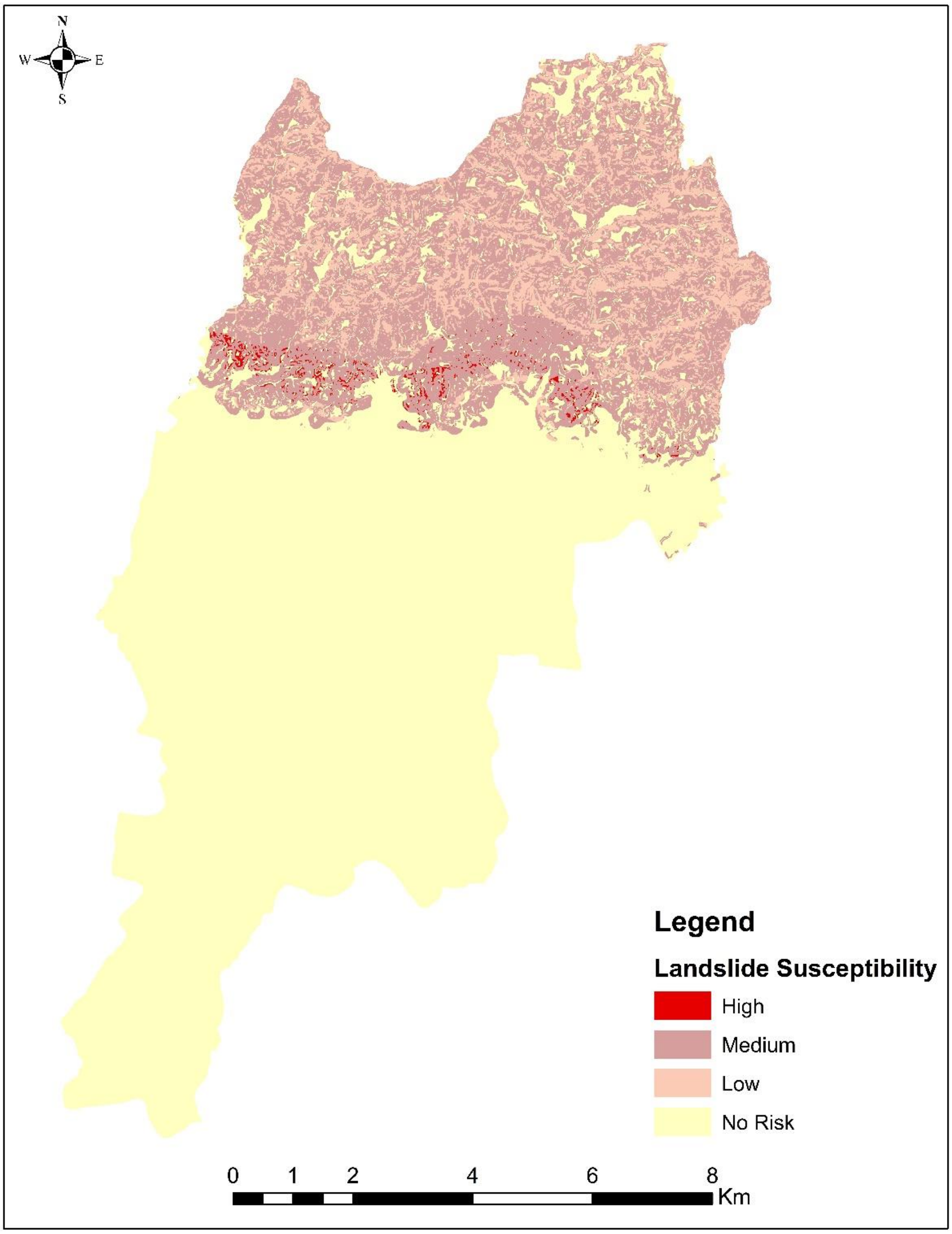


Figure 6.11: Landslide Susceptibility Map

From the Figure 6.12, the area under the curve of the success rate was found as 0.88 and prediction rate as 0.89 showing 89.5 percent prediction accuracy of the model. So, the produced LSM is reliable showing with all satisfactorily validation rates having good accuracy.

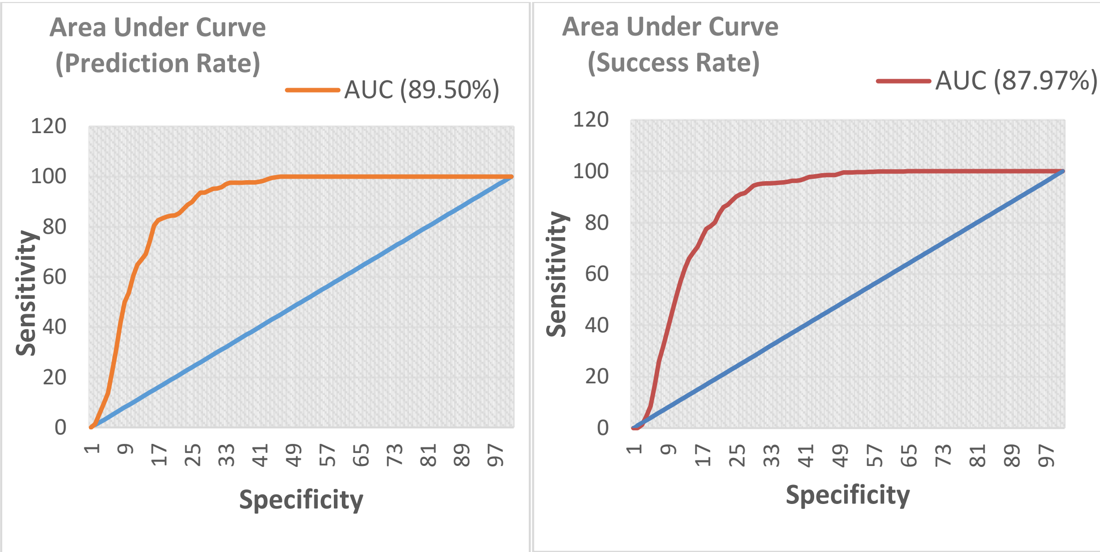


Figure 6.12: LSM Model Validation

Potential Impact of Landslide

The impact of potential landslide assessment was carried out by the process of spatial overlay operation using zonal statistics of landslide susceptibility layer with land use layer 2017. The potential landslide risk in the land use categories is shown in Table 6.5.

Table 6.5: Impact of Landslide Risk on Land Use

S. N.	Land Use Type			Landslide Susceptibility (area in ha)					Overall Risk (%)
	Description	Area (ha)	%	High	Medium	Low	Total	%	
1	Agriculture	5609.35	51.65	0.20	15.23	1.79	17.22	0.46	0.16
2	Forest	4402.78	40.54	48.57	2400.70	1218.76	3668.03	98.94	33.77
3	Water body	353.09	3.25	0.23	15.19	5.98	21.40	0.58	0.20
4	Residential	250.53	2.31	0.00	0.05	0.00	0.05	0.00	0.00
5	Other	100.98	0.93	0.00	0.71	0.00	0.71	0.02	0.01
6	Public Use	92.05	0.85	0.00	0.02	0.00	0.02	0.00	0.00
7	Industrial	40.09	0.37	0.000	0.000	0.000	0.000	0.00	0.00
8	Commercial	9.01	0.08	0.000	0.000	0.000	0.000	0.00	0.00
9	Cultural and Archeological	2.52	0.02	0.000	0.000	0.000	0.000	0.00	0.00
	Total	**10860.39**	**100.00**	**48.99**	**2431.89**	**1226.53**	**3707.42**	**100.00**	**34.14**

Among the municipality extent, about 34.14 percent of area is the landslide risk prone zone. The 98.94 percent of land under forest area is found in risky of the landslide. Total 0.46 percent of land under agriculture has found to be risk by landslide Likewise, 0.58 percent of water body, 0.02 percent of other land use as open area, 0.02 ha of public use area is found under the threat of landslide risk. About 49 ha forest area is found with high risk of landslide as well as 2401 ha forest area in medium risk of landslide. The high and medium risk of landslides are also affected several hectares of forest, agricultural land and public use land and need to be protected through bio-engineering for stability of terrain. The high and medium risk of landslide are high probability of some blockage of river channel in water body and probable of flash flood in the lower plain through outburst of debris dam and therefore need to be management practice of river and river edge slope protection.

6.1.4 Fire Risk

Fire incident generally occurs during the summer season and causes the loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, and environmental damage (Awasthi, 2019). It takes place in the village houses made of thatched grasses as well as building through poor management of fire and randomly occur from the electric circuit malfunction and high voltage transmission line circuit breakdown. It also damages the valuable natural resource as forest, forest animals and forest ecology. The previous fire locations were collected from the moderate-resolution imaging spectroradiometer (MODIS) images and used as fire incidence.

In this study, the following contributing factors were taken in the fire risk assessment using the GIS-based MCDA technique: elevation, slope, aspect, annual precipitation, wind speed, temperature, and NDVI (normalized difference vegetation index), land use, distance from transmission line, and distance from petrol area. The weight of each influencing element was determined utilizing pairwise comparisons and fuzzy membership functions for categorizing the priority rank among influence factors and detail computation described in Appendix-16. The weight of influencing factors utilizing the AHP method is presented in Table 6.6 with a consistency ratio of 0.08 (less than 0.1) for acceptable judgment. The detail of AHP pairwise comparison is described in Appendix-17.

Table 6.6: Weight of Influencing Factors

S.N.	Factors	Weight
1	Slope	0.1361
2	Aspect	0.0375
3	Elevation	0.0343
4	Wind Speed	0.1810
5	Temperature	0.1052
6	Rainfall	0.0377
7	NDVI	0.0528
8	Land Use	0.0588
9	Dist. to Transmission Line	0.1824
10	Dist. to Petrol Pump	0.1742

The weighted overlay function is applied for the forest fire using spatial analysis in GIS environment and prepared fire risk map shown in Figure 6.13. Fire risk assessment is showed that 21.14 percent of municipality extent land occurred in the fire risk in which the distribution of the high risk occupied 0.01 percent, medium risk, 0.49 percent, low risk 20.64 percent and remaining 79 percent land free from fire risk. In this municipality, high fire risk is likely to occur in the forest area at the foot of the Chure region. Also, high fire risk occurs at the intersection of petrol pump location and major transmission route (400 kVA, 132 kVA and 33 kVA). Moderate fire risk exists at the middle portion of Churiya range forest. Most part of Churiya range forest and settlement area occurs at low fire risk.

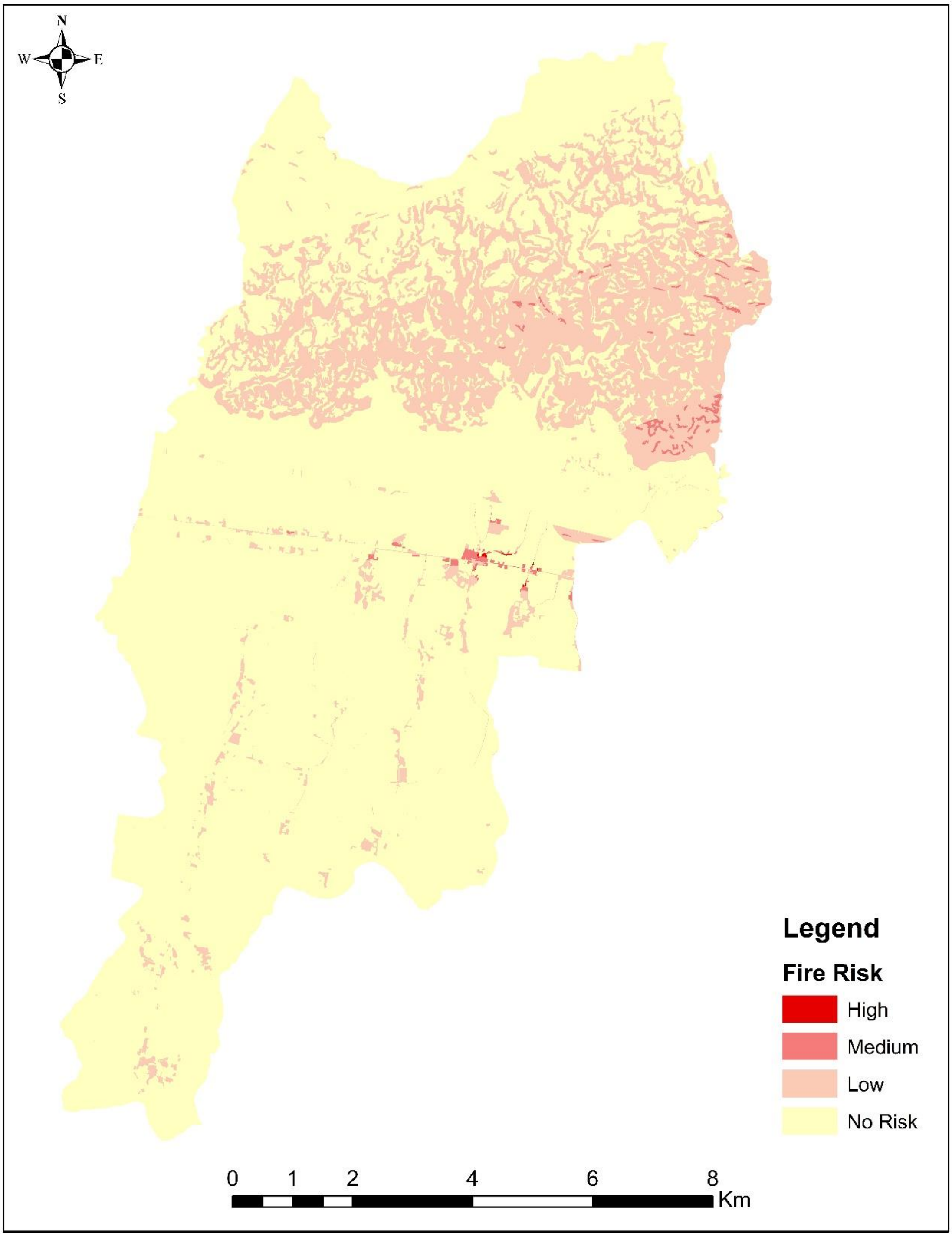


Figure 6.13: Distribution of Fire Risk Zone in Shambhunath Municipality

Potential Impact of Fire Risk

The impact of potential fire risk assessment is carried out by the process of spatial overlay operation using zonal statistics of fire risk susceptibility layer with land use layer 2017. The potential fire risk in the land use categories is shown in Table 6.7.

Table 6.7: Impact of Fire Risk on Land Use

S. N.	Land Use Type			Fire Risk Susceptibility (in ha)					Overall Risk (%)
	Description	**Area (in ha)**	**%**	**High**	**Medium**	**Low**	**Total**	**%**	
1	Agriculture	5609.35	51.65	0.00	0.17	0.32	0.49	0.02	0.01
2	Forest	4402.78	40.54	0.00	32.62	2037.12	2069.74	90.13	47.01
3	Waterbody	353.09	3.25	0.00	0.15	17.95	18.10	0.79	5.12
4	Residential	100.98	0.93	1.13	12.10	130.47	143.70	6.26	57.50
5	Other	250.53	2.31	0.00	0.77	14.15	14.92	0.65	14.78
6	Public Use	92.05	0.85	0.22	3.83	24.04	28.08	1.22	33.86
7	Industrial	40.09	0.37	0.00	2.29	12.93	15.22	0.66	38.24
8	Commercial	9.01	0.08	0.00	0.99	4.14	5.13	0.22	26.98
9	Cultural & Archeology	2.52	0.02	0.00	0.00	0.94	0.94	0.04	37.40
	Total	10860.39	100.00	1.34	52.92	2242.06	2296.33	100.00	21.14

Among the municipality extent, 21.14 percent of area is the fire risk prone zone. About 58 percent of total residential area is fire risk in which 13 ha residential area occurs in high and moderate risk. Likewise, 38 percent of industrial land occurred under medium and low fire risk in which 13 ha industrial area along the surrounding of high voltage transmission line. Similarly, 27 percent of commercial area is occurred under the medium and low fire risk. About 34 percent of public use area is fire risk in which 4 ha public area for high and moderate risk. There are low risk in other designated land use having 15 ha mainly open area covered with shrubs and bushes. The cultural and archeological area are found under low fire risk threat having one ha. The possibility of a fire burn zone is found to be 47 percent in the forest land use in which 33 ha forest land in medium risk, and 2037 ha forest land in low risk. These major affected forest area need to be protected for environment sustainability. The risk of fire is reduced in the forest region to enhance the potential for protection of the environment and forest management sustainability. The incidents of forest fire are minimized through taking preventive measures in high and medium fire risk area.

6.1.5 Seismic Risk

The collected seismic risk data from National Earthquake Monitoring and Research Centre (NEMRC) under Department of Mine and Geology is used for seismic risk evaluation through spatial overlay operation. The entire municipality area is allocated in high risk for seismic vulnerable. Generally, seismic risk is high surrounding to the fault line. So, the distance to the fault line is used as parameter for residential, commercial and industrial land use

6.2 Criteria for Land Suitability Evaluation

Land use associated with physical infrastructure, social infrastructure, and economic activities have been influenced by the provision of criteria for suitability evaluation for land development. From literature review, the essential elements were chosen as criteria and categorized into four groups: public infrastructure, social infrastructure, economic and business activities and other management facilities, and applied in land suitability analysis. These chosen criteria were linked to a close relationship between land utilization; the environment, and catastrophe mitigation; equitable land distribution; and population growth requirement that need spaces for living, working, and recreational purposes. The close interrelationships among social, economic activities and land use is shown in Figure 6.14.

Based on the interaction between social, economic, and infrastructure factors and land use pattern, the chosen criteria were analyzed for their applicability in the current situation at local context and applicable in land suitability evaluation. The chosen criteria from literature review are listed in the sample semi-structure questionnaire described in Appendix-5.

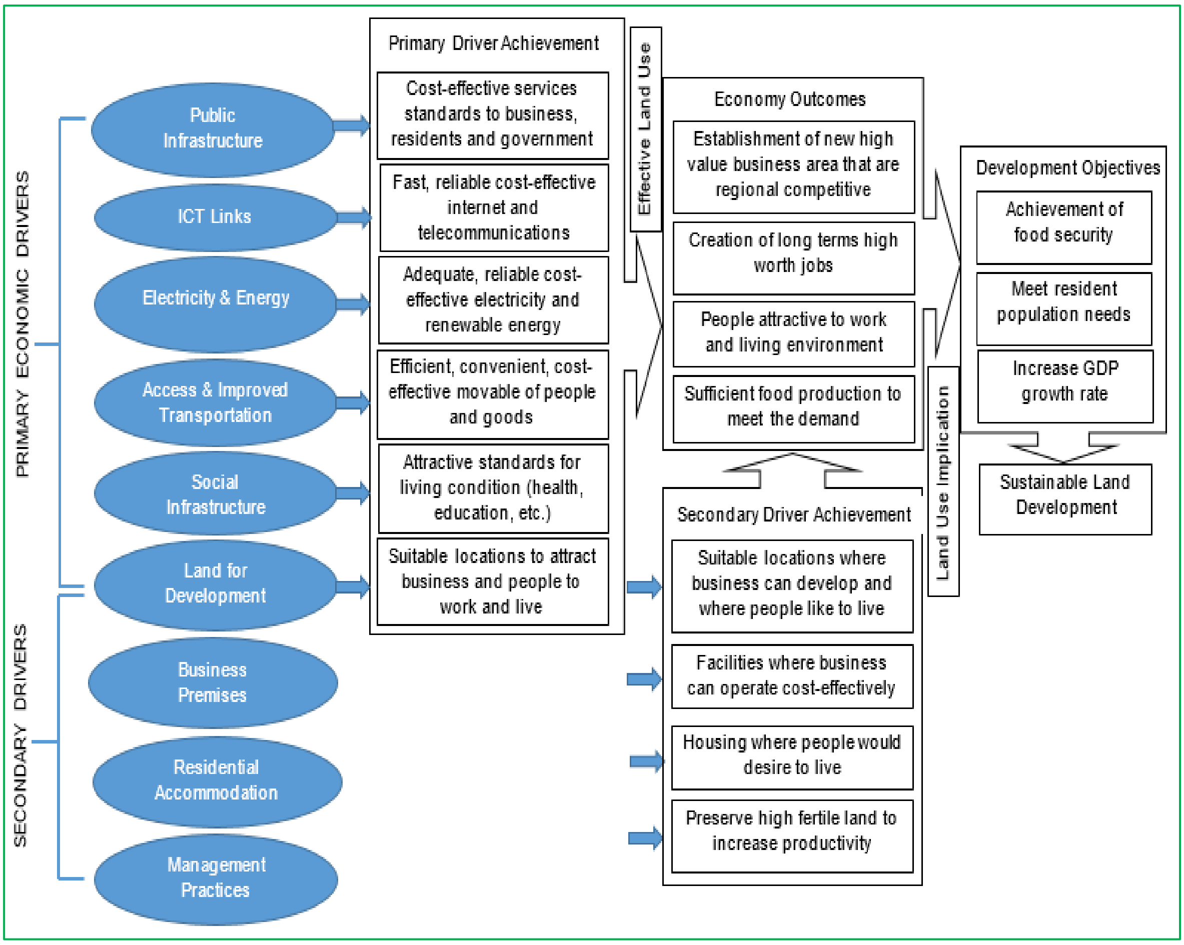


Figure 6.14: Interrelationship among Social, Economic and Land Use

6.2.1 Selection of Parameters

The focus group discussion aims to finalize the criteria based on the views of planning perspective for interaction with decision makers, politician and stakeholders. In general, a set of criteria (parameters/constraints) is applied for proper land use, which means that decisions about how to utilize land are made based on those criteria. Therefore, the specific sets of criteria are determined for specific land use as really affecting in decision making process. The participants of focus group meeting agreed to select the specific criteria for land use classes such as agriculture, residential, commercial, industrial, and forest. The five land use sets of criteria are selected from specified criteria from FGD and presented in Table 6.8.

Table 6.8: Selected Influencing Criteria for Particular Type of Land Use

Criteria	Agriculture	Residential	Commercial	Industrial	Forest
Slope	√	√	√	√	√
Current Land Use	√	√	√	√	√
Geomorphology (Land Form and Landscape)	√	√	√	√	√
Land Capability	√	√	√	√	
Geology (Lithology)	√				√
Soil Type	√				√
Population Density		√	√	√	
Surrounding Settlement/ Commercial		√	√	√	√
Access to Basic Infrastructure		√	√		
Access to Service Centre		√	√		
Strategic Road Network		√		√	√
Employment			√	√	
Land Value			√	√	
Proximity to Fault Line		√	√	√	
Proximity to Stream Line	√				√
Soil Quality (Soil Fertility)	√				√
Air Quality (Distance from Chimney)		√	√		
Noise Pollution (Distance from Strategic Road)		√			
Soil Erosion	√				√
Flood					√
Heritage Landmark				√	√
Local Road Circulation			√		
Vegetation Index					√
Soil Moisture Index	√				
Temperature	√				
Load Capacity/ Soil Strength				√	
Rainfall	√				

Source: Field Survey, 2019

The factors selected for agriculture use include: land use, slope, geology, land form, temperature, soil moisture, soil fertility, soil type, land capability, soil erosion, proximity to water source and rainfall. Some factors: land use, slope, geology, land form, soil type, land capability, risk layers as soil erosion, rainfall, soil fertility, and proximity to water source are chosen from previous researches (Khanal, 2002; Tims, 2009; Nyeko, 2012; Karna, 2013; Pramanik, 2016), whereas some additional factors as such temperature, soil moisture and land capability are selected in local situation for agriculture land use. These selected factors are analyzed and categorized into physical, climate, soil characteristic, conservation practice and human activities variable. Slope, geology, and land form/system are significant criteria as physical variables. Geology describes the physical aspects of soil/rock for ground water availability that is necessary to advance agricultural production and develop to farm plot. Slope describes the management system of terraces land for the productive restoration, conservation, and improvement of land and water resources as well as the overall ecosystem. Land form/land system governs the formation of the associated soils, surficial water systems for crop growth. As climatic variables, mean temperature and annual rainfall are important criteria. High temperature reduces the plant productivity, regular rainfall patterns are essential for healthy plants, and excessive or insufficient rainfall has a detrimental effect on crop growth. Likewise, rainfall/precipitation has strongly increased dramatically with increasing elevation and decreasing temperatures that play vital role for meeting crop water requirements. Soil fertility and soil moisture are major characteristics of soil. Soil fertility describes the high rate of crop production depends fertility rate and arability of land. Soil moisture (the amount of water in the soil) creates the capacity for crop growth and development by intensifying water consumption. Soil moisture is increased through rainfall/precipitation by water contains. Normalized difference water index (NDWI) obtained from infrared (IR) and green (G) bands of WorldView-2 satellite images and used as Soil moisture criteria. The conservation related factors are soil type, land capability and soil erosion. Soil type describes the formation of soil profile containing the parent material, soil texture and soil nutrients. Land capability describes the appropriateness of land for agriculture practices with limited use for conservation initiatives of soil properties. Soil erosion leads soil degradation, loss of soil nutrients, and poor infiltration. Land use and water sources are the human-related variable in agriculture suitability analysis. Land use describes the current state of land use pattern. Proximity to water sources describe the accessibility of water for agricultural productivity.

Similarly, the factors selected for residential use includes: land use, slope, land form, proximity to road, proximity to service center, proximity to infrastructure facilities, proximity to settlement, proximity to business area, proximity to recreation area, far from pollution area, far from fault line and population density. Some factors: land use, slope, land capability, proximity to road, proximity to service center, proximity to infrastructure facilities, proximity to settlement and business area, population density, and noise and air pollution are chosen from previous researches (Yang et al., 2008; Tims, 2009; Hao, 2013; Karna, 2013), whereas some additional factors: land form, proximity to greenery and recreation area, and proximity to fault line are selected in local situation for residential land use. These selected factors are analyzed and categorizes into physical, environment, and socio-economic variables. Slope, land capability, proximity to fault line and land form are significant criteria as physical variables. Slope is used for sewerage and sanitation work and construction stability. Land capability is used to preserve high arable fertile land. The proximity to fault line refers the feasibility of a seismicity zone. Land form is applicable to control development activities for terrain stability in upland formation area. Pollution (noise and poor air quality), and greenery areas are considered environmental variables. The presence of industrial facilities and brick chimneys affect the amount of pollutants in the air. Similarly, noise pollution also happens in areas near highway, major road and industrial location. Greenery area includes recreational facilities area, parks, open space, green belt zone to enhance the quality of life. Population density, service areas, infrastructure facilities, accessibility, and human activities are the socio-economic variables. Population density describe the strain on the environment and growing demand for public facilities within the area. For convenience, service areas are correlated with their closeness to other service areas such as utility centers, schools, hospitals, banks, restaurants, and retail malls. The infrastructure facilities area includes the proximity to strategic road network, sewerage and sanitation, communication and electrification to availability of public facility infrastructures. The accessibility facilities includes mainly as bus route for public transportation. The human activities include the existing land use, proximity to settlement, and business area.

In the same way, the factors selected for commercial use include: land use, slope, land form, land capability, land value, proximity to road, proximity to service center, proximity to infrastructure facilities, proximity to settlement area, far from pollution area, far from fault line, employment status, and population density. Some factors: land use, slope, land capability, proximity to road, proximity to service center, proximity to road and road crossing, and proximity to settlement and business area are chosen from previous research (Tims, 2009). Whereas, the some additional factors: land form, land value, proximity to infrastructure facilities, proximity to pollution area, proximity to fault line, employment status, and population density are selected in local situation for commercial land use. These selected factors are analyzed and categorized into physical, environment, and socio-economic variables. Slope, land capability, proximity to fault line and geomorphology are significant criteria as physical variables. Slope is used for sewerage and sanitation work and construction stability. Land capability is used to preserve high arable fertile land. The proximity to fault line refers the feasibility of a seismicity zone. Geomorphology is applicable to control development activities for terrain stability in upland formation area. The environmental variable that includes air pollution describe the amount of air pollutants produced by industrial facilities and brick chimney. Socio-economic variable include: population density, employment, service area, accessibility, infrastructure facilities, land value and human activities. Population density and employment leads to increase the demand and pressure for public service utilities and facilities. Public transportation provides the accessibility for delivering goods and services through vehicle route. Infrastructure facilities describe the provision of public facilities that close to road network, sewerage and sanitation, and communication, and electrification. Land value represents the selection of commercial location and surrounding service activities and cost benefit analysis in investigation process. The human activities include the existing land use, proximity to intersection of major roads (road crossing), and proximity to settlement.

The factors selected for industrial use include: land use, slope, land form, load capacity, land capability, land value, proximity to road, far from conservation and heritage site, proximity to infrastructure facilities, proximity to settlement and business area, proximity to conservation and heritage site, proximity to fault line, employment status, and population density. Some factors: land use, slope, land form, land capability, proximity to road, proximity to infrastructure facilities, and proximity to settlement and business area are chosen from previous researches (Dia et al., 2008; Tims, 2009), whereas some additional factors: land value, proximity to conservation and heritage site, proximity to fault line, employment status, and population density are selected in local situation for industrial land use. These selected factors are analyzed and categorized into physical, environment, and socio-economic variables. Slope, geology, geomorphology, proximity to fault line and land capability are significant criteria as physical variables. Slope is used for sewerage and construction stability. Geology describes the structure strength of soil stability. Land form is applicable to control development activities for terrain stability in upland formation area. The proximity to fault line refers the feasibility of a seismicity zone to construct earthquake-resistant infrastructure in industrial area. Land capability is used for preserving high arable fertile land. The heritage and conservation sites, as well as the forest areas are applicable to conserve environmental sustainability and act as environmental variable. Socio-economic variable include: population density, employment, land value, infrastructure and human activities. Population density and employment provides the opportunity to enhance industry by available of human resource and meet the demand of goods and products. Land value represents the selection of industrial development area and cost benefit analysis. Public utilities and facilities are described by the infrastructural facilities, which primarily include access to roads, sewerage and sanitation, communication, and electrification for regular industrial activity. The human activities include the existing land use, and proximity to settlement and business area.

Likewise, the factors selected for forest use includes: land use, soil, geology, land form, temperature, soil erosion, flood plain, soil fertility, proximity to road, proximity to water source, far from settlement area and heritage site, and NDVI . Some factors: land use, slope, proximity to road, and proximity to water source are choosen from previous researches (Jafari & Zaredar, 2010; Nyeko, 2012; Karna, 2013), whereas some additional factors: geology, land form, temperature, soil erosion, flood plain, soil fertility, proximity to settlement area and heritage site, and NDVI are selected in local situation for forest land use. These selected factors are analyzed and categorized into physical, management practices, socio-economic condition, and human activities variable. Slope, geology, and land form are significant criteria as physical variables that has been used to manage the terrain's land form due to various hazards. The geological structure support the growth of forest species with strength of rock. Land form is applicable to control development activities for terrain stability. Soil property, flood plain, soil erosion and vegetation index (NDVI) have been incorporated as management parameters. Soil properties based on the soil texture and depth are essential for the establishment of forests. Flood plain and soil erosion are relevant to regulate the surface of top soil and its fertile rate. The conservation area describe with the proximity to existing forest area for enhancing carbon contents, wildlife, and wetland habitat. The vegetation index shows the amount of available vegetation cover. Socio-economic factors include the infrastructure facilities as proximity to strategic road network. The human activities include the existing land use, proximity to settlement for preserving forest area and biodiversity in the municipality.

6.2.2 Standardization of Criteria

During the focus group discussion meeting, participants discussed the applicability of the tentative standards and made any necessary adjustment. The focus group discussion is concentrated to determine the standard rating of sub-criteria of selected criteria used in the land evaluation process for land use classes such as agriculture, residential, commercial, industrial, and forest. In focus group meeting, sub-criteria of selected criteria are adjusted in the form of standard ratings. A tentative set of rating standards is formatted based on the planning standard guidelines and regulation of land development for land use planning. Finally, group discussion agreed rating the standard. The agreed standard rating of the criteria is used for suitability evaluation in particular land use (agriculture, residential, commercial, industrial and forest land) is presented in Appendix-18.

6.2.3 Computation of Weight

During the weight assessment, the analytical hierarchy process (AHP) technique is employed to compute the weight of the each criterion. In this study, AHP technique is appropriate method to determine weight based on the decision maker's views and this technique is also easier to understand for all stakeholders in the process of land use planning. The 1-9 pairwise comparison rating scale is used to compare the relative importance of every two criteria. The relative importance is ranked by number 1 to 9 based on the pairwise comparison rating scale (Table 2.1). The consistency ratio for each land use type from different criteria are also assessed and obtained within the limiting threshold of 0.1.

6.3 Land Suitability Evaluation

In this study, land suitability analysis was conducted with GIS assisted spatial overlay process and applied to assess the satisfaction level of each land use class. The suitability analysis of each land use classes (agriculture, residential, commercial, industrial, and forest) were carried out using MCE-AHP with WLC procedure.

6.3.1 Agriculture

MCE-AHP method was used to compute influence weight of each influencing criteria and shown in Table 6.8 for agriculture land suitability analysis. The selected criterion data for agriculture use was further classified into suitable standard rating of the criteria for agriculture use. Each criterion data is classified and rated with corresponding on the standard ranking scale and presented in Appendix-19. The weight of influencing criteria from MCE-AHP process is shown in Table 6.9 with consistency ratio 0.06 for acceptable of judgment. The detail of AHP-Pairwise comparison ranks for agriculture land is described in Appendix-20.

Table 6.9: Weight of Influencing Criteria for Agriculture Suitability

S.N.	Criteria	Weight
1	Slope	0.1565
2	Geology	0.0329
3	Land Form	0.0515
4	Temperature	0.0349
5	Soil Moisture	0.0996
6	Soil Fertility	0.1509
7	Soil Type	0.0900
8	Land Capability	0.1067
9	Soil Erosion	0.0638
10	Land Use	0.1121
11	Proximity to Water Source	0.0470
12	Rainfall	0.0540

The selected criteria's with its ranks and weights were used for the preparation of the agriculture suitability map. The agriculture suitability index map shows that 3139 ha (29%) land is covered with suitable level followed by moderate suitable level with 3001 ha (28%) for agriculture use. Unsuitable level of agriculture land covers with 2669 ha (25%), poor (marginally) suitable with 2007 ha (18%) and 43 ha (0.40%) with highly suitable agriculture land in the municipality. The distribution of these suitability order of agriculture use is presented in Figure 6.15. The suitability order of agriculture use follows the similar pattern of site suitability analysis for agricultural land use of Darjeeling district (Pramanik, 2016), though the proportion varies. The order of suitable agriculture land is located at low landform in flat terrain, gentle slope, high fertility rate, and land capability class I or class II. These results lead to similar pattern of suitable agriculture land for land use resource planning (Nyeko, 2012) and suitable agriculture land in road network planning (Karna, 2013). The unsuitable and poor suitable agriculture is occupied in the undulation terrain and Siwalik hill. The validity assessment of agriculture suitability was conducted through a spatial analysis with tabulate intersection of existing agriculture practice land and the suitability agriculture index data. The result shows that 97.49 percent of the agricultural practice land occurred in the suitability order of the agriculture suitability index data.

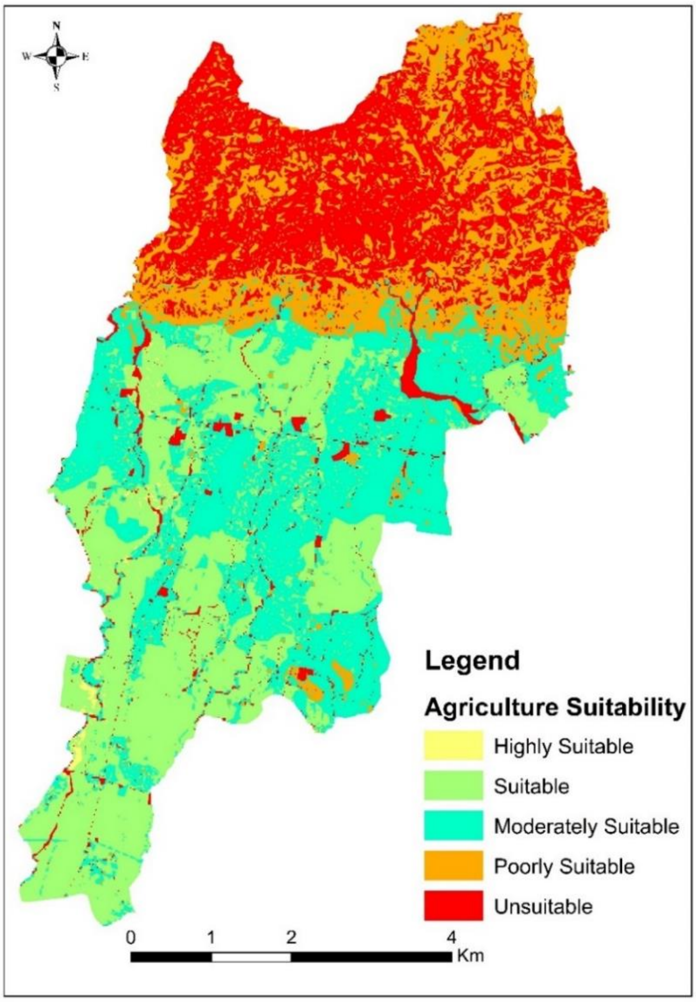


Figure 6.15: Agriculture Suitable Order in Shambhunath Municipality

6.3.2 Residential

MCE-AHP method was used to compute influence weight of each influencing criteria and described in Table 6.8 for residential land suitability analysis. Each criterion data for residential use was classified and rating with corresponding on the standard ranking scale and presented in Appendix-21. The weight of influencing criteria from MCE-AHP process is shown in Table 6.10 with consistency ratio 0.09. The detail of AHP-Pairwise comparison ranks for residential land is described in Appendix-22.

Table 6.10: Weight of Influencing Criteria for Residential Suitability

S.N.	Criteria	Weight
1	Slope	0.1872
2	Land Form	0.0501
3	Land Capability	0.0468
4	Proximity to Service Area	0.1130
5	Proximity to Infrastructure Facilities	0.0907
6	Proximity to Strategic Road	0.0712
7	Land Use	0.0983
8	Proximity to Existing Residential and Commercial Area	0.1188
9	Proximity to Greenery Area/Recreation	0.0602
10	Proximity to Pollution (Air/Noise)	0.0359
11	Proximity to Fault line	0.0437
12	Population Density	0.0841

The selected criteria's with its ranks and weights were used for the preparation of the residential suitability map. Residential suitability index map shows that 4107.80 ha (38%) extent is covered with suitable level followed by moderate suitable level with 527 ha (5%) for residential use. However, highly suitability level of residential area covers only 0.19 ha in the municipality. The distribution of these suitability order of residential use is presented in Figure 6.16. The suitability order of residential use follows the similar pattern for urban land use planning in Lanzhou City (Dia et al., 2001), the suitability assessment for New Minia City, Egypt (Aly et al., 2005), and urban land use management at Changsha City (Yang et al., 2008). The spatial pattern of residential suitable order occurs mainly along the road network in urban development area and surrounding to the existing settlement in rural area. The validity assessment of residential suitability was conducted through a spatial analysis with tabulate intersection of existing residential land and the suitability residential index data. The result shows that 98.70 percent of the residential area occurred in the suitability order of the residential suitability index data.

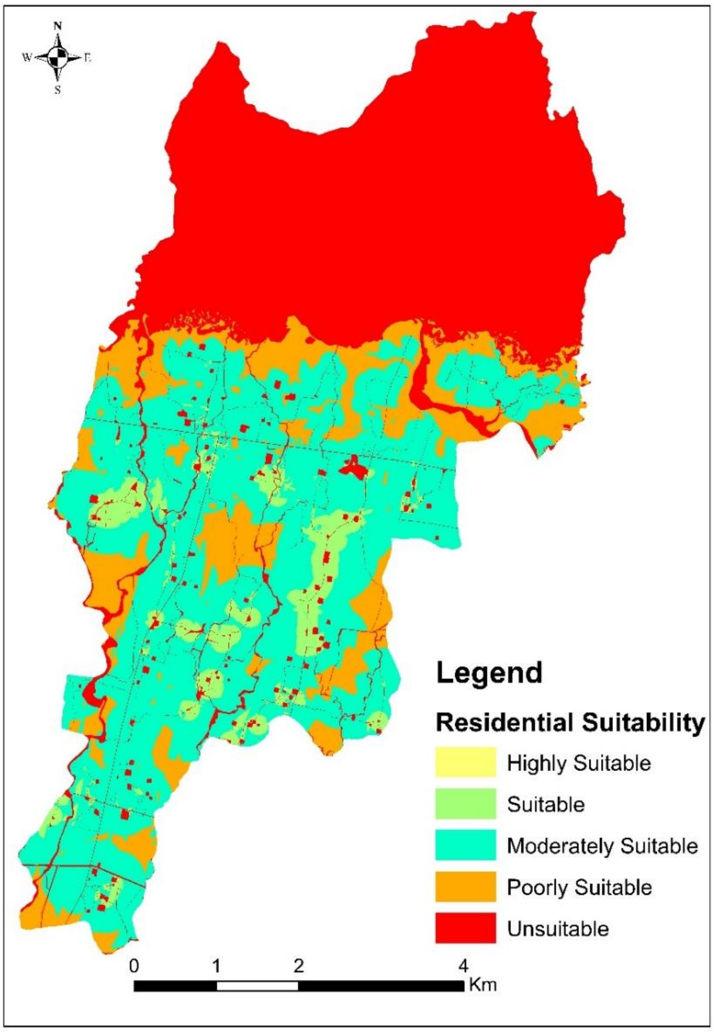


Figure 6.16: Residential Suitable Order in Shambhunath Municipality

6.3.3 Commercial

MCE-AHP method was used to compute influence weight of each influencing criteria and described in Table 6.8 for commercial land suitability analysis. The selected criterion data was further classified into suitable standard rating of the criteria for commercial use. Each criterion data is classified and rating with corresponding on the standard ranking scale and presented in Appendix-23. The weight of influencing criteria from MCE-AHP process is shown in Table 6.11 with consistency ratio 0.07 for acceptable of judgment. The detail of AHP-Pairwise comparison rank for commercial land is described in Appendix-24.

Table 6.11: Weight of Influencing Criteria for Commercial Suitability

S.N.	Criteria	Weight
1	Slope	0.1833
2	Land Form	0.0552
3	Land Capability	0.0589
4	Land Value	0.1059
5	Proximity to Infrastructure Facilities	0.0775
6	Proximity to Local Road Circulation	0.0662
7	Land Use	0.1488
8	Proximity to Settlement Area	0.1095
9	Proximity to Service Area	0.0698
10	Proximity to Pollution (Air Quality)	0.0333
11	Proximity to Fault line	0.0373
12	Population Density and Employment	0.0544

The selected criteria with its ranks and weights were used for the preparation of commercial suitability map. The commercial suitability index map shows that 3797.80 ha (35%) is covered with moderate suitable level followed by the suitable level with 1690 ha (16%) for commercial use. However, highly suitability level of commercial area covers only 91 ha (about 1%) in the municipality. The distribution of these suitability order of commercial is presented in Figure 6.17. The majority of highly suitable order of commercial land occurs along strategic road (East West highway, feeder road) and surrounding to the existing commercial area. Suitable order of commercial land also occurs at the intersection of road junction in the rural settlement area. The suitable order of commercial use follow the similar pattern in GIS based model for land use and development of master plan in Rawanda (Tims, 2009) however it varies in nature. The validity assessment of commercial suitability was conducted through a spatial analysis with tabulate intersection of existing commercial area and the suitability commercial index data. The result shows that 98.40 percent of the commercial area occurred in the suitability order of the commercial suitability index data.

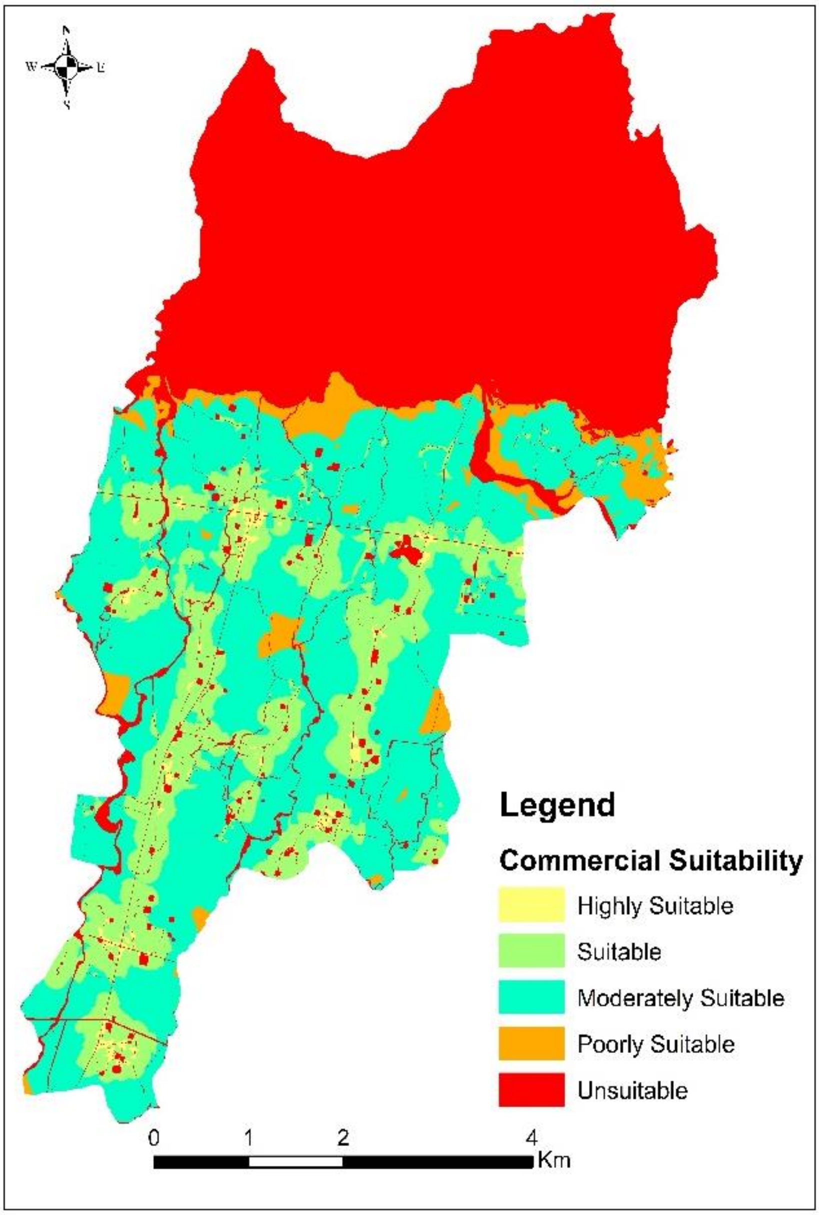


Figure 6.17: Commercial Suitable Order in Shambhunath Municipality

6.3.4 Industrial

MCE-AHP method is used to compute influence weight of each influencing criteria and described in Table 6.8 for industrial land suitability analysis. The selected criterion data is further classified into suitable standard rating of the criteria for industrial use. Each criterion data is classified and rating with corresponding on the standard ranking scale and presented in Appendix-25. The weight of influencing criteria from MCE-AHP process is shown in Table 6.12 with consistency ratio 0.09. The detail of AHP-Pairwise comparison ranks for industrial land is described in Appendix-26.

Table 6.12: Weight of Influencing Criteria for Industrial Suitability

S.N.	Criteria	Weight
1	Slope	0.1884
2	Land Form	0.0649
3	Load Capacity	0.0509
4	Land Capability	0.1034
5	Proximity to Infrastructure Facilities	0.0904
6	Proximity to Strategic Road Network	0.1000
7	Land Use	0.1214
8	Proximity to Settlement and Commercial Area	0.0763
9	Land Value	0.0636
10	Proximity to Conservation Area/ Heritage Site	0.0514
11	Proximity to Fault line	0.0453
12	Population Density/Employment	0.0439

The selected criteria with its ranks are used for the preparation of the industrial suitability map. The industrial suitability index map shows that 5143 ha (47%) is covered with moderate suitable level followed by suitable level with 61 ha (0.56%) for industrial use. However, highly suitability level of industrial area covers only 0.12 ha in the municipality.The distribution of these suitability order of industrial use is presented in Figure 6.18. The most appropriate location for industrial area occurs at Devdhar settlement along East West highway, the north of the Rupani Bazar at the foot of Chure range, the barren cultivable land near Khando River along agriculture road, and the south west direction of Kathauna Bazar along Kathauna-Pato feeder road. The suitable order of industrial use follow similar pattern to land use suitability of an industrial city in northeast China (Dia et al., 2008). The validity assessment of industrial suitability was conducted through a spatial analysis with tabulate intersection of existing industrial area and the suitability industrial index data. The result shows that 98.40 percent of the industrial area occurred in the suitability order of the industrial suitability index data.

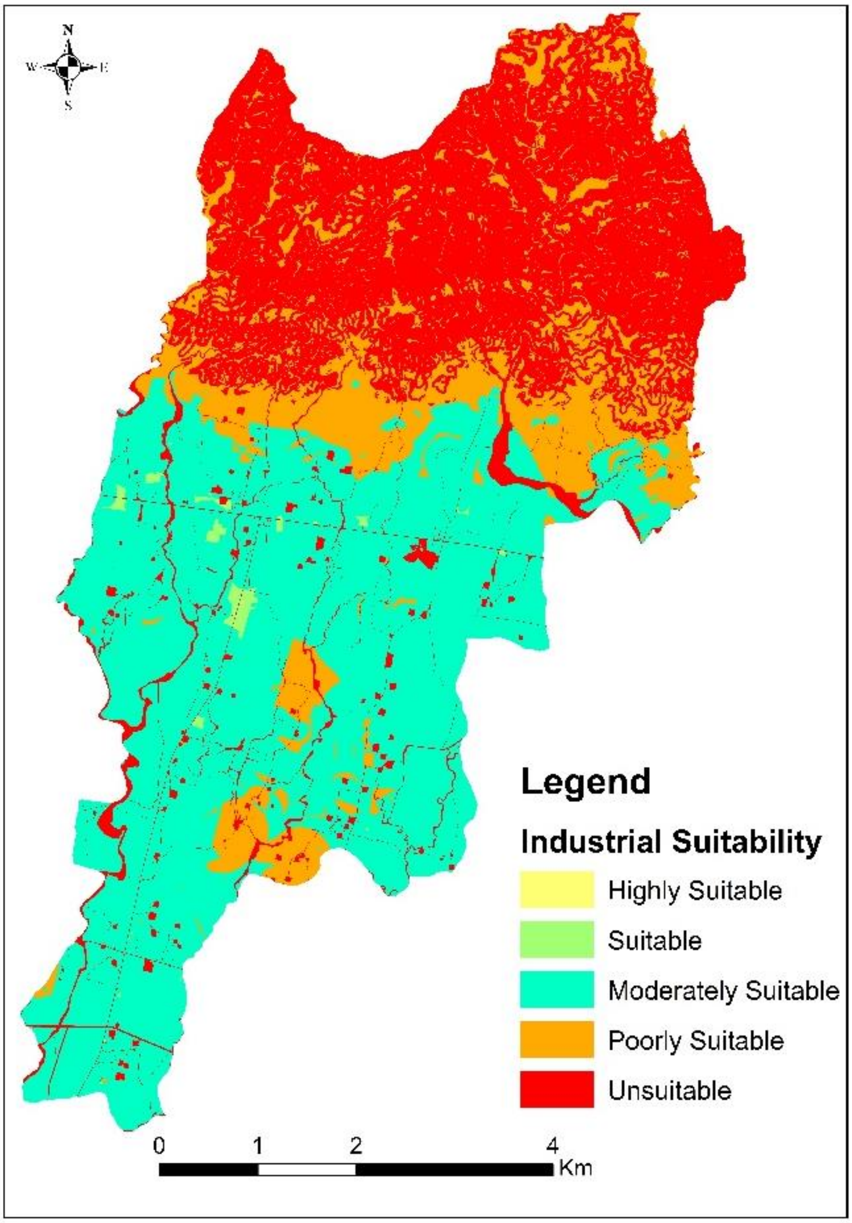


Figure 6.18: Industrial Suitable Order in Shambhunath Municipality

6.3.5 Forest

MCE-AHP method is used to compute influence weight of each influencing criteria and described in Table 6.8 for forest land suitability analysis. The selected criterion data is further classified into suitable standard rating of the criteria for industrial. Each criterion data is classified and rating with corresponding based on the standard ranking scale and presented in Appendix-27. The weight of influencing criteria from MCE-AHP process is shown in Table 6.13 with consistency ratio 0.07 (less than 0.1). The detail of AHP pairwise comparison ranks for forest land is described in Appendix-28.

Table 6.13: Weight of Influencing Criteria for Forest Suitability

S.N.	Criteria	Weight
1	Slope	0.1447
2	Soil	0.0871
3	Geology	0.0434
4	Land Form	0.0480
5	Flood Plain	0.0691
6	Soil Erosion	0.0998
7	Land Use	0.0911
8	Proximity to Strategic Road Network	0.0382
9	Proximity to Stream Network	0.0778
10	Proximity to Settlement Area/ Heritage Site	0.0364
11	NDVI	0.0954
12	Soil Fertility	0.1690

The selected criteria with its ranks are used for the preparation of the forest suitability map. Forest suitability index map depicts that 5840 ha (54%) is covered with the majority of poorly suitability level followed by suitable level with 2810 ha (26%), moderately suitable level with 1835 ha (17%) and 376 ha (3.5%) with highly suitable for forest use. The distribution of these suitability order of forest use is presented in Figure 6.19. The suitable and highly suitable forest use land is located in greater than 15^0 slope mainly in Siwalik hill and moderate suitable land in slope greater than 5^0 for forest area observed surrounding to the river course (mainly Khando River) in the scattered pattern. The suitable order of forest use follow similar pattern to the land suitability analysis forest use (Jafari & Zaredar, 2010) and suitable forest land in road network planning (Karna, 2013). The validity assessment of forest suitability was conducted through a spatial analysis with tabulate intersection of existing forest area and the suitability forest index data. The result shows that 99.34 percent of the forest area occurred in the suitability order of the forest suitability index data.

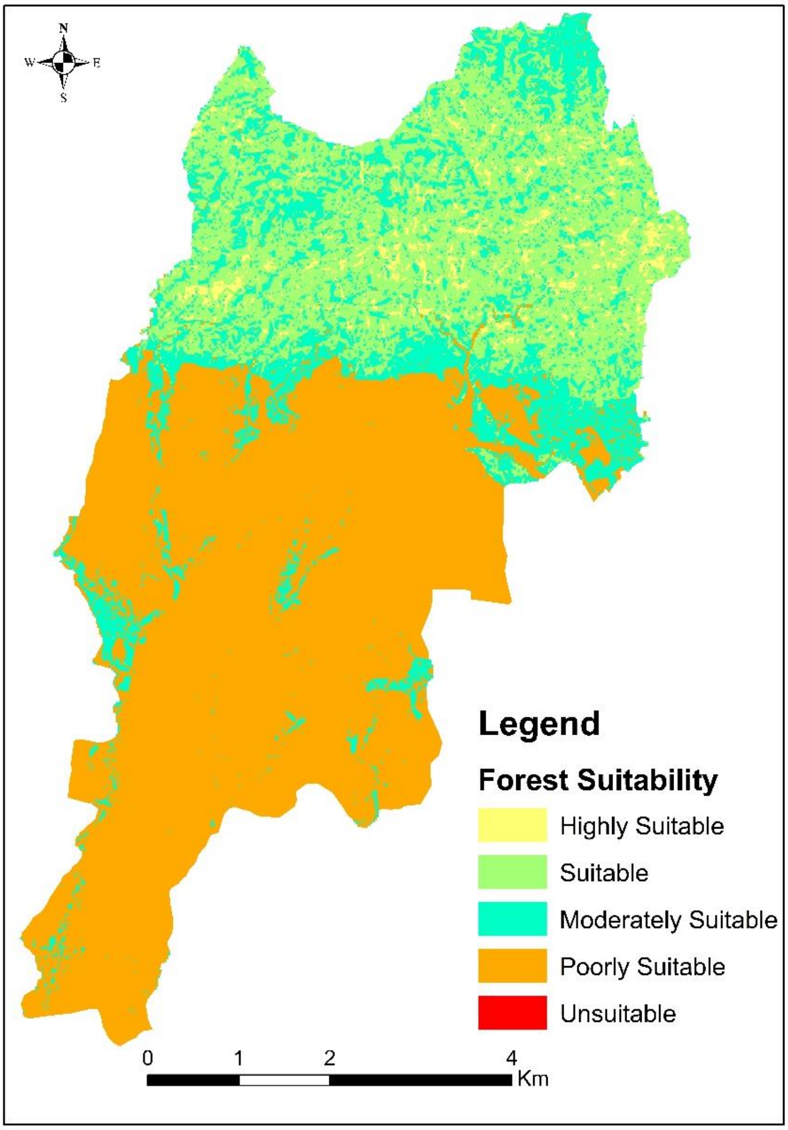


Figure 6.19: Forest Suitability Order in Shambhunath Municipality

Tarai region was previously covered with dense forest in arable land, high fertility rate and land capability class I, which is ideal for forest cover and timber production. The foot of the Chure hill (Bhabar region) is also covered with alluvium land form, arable land, high fertility rate, and use for forest use. However, Bhabar region has recently witnessed a rapidly changing landscape from forest to agriculture land, built-up area, and construction of different physical infrastructure. In addition, existing land use practices, available physical infrastructure and present settlement area have been taken into consideration in land suitability for potential forest use. So, suitability order of forest use land occurs poorly suitable in the southern part of East West highway.

Chapter – 7

LAND USE PLANNING

The chapter focuses on need assessment; developing infrastructure guideline for the preparation of infrastructure development plan; preparation of land use plan based on scenario model, integrating risk layers and developing infrastructure; and optimization through SWOT analysis.

7.1 Need Assessment

Need assessment is conducted through the assessment in the context of immaterial needs for development of physical infrastructure plan with the consideration of human well-being as a whole; level of health, securing human rights, possibilities and possibilities of choice, as emphasized in a number of different strategic documents, research reports and in public domain. Development of physical infrastructure plan with its services and perception of their benefit is identified based on the consultation with local people for determination of the respective needs. In this study, individual and community based requirement is identified through RRA, PRA and FGD techniques with reference to demographic situation (population growth, working age population and availability of labor force), economic activities as trade facilities and industry, land tenure and land value, physical infrastructure (road, electricity, telecommunication facilities, water supply, waste water and sewerage system), and social infrastructure (health services center, educational center, sport and recreational facilities, security series and other public buildings).

7.1.1 Population Growth

Population growth represents the change in population in certain extent and generally leads to the change in agricultural land use. Population data for different years since 1971 is available at Central Bureau of Statistics (CBS), Nepal and collected based on the previous VDC within the municipality as Shambhunath, Mohanpur, Bhangaha, Basbalpur, Khoksar Parwaha, Arnaha, and Rampur Jamuwa. The population of the municipality is computed totaling the sum of the previous VDCs population. The population of 1954 and 1961 derived from the collected population data (1971-2011) using linear regression trend line in backward forecast of 17 years. Population before 1991 was least population density (238 per sq.km) and lesser pressure on agriculture land. After 1991, population density and internal migration rapidly increased. The population size at ward level was converted based on the collected and derived population data. The frequent change of population size occurred in the various wards boundaries in the municipality. The population size in the municipality from 1954 to 2021 is presented in Table 7.1

Table 7.1: Population Growth Trend

S.N.	Year	Population
1	1954	11743
2	1961	13962
3	1971	16852
4	1981	21334
5	1991	25814
6	2001	30746
7	2011	35213
8	2021	39634

Source: CBS, 1971-2011; NSO, 2023

The population size of the municipality increased from 11743 to 35213 in 57 years with the annual growth rate of 4.12 percent between 1954-2011, 38422 in 2018 (CBS, 2018), and 39634 in 2021(NSO, 2023). Using an exponential model, a trend of population size increase for the 16 years between 2021 and 2037 is predicted to be 56862 and presented in Figure 7.1.

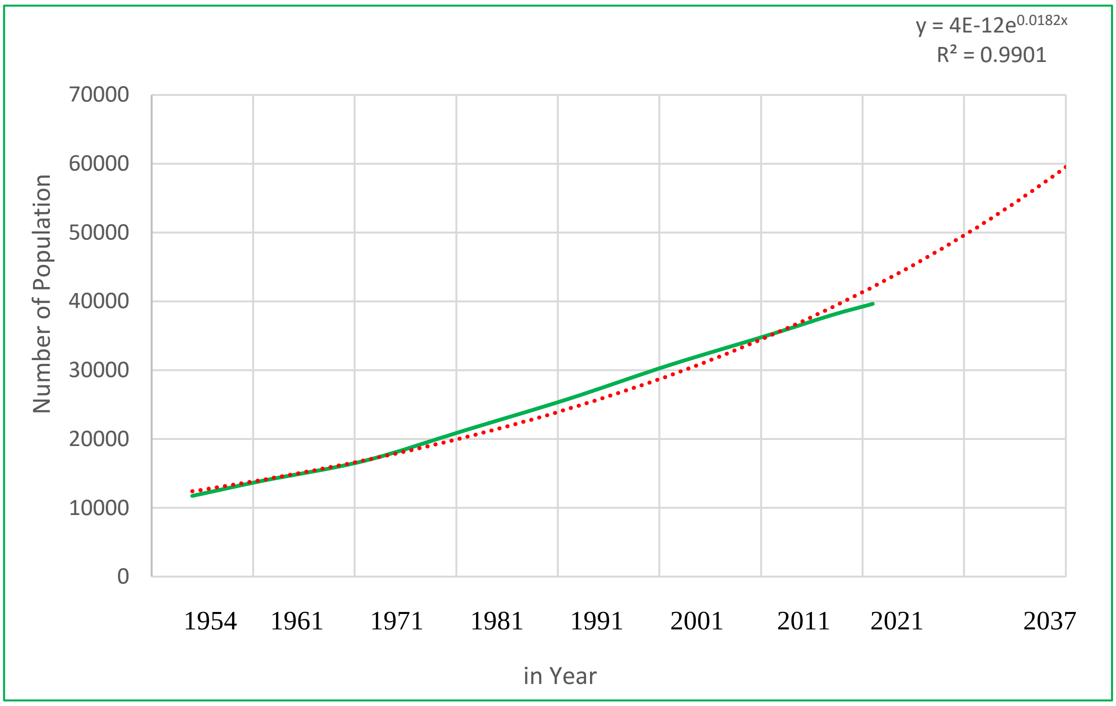


Figure 7.1: Trend of Population Growth in Shambhunath Municipality

7.1.2 Working Age Population

The working age population is represented the population aged between 15 to 59 years. In Nepal, working age population is increased from 53 percent in 2001 (CBS, 2003), 57 percent in 2011 (CBS, 2012) and 61 percent in 2021 (NSO, 2023). So, the population structure is shifted to benefit from the demographic dividend and increase the number active working age group population for income earners in the country. A higher proportion of the working age group population live in urban and sub-urban areas. This indicates that the younger residents of rural areas moved to urban and sub-urban areas for better education with the availability of service facilities (school, campus, and polytechnic institute) and opportunities of business, job/employment at company and industries (CBS, 2014). In the municipality, there are 24,058 working age people who are not dependent on anyone. These people are responsible for caring for the dependent population (mainly the children and the elderly). The population based on age group is shown in Table 7.2.

Table 7.2: Age Group Population

Age group in years	Population			Percentage		
	Total	Male	Female	Total	Male	Female
00-04 Yrs.	3936	2160	1776	9.93	11.36	8.61
05-09 Yrs.	3668	1877	1791	9.25	9.88	8.68
10-14 Yrs.	3806	1970	1836	9.60	10.37	8.90
15-19 Yrs.	3989	1965	2024	10.06	10.34	9.81
20-24 Yrs.	3951	1767	2184	9.97	9.30	10.59
25-29 Yrs.	3172	1359	1813	8.00	7.15	8.79
30-34 Yrs.	2618	1142	1476	6.61	6.01	7.16
35-39 Yrs.	2688	1108	1580	6.78	5.83	7.66
40-44 Yrs.	2143	972	1171	5.41	5.11	5.68
45-49 Yrs.	1945	897	1048	4.91	4.72	5.08
50-54 Yrs.	2017	968	1049	5.09	5.09	5.09
55-59 Yrs.	1535	804	731	3.87	4.23	3.54
60-64 Yrs.	1277	613	664	3.22	3.23	3.22
65-69 Yrs.	1255	578	677	3.17	3.04	3.28
70-74 Yrs.	964	479	485	2.43	2.52	2.35
75-79 Yrs.	418	228	190	1.05	1.20	0.92
80-84 Yrs.	127	64	63	0.32	0.34	0.31
85-89 Yrs.	69	35	34	0.17	0.18	0.16
90-94 Yrs.	31	10	21	0.08	0.05	0.10
95+ Yrs.	25	10	15	0.06	0.05	0.07
Total	**39634**	**19006**	**20628**	**100.00**	**100.00**	**100.00**

Source: NSO, 2023

7.1.3 Availability of Labor Force

People who engage in any economic activities for variety of occupation and employment both locally and aboard depend on the availability of labor force. The population of available labor force above 10 years is 22058 (NSO, 2023) in the municipality. The type of labor activities in the municipality are agriculture, wholesale, retail trade; repair of vehicles and motorcycle, construction, manufacturing, transportation and storage, accommodation and food service activities, financial and insurance activities, financial and insurance activities, professionals, electricity, information and communication, administration and support service activities, mining and quarrying, waters supply, sewerage, waste management and remediation activities, and real estate activities. The detail of availability labor force within the municipality is presented in Table 7.3.

Table 7.3: Available Labor Force

S.N.	Type of Labor Activities	Population	Percentage
1	Agriculture	14251	64.61
2	Wholesale, retail trade; repair of vehicles and motorcycle	3107	14.09
3	Construction	2015	9.14
4	Manufacturing	945	4.28
5	Transportation and storage	547	2.48
6	Accommodation and food service activities	423	1.92
7	Financial and insurance activities	271	1.23
8	Professionals	124	0.56
9	Electricity	75	0.34
10	Information and communication	75	0.34
11	Administration and support service activities	75	0.34
12	Mining and quarrying	50	0.23
13	Waters supply, sewerage, waste management and remediation activities	50	0.23
14	Real estate activities	50	0.23
	Total	**22058**	**100.00**

Source: NSO, 2023

Total of 65 percent economically active people are engaged in agriculture; 14 percent in wholesale and retail trade, repair of vehicles, and motorcycle; 9 percent in construction; 4 percent in manufacturing; 2 percent in transportation and storage; and 2 percent in accommodation and food service activities. The remaining group of labors/workers is engaged in activities related to accommodation and food service activities, financial and insurance activities, financial and insurance activities, professionals, electricity, information and communication, administration and support service activities, mining and quarrying, waters supply, sewerage, waste management and remediation activities, and real estate activities.

7.1.4 Trade Facilities and Industry

Major business area of Shambhunath Municipality is Kathauna Bazar are located at the junction of East West highway and feeder road of Kathauna-Pato. Most of the business activities are conducted from Kathauna as central commercial area. Many market centers are developed in many areas namely Rupani, Khoksar, Dangrahi Bazar (Traffic Chock), and Devdhar (Bhidiya Bazar) along East West highway and Shivnagar, Basantapur, Rajpur, Arnaha and Kushaha along feeder roads near the existing settlement areas (Figure 7.2).

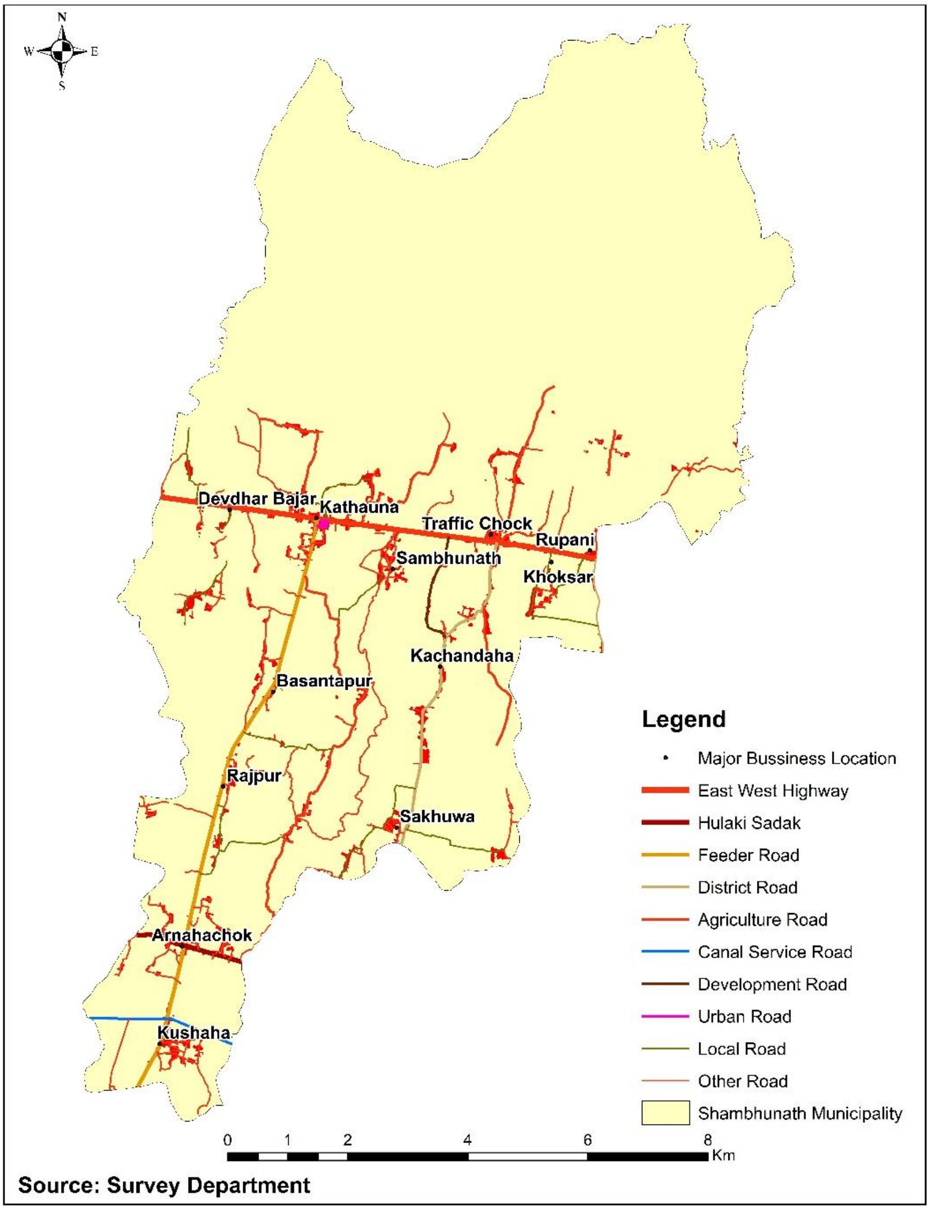


Figure 7.2: Business and Industrial Area in Shambhunath Municipality

Some small business areas are located nearby Kachandaha and Sakhuwa settlement along district road, which is the potential business area. Also, small business area is developed surrounding to Shambhunath Temple area. Such developments of business and market facilities have raised the pressure on agriculture land, and placed impact on food and fodder production. Agriculture production is favorable condition for food surplus zone mainly in agricultural land. There are 4 agro industries (seller rice mill) and supplied to the local market at Rajbiraj, Lahan and other parts of the country. The half portion of vegetable is supplied to Rajbiraj, Lahan and surrounding local market. Likewise, horticulture production is mainly mango and litchi surplus of these fruits are supplied to Kathmandu, Pokhara, etc. The fish (113 MT), poultry (21 MT) and livestock (one MT) are supplied to local market and local consumption. The milk production (5 MT) is moderately rate of production that used by local people only. The clothes, medicine, petroleum fuel, ginger products, and cosmetic goods are imported from Rajbiraj, Lahan and the nearest market of India (Kunauli and Laukahi). Agriculture seeds, fertilizer, pesticides are also imported from Rajbiraj, Lahan and Indian markets. For the fish farming, fingerlings are collected from Lahan, Fatehpur and Tarhara Fish Farms. Likewise, hatchery and poultry feed are purchased from local markets.

Furniture products (plastic and steel) are also collected from Lahan and local markets. There are eight fixed chimney for brick production and supplied brick to the Rajbiraj and surrounding settlement. There is one large saw mill that supplies furniture within the municipality. The trade and business function of agricultural product are not properly managed to the famer for obtaining reliable price of products and involved the agriculture broker agent in local market for collecting agriculture product and supplied to destination market.

7.1.5 Land Tenure

Land tenure is described as the legal rights of land that secure for its use. In Nepal, formal and informal land tenure mechanism is occurred to use the right of land. The right of land was collected from interaction of local respondent and cross-check with land record data at Land Record and Revenue Office, Rajbiraj (Table 7.4).

Table 7.4: Types of Land Tenure in Shambhunath Municipality

S.N.	Land Tenure	Area (in ha)	Percentage
1	Raikar (Private Land)	6111.22	56.27
2	Government Land	4622.32	42.56
3	Public Land	89.23	0.82
4	Community Land	20.39	0.19
5	Informal Land	9.57	0.09
6	Guthi Land	7.66	0.07
	Total	10860.39	100.00

Source: Field Survey, 2019

Raikar (private land) is the dominated land with 56 percent extent of the municipality having 6111 ha. Government land is the second dominated land use having 43 percent with 4622 ha followed by public land with one percent (89 ha). Likewise, the community land covers 20 ha, informal land occupied by landless people with 9.57 ha and guthi land with 7.66 ha. Raikar land is required for developing physical infrastructure and reshape of land parcels on the basis of projected population and meeting the socio-economic needs. The right of these developable lands is established either acquired by government or land readjustment process through land pooling. These developable land acquired by government has involved more compensation of high cost and tedious process. So, land pooling approach is suited for land development by raising awareness of local people about land development and land use planning. Government involves in land pooling and provides incentives for infrastructure development, and maintenance cost in the land developing areas.

7.1.6 Road Network

The existing road network with major river and stream within the municipality is shown in Figure 7.3.

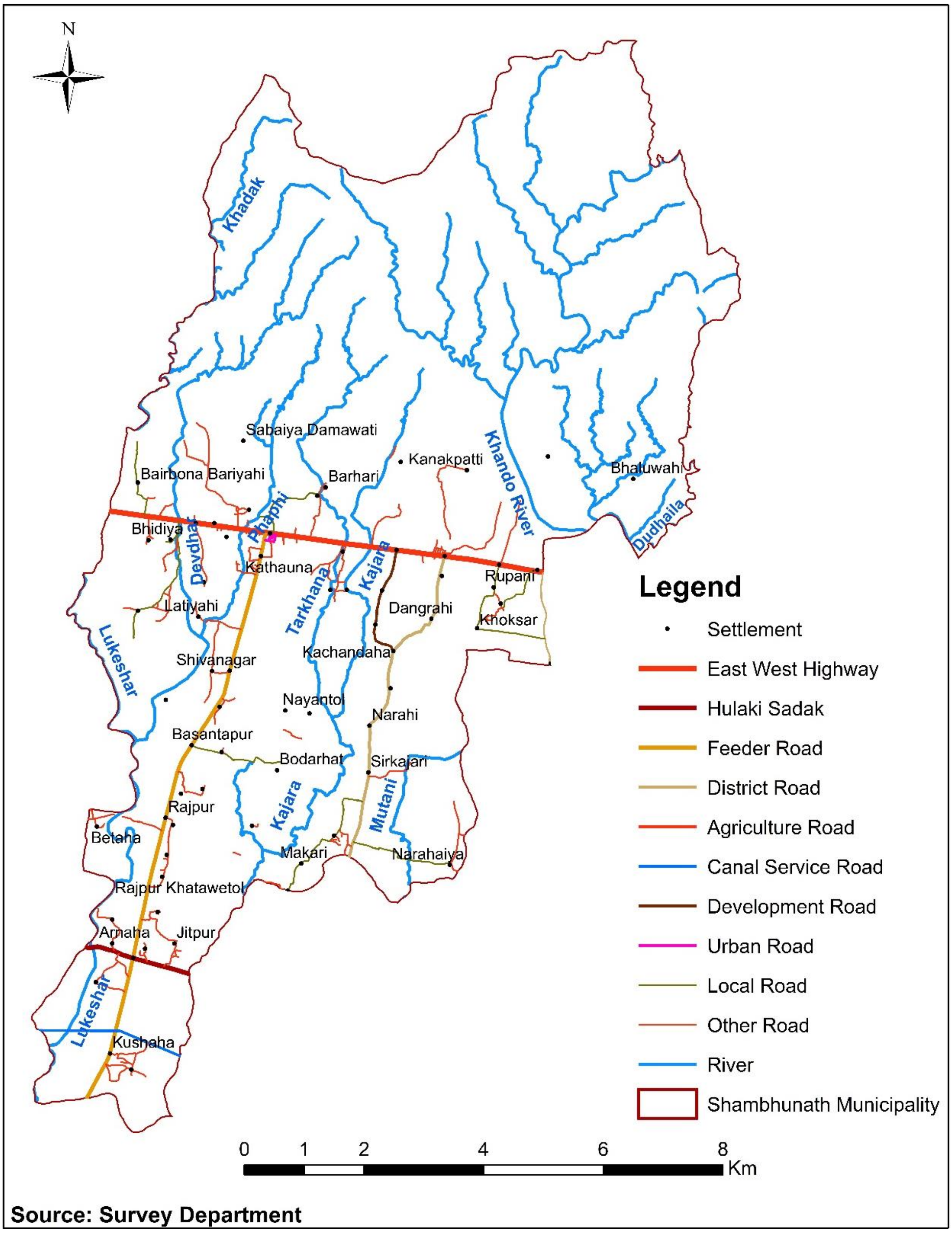


Figure 7.3: Existing Road Network of Shambhunath Municipality

The connectivity network of road in Shambhunath Municipality is poor condition with limited road density, i.e. 1 km per sq. km. However, this municipality has comparatively higher road density than average road density 0.3441 km per sq. km. in Nepal (FNCCI, 2022) and 0.5895 km per sq. km. in Madhesh Province (Nepal in Data, 2018). Although this municipality's effective population density per 1,000 people is 2.7 km, some portion of East West highway and Kathauna-Pato feeder road has also in poor condition, reflecting the inadequate maintenance of pavement and road drainage. Many rural settlements are connected with strategic road network. The distribution of types of material for road construction is shown in Table 7.5.

Table 7.5: Types of Material for Road Construction

S.N.	Description	Length (km)
1	Earthen Road	43.273
2	Graveled Road	25.343
3	Asphalt Black Top Road	24.595
4	RCC Road	15.395
	Grand Total	**108.607**

Source: Field Survey, 2019

Major large settlements and municipality headquarter are linked with asphaltic black top road or gravel and earthen roads. Some portion of feeder roads, district roads, and Hulaki Sadak are constructed with asphalt, while remaining portion is built with gravel and pebbles rather than asphalt. However, the main rivers and streams along feeder road, district road, and Hulaki Sadak lack the bridges and culverts. Agriculture and development roads are exclusively constructed with gravel. Similar to this, concrete is mostly used to build local and urban roads. Some portion of other roads are constructed with gravel and concrete, while the remaining portion is built with earthen. Vehicles are not used in these local roads or other roads in the rainy season. There are no bridges or culverts at the major river and stream crossings on the road network except for the strategic road. Aside from the East West highway, the road width are not kept at their standard width. Therefore, in order to facilitate simple access to public transportation inside the municipality, densification of the current road network is necessary.

7.1.7 Electricity

Electricity is supplied through transmission line within the municipality. The existing electricity transmission line network within the municipality is shown in Figure 7.4.

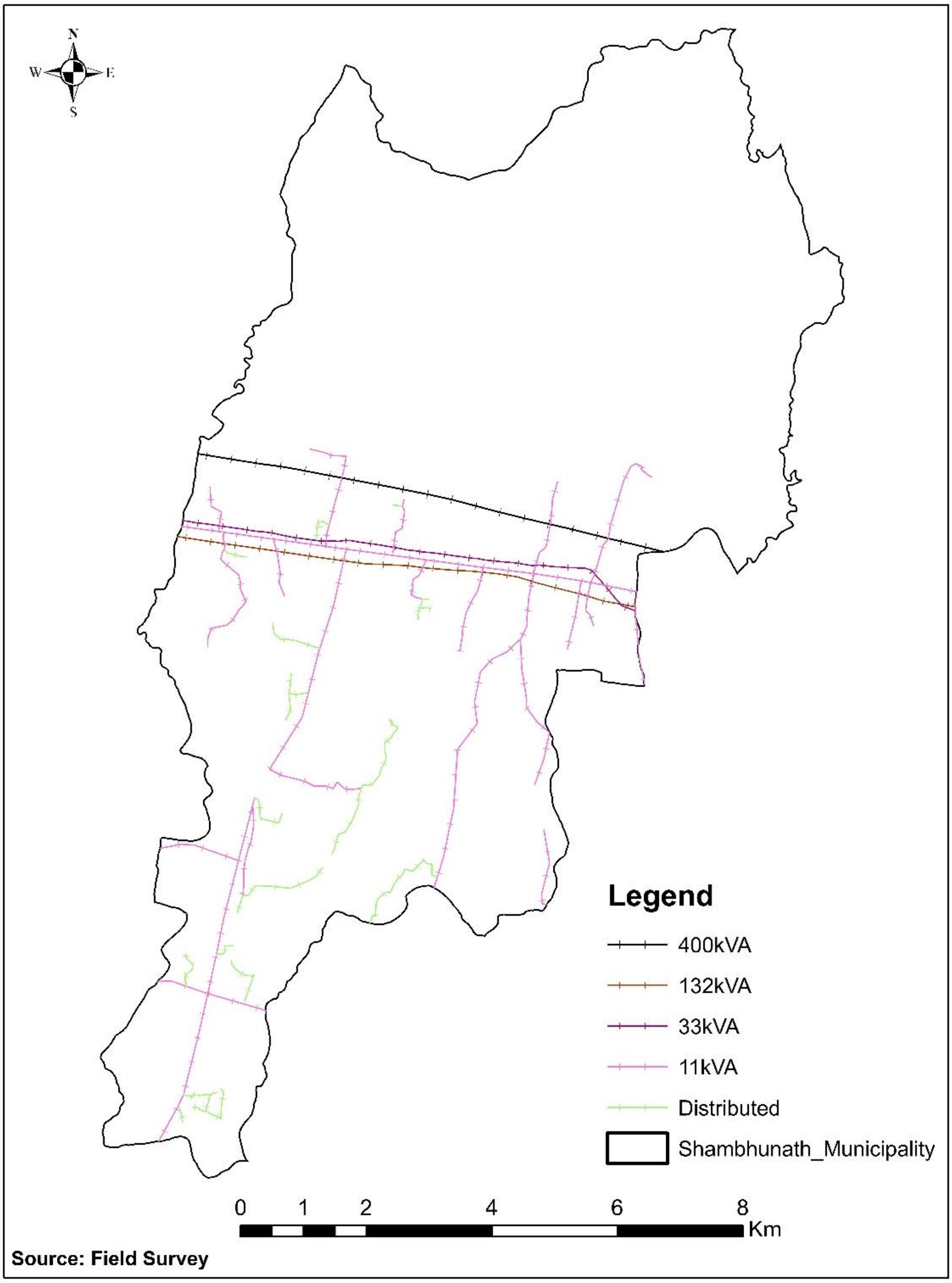


Figure 7.4: Nature and Coverage of Electricity Network

The northern and middle part of major settlement area are linked by national grid of electricity from Rupani substation. The southern settlement are connected with national grid of electricity from Rajbiraj substation. The distribution of electricity transmission line is shown in Table 7.6.

Table 7.6: Nature of Electricity Transmission Line

S.N.	Description	Length (Km)
1	400kVA	8.827
2	132kVA	7.543
3	33kVA	8.195
4	11kVA	49.418
5	Distributed or Local	15.366
	Grand Total	**89.349**

Source: Field Survey, 2019

Most of the households have electricity facility but less than one percent slum people are not accessed of electricity facility. These slum people use kerosene oil for lightening. Currently, no power is produced from renewable resources, except for limited use of solar panels and bio-gas. Some households have used solar and bio-gas for lightening, alternative to the electricity (load shedding and disturbance of grid electricity). The poor people use kerosene for lightening alternative to the electricity. Most of the electric transmission lines are transmitted by electric pole along the road network. Local distributed power line and 11 kVA share the same transmission path. The majority of transmission and distribution routes employ concrete and metal poles, although some local routes were established with wooden or bamboo poles.

7.1.8 Telecommunications

The landline telecommunications network is established at Kathauna bazar (headquarter of the municipality) only while the mobile telecommunication network (Namaste and Ncell) covers the entire municipality. The majority of individuals utilize mobile devices. Only 10 percent of households currently utilize landlines. Internet accessibility is established along the East West highway, though not yet available at the entire municipality. Some ward offices are connected to the internet via Nepal Telecom's asymmetric digital subscriber line (ADSL) service. The current speed and reliability of landlines and the Internet is satisfactory for most business and personal uses. The fiber-optic lines are also available along the East West highway. However, the local government intends to go forward with information communication technology (ICT) based enterprises as one of its main economic drivers, so fiber-optic lines need to be installed along the Kathauna-Pato feeder road and the Traffic Chock-Pathergadha district road. The mobile network is also sufficient for current use. However, the modern commercial people attract to 4G facilities for communication. It is also important to promote new technology as business necessities and as part of everyone in the community's modern way of life. The majority of telecommunications lines are situated along the road network on electric poles.

7.1.9 Water Supply

Underground water is the major source of water supply to meet current demands for drinking water and other purposes in this area. Majority of the people use underground water through tube wells in private as well as public for drinking purpose. Total 90 percent houses have installed tube wells, except very poor people. Pipeline water supply mechanism is installed at Kathauna Bazar having 3.25 km pipeline network. It collects the ground water through deep boring in the capacity of 200 m^3 tanks, filters it, and then supplies it twice daily through an ancient pipeline system that is ten years old. There are provision for testing the quality of water on monthly basis (if demand by different agency it is done even twice a month). The little amount of iron is detected in the record but below the danger level for human health. In the municipality, one third tube wells are problem of arsenic concentration that danger for human health. The settlements except Kathauna Bazar are the problem for safe drinking water in the municipality.

7.1.10 Wastewater and Sewerage

The surface drainage line occurs as 7.75 km for wastewater management and sewage. Most houses, business building, offices and public buildings use individual septic tanks for managing wastewater. Wastewater management is limited to collection of wastewater originating from different sources through open and underground sewer lines and disposal of untreated wastewater in the rivers and other surface water bodies in the municipality. Wastewater is produced from the domestic routes includes greywater and black water produced in washing, cleaning, bathing and sanitary uses. Only small numbers of houses at Kathauna Bazar are connected to sanitary wastewater system and remaining settlement of most houses dispose the wastewater directly into the rivers and other water bodies. Therefore, the direct disposal of solid and liquid wastes along rivers and other surface water bodies has a major negative impact on the water quality in agricultural lands. The rainwater runoff of the settlement areas are directly disposed into agriculture land and rivers. There is no well manage drainage system in the municipality. In addition to wastewater and sewage from domestic and industrial sources, the rivers are also fed by storm water directly through the roads and streets drains. Additionally, different types of solid waste are dumped in varying quantities directly into the urban streets which are then directly into rivers after every rainstorm. These wastes contribute significantly to wastewater and are a cause of river pollution.

7.1.11 Health Services

The public health initiatives serve to maintain people's health in an effective manner by preventing and controlling risk factors, diseases, and injuries across the board. These initiatives are coordinated by the local community. According to the federal structure of Nepal, the federal government is responsible for developing and directing the public health system through guaranteeing the availability of access and equity to high quality healthcare. The federal government also funded well equipped specialty hospitals and healthcare facilities around the nation. It is the duty of the province government to promote healthy lifestyles, healthy communities, and the prevention of communicable diseases and environmental health threats. Additionally, the provincial government contributed funds for the development of specialized hospitals and healthcare facilities around the province. Local government is responsible to manage emergency medical services and preventing disease and risk factors. Local government provides antenatal and postnatal clinics, child health clinic with immunization, family planning, dressings and nutrition counseling. The availability of primary healthcare facilities at the local level and health posts at the ward level enables the provision of these services. In Nepal, the available of health institution and skill health professional has limited as 0.17 physicians with 0.51 nurses and midwives per 1000 population in the country (Rana, 2018). In Shambhunath Municipality, health facilities is very poor. There are five sub-health posts and one private primary health facility, and no specialty health institutions. There are only 7 small medical pharmacies mainly located at Kathauna Bazaar and Arnaha. There is urgent need of at least 25 bed hospital to provide medical, surgical and obstetric care services with augmented by the provision of basic laboratory investigations; pharmacy services; routine diagnostic imaging; basic physiotherapy; nutrition/dietetics services; outpatient clinics; accident and emergency services; ambulance services; surgical operations and biomedical maintenance. For easy access to health facilities, upgrading an existing medical facility to a health center with medical pharmacies may be the best solution.

7.1.12 Education

Education plays an important role in shaping, sharpening and directing an individual, the society and the nation towards achieving the desired goals. By our constitution, education facilities are fundamental right of all citizens. Education promotes knowledge and skills of people in good quality in terms of technical, professional and employment. Federal government is responsible for planning and supervising the educational system through ensuring equity and assuring access to high-quality education. The federal government frames effective policy frameworks, manages central universities, and accredits various educational degrees around the country. Provincial government is responsible for managing universities, implementing operational policies, establishing guidelines for the development of curricula, implementing evaluation procedures, managing human resources, and providing physical facilities. Local government is responsible for operating and managing secondary education (class IX-XII), access to basic education (class I-VIII) and access to early childhood education for aged 4 to 5 years. Education facilities within the municipality are at satisfactory condition. However, there are no technical education and vocational training center and campus for graduate level as bachelor and master degree in the municipality. There are available of 20 primary schools (15 community and 5 Private), 7 secondary schools (4 community and 3 Private), and 8 madrasahs for Muslim people. Most underprivileged children attend community schools, however most community schools lack adequate physical facilities and science labs, especially in the secondary level.

7.1.13 Sports and Recreational Facilities

Sports and recreational facilities are poor in the Shambhunath Municipality. In the north, there are not enough significant sports and entertainment facilities. Those activities are rather performed in the forest and numerous mango orchards. Similar to this, there are not any sporting or recreational facilities in the commercial areas or communities along the East West highway. Many schools provide playground for children to engage in sport activities. However, some schools lack playgrounds for sports. Among 33 schools, only 19 schools have their own playgrounds. All community schools, two private schools and one Madarsha have their own playgrounds. One major open space of large extent (one ha) is available near Ram Janaki temple along feeder road at Basantapur. Besides, there is no any stadium, park, picnic spot and other recreational facilities within the municipality.

7.1.14 Security Services

In Shambhunath Municipality, security service is weak. People have to depend on security services, such as those provided by the district traffic police station at Dangrahi Bazar (Traffic Chock), area police station located at Rupani and police station at Kathauna Bazar. There are no other security services (Nepalese army, armed police force, local police office) accessible in the municipality. There needs a major police station serving as the city police at Kathauna Bazar and smaller stations serving as police posts are needed at Arnaha and Sakhuwa. Rural settlements in the municipality, the majority of the houses are constructed with wood, have thatched roofs that are closely spaced apart. As a result, there is a high risk that a fire incident will take place in these settlements. However, the municipality lacks own fire station and fire brigade, and depends on the fire station in Rajbiraj and Lahan. Therefore, a fire station and fire brigade is absolutely necessary for the municipality.

7.1.15 Public Buildings

The Shambhunath Municipality's administrative office is situated at Kathauna, the former office building of the Mohanpur VDC. This building is out-of-date and inadequately sized to meet the needs of the municipal executive committee and other local government services. Currently, the facilities for two wards' administrative units are found in the same building as the previous VDC. Within the municipality and at the ward level, the various functional organizational buildings (Reiyukai building, integrated urban development office, bazar management office, etc.) are existent but insufficient. The two forestry unit offices are located at Rupani and Sabaiya Damawati. The management of the other facilities (agriculture, livestock, health post, birthing center) is inadequate due to the building's antiquity and limited size. In order to provide housing for the elderly, orphans, and other victimized citizens, the municipality needs to construct additional public institutions and government offices.

7.2 Developing Guided Physical Infrastructure

Physical infrastructure development is a process that establishes the conditions for ecosystems to function properly, and produce physical and social capital that people and communities may use to meet their needs. It is the spatial plan of a territorial system that is connected to social and economic activity. Designing a physical infrastructure plan is challenging task for the planners to incorporate several states and multiple functions as well as the effects of developing infrastructure. Also, designed physical infrastructure plan is analyze to look from several socio-economic, historical, and geographic perspectives. Therefore, physical infrastructure development plan is prepared in close consultation with the local communities to meet the public demand for a specific LU that arises from need assessment, constraints imposed by bio-physical environment, and the society including individuals, groups, communities and government It is primarily driven by changes in the population, technological intervention, livelihood strategies, perception, political economy and institutions and biophysical environment. It is produced separately for each settlement area with the consideration of current infrastructure situation, demographic trends, environmental circumstances, and social issues. In addition, the document emphasized the lack of local infrastructure facilities, the requirement for development activities relevant to each settlement area, the settlements' ability for future development, and it listed the opportunities and restrictions. Infrastructures are the physical manifestations of development and redevelopment agendas and actions in the public and private sectors. Future economic development and social progress that directly influences primary economy are dependent on physical infrastructure. In this research, the guided physical infrastructure is constructed in accordance with planning norms and standards, as well as development targets that result from need assessment. It is developed with a 20 years long term vision aiming to achieve a stable and diversified economy with sustained growth; enhanced human development and improved quality of life; environmental sustainability and strategies for mitigation of disasters; efficient, responsive and accountable system of governance; and sustainable land development.

7.2.1 Planning Guidelines

The planning guidelines are described as the norms and standards to be followed in developing physical infrastructure plan. Generally, norms represent the socially or institutionally set values that shape and govern the behavior pattern including physical and social relations in each space (DUDBC, 2013). The standard represents the level and quality of infrastructure services that make the built environment functional and desirable. The planning guideline is required for coherent with appropriate norms and standards to provide an appropriate level of services and meet the long term demand of developing infrastructure. It is used in the preparation of physical infrastructure plan in order to meet social needs in areas that can be developed (both urban and rural environments), increase economic efficiency, and enhance quality of life. In this research, physical infrastructure guidelines are developed based on planning norm and guideline, 2013 and modified in the local context through interaction with local stakeholder and decision maker (in Appendix-29). It serves as the basis for creating a physical infrastructure plan that can accommodate the demand of the projected population (56862) in year 2037 A.D.

7.2.2 Physical Infrastructure Plan

The physical infrastructure plan is designed in accordance with planning norms and standards, as well as development targets that result from need assessment. The present settlement and infrastructure in the municipality have neither planned nor follows the parameter of sustainable development. Similarly, some squatter and slum settlements situated in vulnerable and unsafe public places are devoid of the fundamental infrastructure and services. Also, land value increase the cost component for infrastructure development. The cost component includes the location, closeness, and accessibility, development costs, productivity, shape, and size of the plots, among other factors, that affect residential property values in a free market. Population projections are used to determine the demand for land for residential and commercial development as well as for infrastructure expansions based on economic activity. The demands for housing is also influenced by migration, increasing urbanization rate, changes in income status, the stage of economic growth, and variations in land productivity. To support the fundamental physical infrastructure for economic, environmental, historic, and social values, developable land is necessary.

Generally, land pooling is one tools for land readjustment (LR) for land development and redevelopment through a structure where landowners pool their property and develop land in appropriate size and shape with the availability of basic service infrastructure. In this research, land pooling approach is applied for developing physical infrastructure plan in the new developable land in the municipality based on planning guideline. The road infrastructures are designed by connecting with each and every land plot having accommodated utility service facilities along and across the designed roads. The laying of utilities services are carried out considering the ease maintenance and operation that affect the traffic flow and conflict with other services to the minimum. Location of such services and facilities are proposed in such way that minor or no adjustments has required with road networks taken up later. Generally, these service facilities are arranged in order of sewer line, storm water drain, water supply lines, electricity cables and poles, telecommunication cables, cross conduct ducts and others. The major road networks are planned through least cost path tool to consider the less excavation work for base and sub-base only and reducing the cost for road construction and maintenance. The land development activities are designed on the basis of land pooling at the ward level. The ward wise developed physical infrastructure plan (in Appendix-30) and prepared physical development plan at municipality level is shown in Figure 7.5.

The road network is designed for construction of adequate public infrastructure as service standard, efficient and convenient access of road transportation. Also, it is required for providing an essential role in marketing agricultural production and acts as the vital role for giving access to health, education, business activities, and agricultural extension services in respect of the distributions of agricultural inputs. So, there is proposed 145.25 km for the planned road consisting 5.25 km as agriculture road, 30.88 km as local road and 109.12 km as other road. A total of 11 major bridges are proposed to strengthen the transportation route. One bus park is proposed within the municipality to manage the public vehicle (Table 7.7).

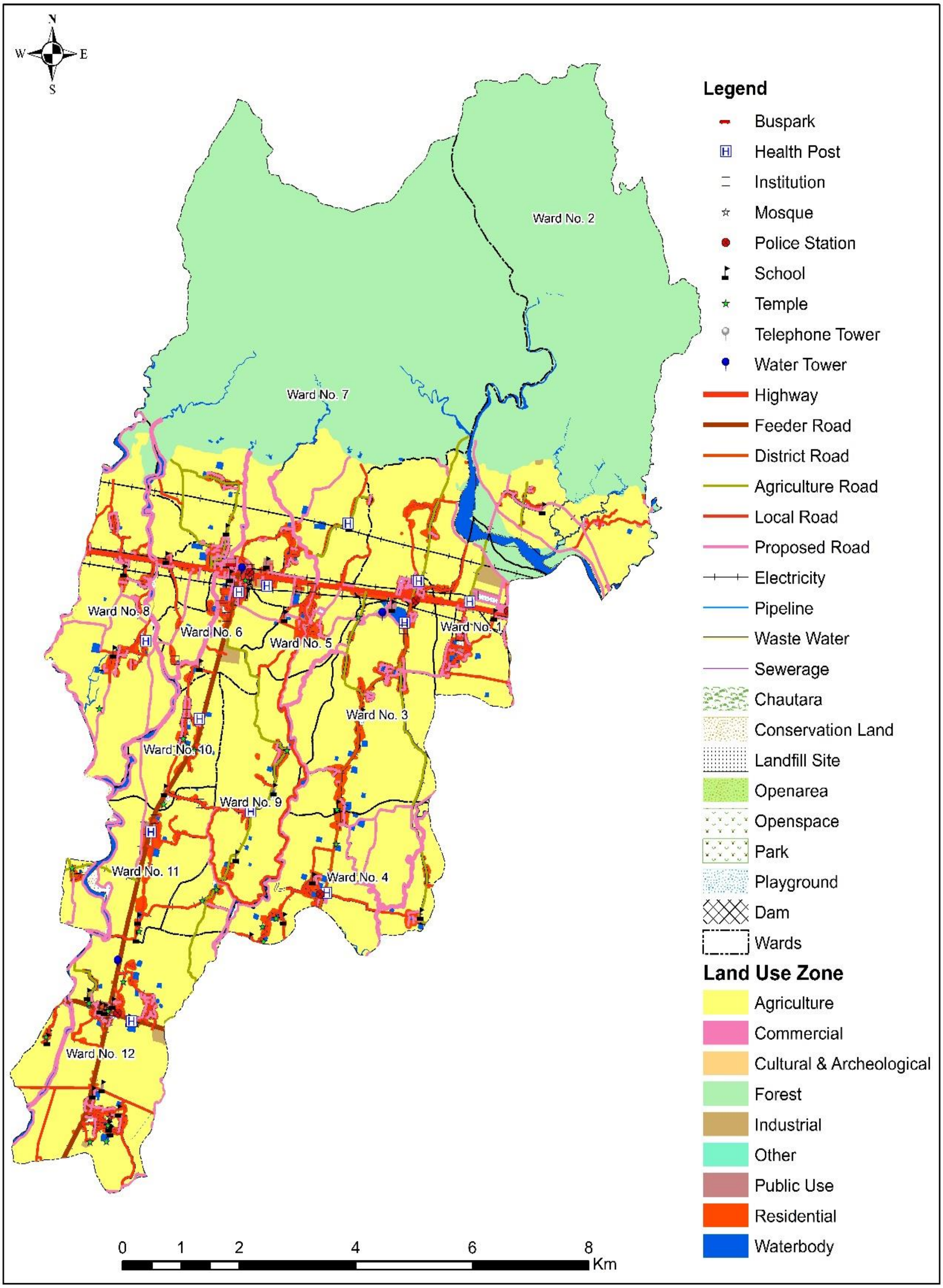


Figure 7.5: Physical Development Plan of Shambhunath Municipality

Table 7.7: Status of Planned Developing Infrastructure Status

S.N.	Description	Unit	Existing	Proposed	Total
1	Transportation				
	Highway	Km	9.18	-	9.18
	Feeder Road	Km	10.02	-	10.02
	District Road	Km	9.67	-	9.67
	Agriculture Road	Km	20.58	5.25	25.83
	Local Road	Km	18.48	30.88	49.36
	Other Road	Km	65.46	109.12	174.58
	Bridge	No.	7	11	18
	Bus Park	No., ha	-	1, 2	1, 2
2	Water supply	km	3.25	35.81	39.06
3	Sewerage & Sanitation Work				
	Surface Drainage and Sewerage	km	7.55	175.35	182.90
	Sanitation	km	-	18.40	18.40
	Landfill Site	No., ha		2, 10	2, 10
4	Electricity	Km	88.17	32.04	120.21
5	Telecommunication (network and exchange)	Km, No.	1.5 & 0	17.5&1	19.0 &1
6	Educational Institution				
	Primary	No.	26	18	44
	Secondary	No.	7	8	15
	Campus	No.	-	1	1
	Polytechnic	No.	-	1	1
	Library	No.	-	3	3
7	Health Institution				
	Health Post	No.	3	5	8
	Primary Health Centre	No.	-	1	1
	Hospital	No.	-	1	1
8	Social Services				
	Old age home	No.	-	1	1
	Orphanage	No.	-	1	1
	Institution Building	No.	5	9	14
9	Economic Infrastructure				
	Multipurpose Hall	No.	-	1	1
	Commercial Centre	No.	-	3	3
	Vegetable Market	No.	1	2	3
10	Security Services				
	Police Station	No.	-	1	1
	Police Post	No.	3	2	5
	Fire Station	No.	-	1	1
11	Recreation Activities				
	Playground	No., ha	2, 1.3	13, 13.2	15, 14.5
	Parks and Picnic Sports	No., ha	2, 11.1	8, 116.5	10, 127.6
	Open space	No., ha	21, 4.1	24, 6.7	45, 10.8

Similarly, the infrastructure for water services is also properly managed to improve the living standards and ensure efficient service delivery. Water service networks comprise the supply of drinking water, the control of surface runoff from rainfall and other human activities, the reinforcement of waste water networks, and sanitation operations. Also, the sewerage system is planned based on the situation of the terrain with reference to the planning guideline. Around Kathauna Settlement, the pipeline from the water tower tank is expanded. Two water tower tanks proposed at Tulapatti (Arnaha) and Dangrahi (Traffic Chock). A 35.81 km pipeline supply for drinking water is planned three water tower tanks. Similarly, 18.40 km of sanitation work at Kathauna and Traffic Chock is proposed for waste water management. For handling water from rainfall, a total surface water drainage system of 175.35 km is proposed for managing surface storm watern management.

Education service is required to provide the quality of education and easily accessibility of higher and technical education. The educational institutes, mainly schools, are sufficient within the municipality having 33 no. of schools, but 8 community and 7 private schools required for upgrading up to secondary school for increasing public service. But there is lack of polytechnic institution, campus and library. Additionally, one polytechnic institute and one library are proposed in the municipality to develop high skilled and technical human resource. Similarly, one campus is also proposed for meeting the higher education at local level. In addition, health service provides affordable, accountable, qualitative and accessible universal health-care facilities for every citizen. So, one community hospital having 15 beds occupancy and 8 health posts having birthing center are also proposed to increase heath infrastructure facilities and services.

The demand of electricity facilitieteis is increasing for lighting, cooking and other purposes to ensure access to affordable, reliable, sustainable and modern energy. Therefore, a total 32.5 km electric distributed network transmission line is proposed to strengthen the electricity availability. Also, telecommunication facilities are inceasing for addressing converged regime of telecommunications, broadcasting and ICT in a well-defined and consistent enactment and regulatory framework. The mobile telecommunication and limited cable network telecommunication are sufficient and proposed one telecommunication exchange for strengthening the board band telecommunication through optical fiber and availability of internet facilities.

Likewise, one multipurpose hall is proposed at Kathauna Bazar to provide a well-equipped space suitable for a wide range of activities such as exhibitions, functions, musical performances, sports and speeches. In addition, the total 3 commercial centers are proposed in distributed location at Rupani Bazar, Traffic Chock and Arnaha for increasing the commercial activities and provides services inclusive of shopping, restaurants, entertainment, and general retail services. Two vegetable markets are also proposed in order to support farmer economic growth by enabling them to sell produce and other goods directly from their fields and to buy fresh produce from local people in order to meet their personal needs.

Additionally, one old age and one orphan building are planned to enhance the social basic infrastructure within the municipality. One fire station and additional two police stations are proposed to increase the security service area. One orphanage, one old age home and 14 institutional buildings are proposed for enhancing social services within the municipality. One stadium and 13 playgrounds are planned for increasing the recreational service facilities. One community park is proposed for increasing the recreational service facilities at near surrounding with 7 ha public ponds and

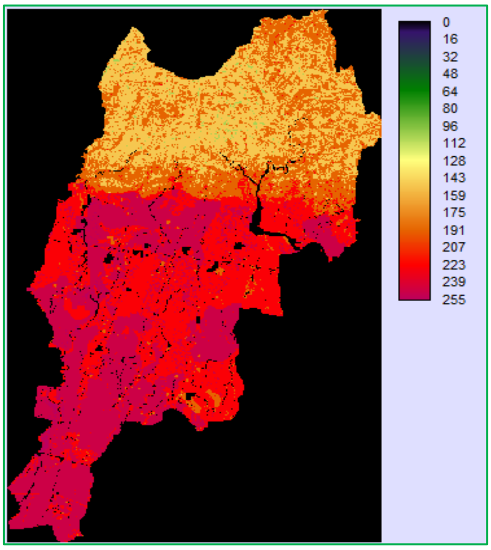
Shambhunath Temple for preserving heritage and cultural site. Additionally, 24 open space/open area are proposed for mitigation occurrence of any risk. The two landfill sites are proposed (one large 8 ha and another small 2 ha) for constructing treatment plant to manage sanitation and sewerage waste products. There is required 6 km major dam and 98 km protection embankment as retaining wall. The land obtained from construction of dam is used for plantation along the small river course having small patches (9 ha). Similarly, the land obtained from construction of dam along Khando River about 72 ha is used for forest plantation to conserve biodiversity and managing practices of the environment.

7.3 Land Use Planning

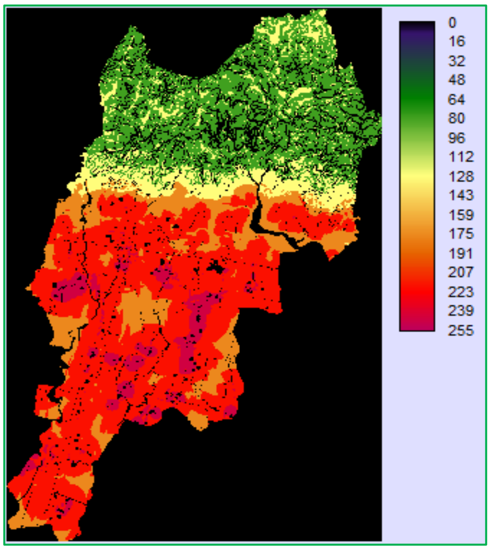
Scenario based land use planning model with CA technique is used in decision making process. Initially, the scenario model of land use 2017 is developed from land use data 1996 as base layer with suitability maps of different land use, and validated with existing land use 2017. After validation has found satisfactory level, then the simulated land use map for planning year 2037 is simulated/projected from the land use data 2017 as base layer with suitability maps of different land use. The integrated land use plan is generated using a projected land use map for 2037 and includes risk layers, various sectorial plans, and physical infrastructure development plan. An optimal land use plan is then generated through stakeholder interaction and SWOT analysis from the modification of the integrated land use plan.

7.3.1 Standardization of Factors

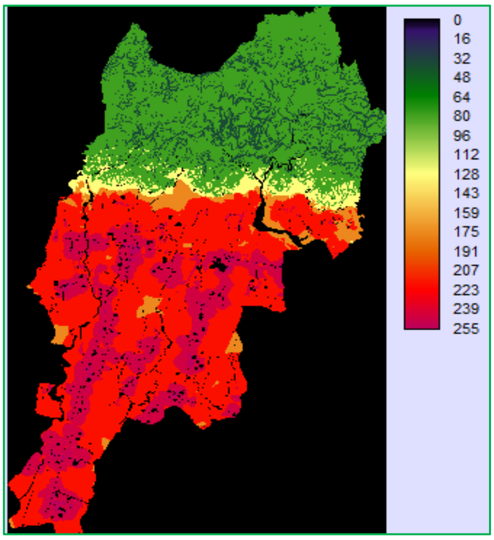
The standardized suitability map of agriculture, residential, commercial, industrial, and forest is shown in Figure 7.6.



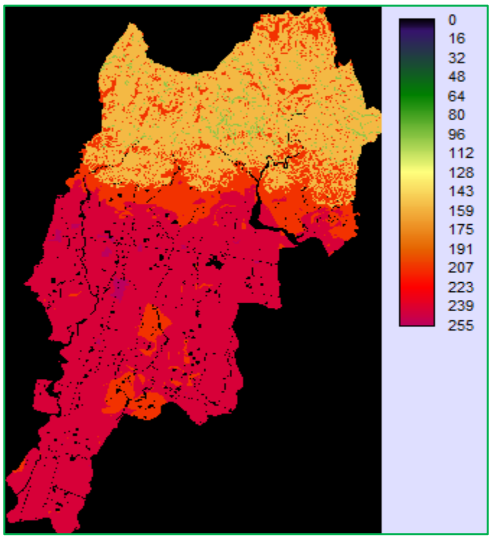
a) Agriculture



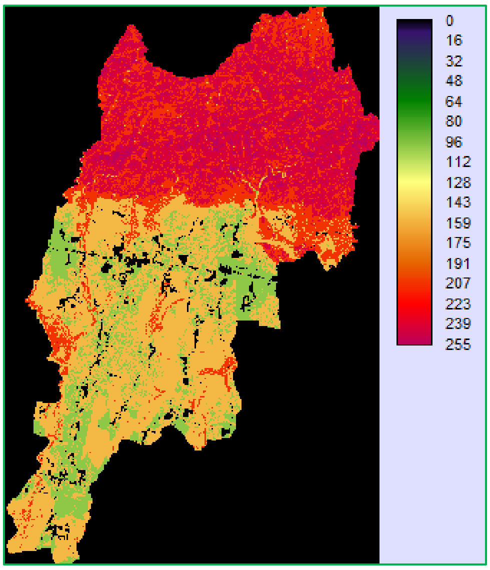
b) Residential



c) Commercial



d) Industrial



e) Forest

Figure 7.6: Standard Suitable Maps: a) Agriculture, b) Residential, c) Commercial, d) Industrial and e) Forest

7.3.2 Simulation of Land Use

The simulation of land use map 2017 is prepared and validated with land use map 2017 as reference map. The accuracy of simulated results found well level with the overall Kappa index value 0.89. In the Kappa variation, K_{no}, $K_{location}$ and $K_{quantity}$ has obtained with 0.86, 0.89 and 0.81 respectively. Consequently, it is determined that the simulation model is at a satisfactory level. Then, the simulated land use map for 2037 is prepared and presented in Figure 7.7.

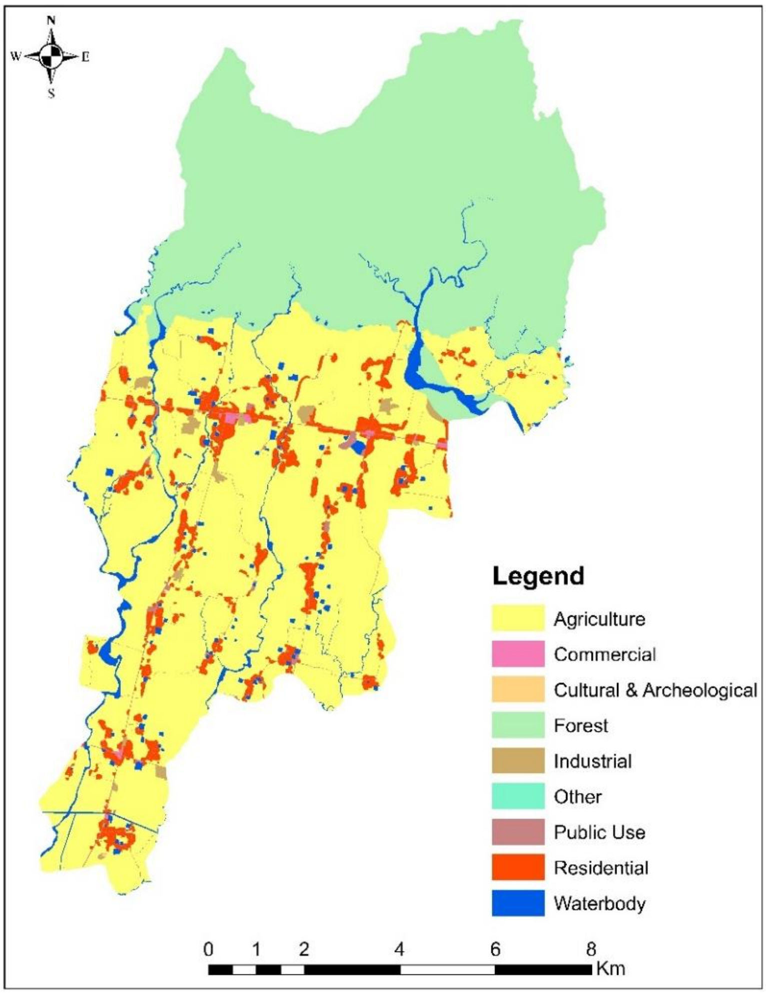


Figure 7.7: Simulated Land Use for 2037

Simulated land use map for 2037 critically evaluated on the basis of suitability maps that depends on the infrastructure guideline policy for developing infrastructure. Changes in infrastructural facilities affect the index suitability maps and the simulated results. As a result, there exist linkages and correlations between the physical infrastructure plan and simulated outcomes. Therefore, the physical infrastructure plan was adjusted based on the suitability maps for each land use class and the simulated land use map for 2037. There are only 1 percent variation at a satisfactory level in the simulation result after three time of iteration process, the simulated land use map for 2037 is then finalized.

7.3.3 Integrated Land Use Plan

The simulation land use map for 2037 is compared to the land suitability index map of land use classes in order to examine the simulation's adequate findings. Then, an integrated land use plan is generated with the integration of simulation land use map for 2037, risk layers, various sectorial plans, and physical infrastructure plan based on spatial planning and presented in Figure 7.8.

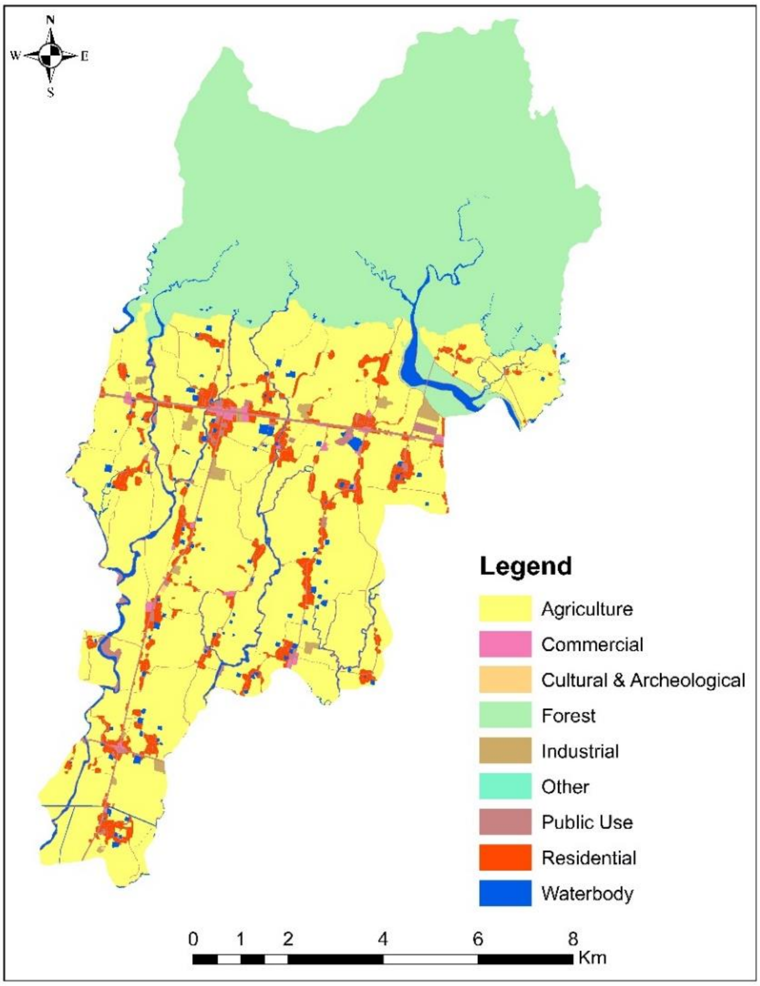


Figure 7.8: Integrated Land Use Plan

7.3.4 SWOT Analysis

In this study, SWOT analysis is carried out for improvement of integrated land use plan to generate optimal land use plan, and analyze the feasibility status of developed land use plan and its implementation at the local level. SWOT analysis determines the strength, weakness, opportunity and threats of land use plan. In SWOT analysis process, the land use plan is assessed subjectively in terms of its technical viability, human resource capacity to handle the data, and financially feasible. The result of SWOT analysis supports the plan's acceptability among local citizens, stakeholders, and the government. The summarized result of SWOT analysis is presented in Table 7.8.

Table 7.8: Summary of SWOT Analysis

Strength	Weakness
• Integrated geospatial technique for expert rationalism in knowledge-based participatory land use planning. • Identification of real expression of land use problems and solved by the local people themselves based on spatial information of planning data. • Allocation of specific land use based on the suitability level of land use classes. • Developing infrastructure plan based on simulated land use change and future population needs and integration of these plan in land use planning process. • Incorporating risk layer as constraints for development and construction for safe settlement, business area, and public institutions. • Support to develop local land use plan and harmonious with regional, provincial and national frameworks of development activities. • Meet the legal provision and people needs at local level as well as quite practical, technically acceptable and feasible for implementation of land use plan.	• Holistic approach inclusion of both qualitative and quantitative method applied in nature vulnerable criticism for achieving sustainable natural resources management, but it is superficial, not in-depth analysis and sophisticated GIS modelling. • Limited sampled information collected from PRA technique for building database system and incorporation of these information in planning process that portraying a partial view of the ground reality. • People perceptions and technical expert knowledge used for building and validating the developed approach in certain degree of subjectivity evaluation that indeed affect the end results. • Required high technical knowledge and skilled in GIS processing for carry out entire model process. • Developed approach criticized as more extractive and very little involvement of local people in need assessment, development of physical infrastructure and land use allocation process.

Opportunity	Threat
• Right time to implement land use plan to control the conflict of land use, land fragmentation, and construction of developing physical infrastructure. • Manage land development through construction of land development code for preserving agriculture land for food security, conserving biodiversity, and eco-friendly environment in sustainable manner. • Allocate the optimum use of land in a hygienic, beautiful, well facilitated and safe location for enhancing well planned urbanization and developing infrastructures. • Control the function of land market by reducing the illegal involvement of third party in land transaction process. • Consideration of the medium to long term planning perspective towards sustainable development.	• Raised questions in land use planning approach for the cost effectiveness and technical feasibility in the particular (socio-economic and political) context. • Preparation and modification of land use plan require a very high level of expertise that may not be always available at local level. • Local politician and land brokers create pressure for allocating the land along road and its surrounding up to 300m as residential and commercial use. • Local poor and landless people lose the control of their land rights on shelter location on public and government land in a high risk area. • Need for effective contribution and legitimization of the local knowledge in formulation, and decision making in preparing and modification of land use plan.

The detail description of SWOT analysis result is described below.

Strength

From a scientific point of view, the land use plan is prepared in holistic approach of spatial planning to allocate developing physical infrastructure and specific land use based on interaction with local people and stakeholders. The integrated geospatial technique comprises bottom-up land use planning with expert rationalism and local knowledge for knowledge-based participatory land use planning. The use of probability rules for local knowledge representation proved to be useful and relevant for linking qualitative and quantitative data. The facility offered by the spatial database in GIS (storage, updating, easy retrieval and analysis of the information) reduces the drawbacks of the method, such as high level of generalization that takes place from village to municipal level. The socio-economic and spatial data are linked to minimize land use conflicts in decision making process for generating spatial plan. So, the approach reinforce the credibility of integration of local knowledge as an operational tool in land use planning and sustainable natural resources management. From a participatory land use planning perspective, it is clear that the real expression of land use problems is identified and solved by the local people themselves based on spatial information of planning data. For instance, more detailed analysis is involved in land use planning with local spatial information that helps for minimize the quality of land degradation at the municipal scale.

In knowledge-based participatory land use planning, the expert opinion is collected through interaction with the local people for identification of the variables. These variables are based on local indicators, the probability matrices, and the information cross-checked from the first participatory diagnosis. The major causes of land quality degradation identify through the construction of probability matrices which may be utilized to improve the strategy design. The designed approach also consider the trend of land use change and its transformation rate as a factor that used in suitability analysis of land use maps. These suitability maps are used to create physical infrastructure plan and simulation of future land use, both of which are necessary for producing a land use plan. Land use plan integrates infrastructure development plan and simulation of future land use on allocating the proper land use class. Also, land use plan includes the risk layers as constraints to construct infrastructure safely and control the environmental stability as the risk sensitive zone.

Finally, this approach provides necessary assistance for developing local land use plans. This approach also integrates the land use plan with regional and local development initiatives to ensure that it is successfully implemented at the rural/municipal, provincial, and national levels. The approach and methods used in the preparation of land use plan meet the provision of Land Use Policy, 2015, and Land Use Act, 2019 as well as fulfill the local people needs at local level. Since every technique and material employed is quite practical and technically acceptable, this approach for preparing land use plan is reasonably realistic.

Weakness

In this study, a holistic approach is used in the analysis, which can be criticized from both sides because it uses both qualitative and quantitative methods. For instance, practitioners of the holistic approach have found that the application of soft qualitative method (RRA and PRA) makes it superficial, not in-depth analysis and sophisticated modeling in order to achieve sustainable natural resource management. A certain amount of subjectivity analysis is used to validate the holistic approach, which is generated based on qualitative data (local people's perspectives and expert knowledge) and influences the end results. In general, the validation issue is presented scientifically by integrating expert knowledge and locals' perceptions in the land use planning process. For such validation issue of bias are minimized during the participatory surveys through cross-check of the data/information collected from different sources but the process is labor-intensive, tedious and time consuming. In the particular context of infrastructure development and land use planning process, the information obtained from the local level committees/body was cross-checked (when necessary) with the villages' elders who had good historical knowledge of the natural resources. The use of quantitative data (probability matrices) for representing quality information (local people's perception) negatively interpreted from a social science perspective, although quantitative instruments like scoring techniques is used in PRA methods. Despite the use of PRA, the planning territorial unit is a limiting factor in the participatory planning process that prevents the comprehensive expression and accurate depiction of specific land use issues as experienced by the less powerful groups (mostly women and indigenous people). Also, incomplete information is used in the planning process that represents the partial representation of the reality of local land use issues.

The developed methods of land use planning require highly technical knowledge and skilled in GIS processing to carry out land suitability analysis of land use class, proper allocation of land use and risk analysis. Therefore, for many reasons (technical, organizational, infrastructure, etc.), an operational use of GIS is not feasible at the local level. In this case, integrated top-down and bottom-up planning in a GIS environment is criticized as mostly extractive, less involvement of local participation in need assessment, physical infrastructure development and allocation of proper land use class. Therefore, it is necessary to empower the local population in order to raise understanding about land use planning and prevent them from having a significant impact on the formulation of land use policies.

The existing residential land use class in risk area is not settled properly in safe place and not prepared integrated settlement plan for mitigation of risk prone area. The land obtained after the construction of embankment along water body is very difficult to use in community forest, manage properly for park facilities, and conserving environment through plantation of tree, shrub and busses. The scattered tree along the pond and lake surrounding is not managed properly. So, there are lacking of recreational value as picnic spot. The land use plan does not properly preserved the public and government land such as ROW of roads and transmission line those previously acquired. The existing brick chimney area are proposed industrial area that creates the environmental pollution effect the public health of the nearer settlement. But, these brick factory may not be used as industrial area in future. The industrial activities are not constructed immediately in proposed industrial zone for employment that necessary for local people, employee of brick factory, and less production of brick for trade and business.

Opportunity

After analyzing different resources and haphazard development of infrastructure, it is felt that preparing land use plan and its implementation is the right time for local government to control the land use conflict. Haphazard land development can be managed by constructing buildings by laws for sustainable land development and preserve agriculture land for food security as well as conserve the biodiversity for eco-friendly environment. Therefore, the prepared land use plan is quite significant for designing the medium and long-term planning period. The use of participatory knowledge and expert opinion are incorporated in GIS based analysis to support the integrated land use planning and its development in future. The approach of developing a GIS based planning method has been proved as an efficient to integrate spatial information and local knowledge in the planning process. The integration of qualitative information through PRA and FGD in GIS based planning tool helps to improve the decision support model for biophysical and socio-economic data collection, and analysis. In this study, the holistic approach is adopted to link between the federal, provincial and local government. It is believed that this approach process will certainly contribute further decentralization and empowerment of the local communities. Using a GIS-based planning method is expected to promote accountability. It is hoped that the planned GIS-based planning process will take into account the institutional and technological impediments that need to be removed from current GIS development.

Land use planning is carried out for optimum use of land for maximum benefit and managing land resources in sustainable way. Land use information system (LUIS) is technically developed and equipped to make optimum use of lands for a hygienic, beautiful, well facilitated and safe human settlement. It also supports the growth of physical infrastructures and a planned, sustainable urbanization. It is made easier to preserve arable land for enhancing agricultural productivity to meet local food demand and attain food security. Additionally, this plan promotes the preservation, development, and management of forests, greenbelts, recreation areas, open spaces, water, watersheds, or wetlands. It controls the reduction of climate change's consequences, the prevention of natural disasters, the preservation of biological diversity, and environmental protection. It also works to regulate the real estate market by minimizing unauthorized third party involvement in land transaction process.

Threat

The discussion above does not minimize the existence of significant threat to the applicability of this approach used in this study. For instance, this approach utilized in the land use planning raises the important questions pertaining to the context of cost effectiveness and technological feasibility in the specific (socio-economic and political) manner. The result of this approach can be rationally seen in the long-term perspective when the local people’s tangible and non-tangible benefits are considered in land use planning process. More importantly, the methods and techniques used for preparing and modification of land use plan involve a very high level of expertise (i.e. theoretical, conceptual, modeling and programming skills) that may not be necessarily always available at local level. To overcome this difficulty it is necessary to build a user friendly interface to allow the best possible use by the local GIS analysts. Another threat is the local poor and land less people would lose the control of their information as well as land rights on shelter location on public and government land in a high risk area. The possibility that PRA information being controlled by the elite group's relatively small community in society, those influences planning for physical infrastructure development and land use plan. This possibility grows when integrating PRA information is integrated with GIS databases because the information will be really handled by GIS specialists. So, participatory GIS should only serve as a technocratic instrument because there is a large risk of seizing information by elite group in close to GIS specialist at local level. This technocratic instrument may be a step backward in favor of a top-down approach according to the expert opinion. Therefore, it requires better mechanism and tool for protection the local information. The mechanism and tools includes: legal, political, or administrative frameworks, additional visualization tools like interactive three-dimensional maps. The participatory GIS will successfully support the legitimization of local knowledge in planning process and empower the local citizen to influence on policy development and decision making process.

Local politicians and land brokers creates pressure to allocate the land along road and its surrounding up to 300 m as residential and commercial land. It may create the unfair land market holding for unproductive activities as agriculture land as barren and increases land value highly, and unaffordable to the poor and low income people. The shelter for land less people and scattered slum people is mostly constructed in risk zone either along river bank in the flood prone area or government land in forest area. But, these lands are essential to use for conserving biodiversity and land quality degradation form soil erosion. The federal, provincial and local government provide residential land in safe risk area to the poor, land less, squatter and disorganized settlers' people providing residential land in safe risk area and support for biodiversity conservation.

7.3.5 Optimal Land Use Plan

Optimal land use plan has been prepared from the modification of land use plan in subjective analysis by preserving the strength and opportunity, incorporating the weakness and minimizing the threats felt in SWOT analysis. Subjective analysis has been carried out for addressing the threat raised by local politician and land broker mainly for expansion of residential and commercial land use along road within 300 m surroundings. Also, residential area occurred in the risk prone land need to be addressed and allocated in safe zone through resettlement plan. Population growth rate, land capabilities, physical infrastructure, cadastral data with land records, and current land use information are also taken into consideration in a subjective analysis when allocating residential and commercial area. Similar process is also used in the resettlement plan to move existing residential areas from dangerous locations to safe zones. Likewise, public use land identified from the cadastral information and acquired by government is integrated in land use plan. The environmental degradation from the existing industrial area is modified by considering the suitability maps and allocated as agriculture land in optimal land use plan. Similarly, the forest land surrounding the embankment area along the Khando River is allocated for park area and recreational area (picnic spot) with forest, lake and pond area. The prepared optimal use plan is prepared and presented in Figure 7.9.

In the optimal land use plan for 2037, the agriculture land use dominates with 5034 ha (46 % of the municipality extent) but reduce the existing agriculture land that was reported in 2017. The decreased agriculture land use accounts 575 ha and transformed into built-up area as residential 201 ha, commercial 26 ha, industrial 3 ha and public use 345 ha. In the optimal land use plan, these built-up area in safe location with sufficient physical social, and service infrastructure. The forest land is the second dominated land use which occupy 40 percent area of the municipality (4352 ha). The forest land reduces 51 ha in this optimal land use plan for public use as picnic spot and construction dam for slope stability and control soil erosion. Residential area is covered with 4.16 percent of the municipal extent and increased with 201 ha that is proposed to meet the demand of residential land for growing population, migrated people and resettlement in risk safe area.

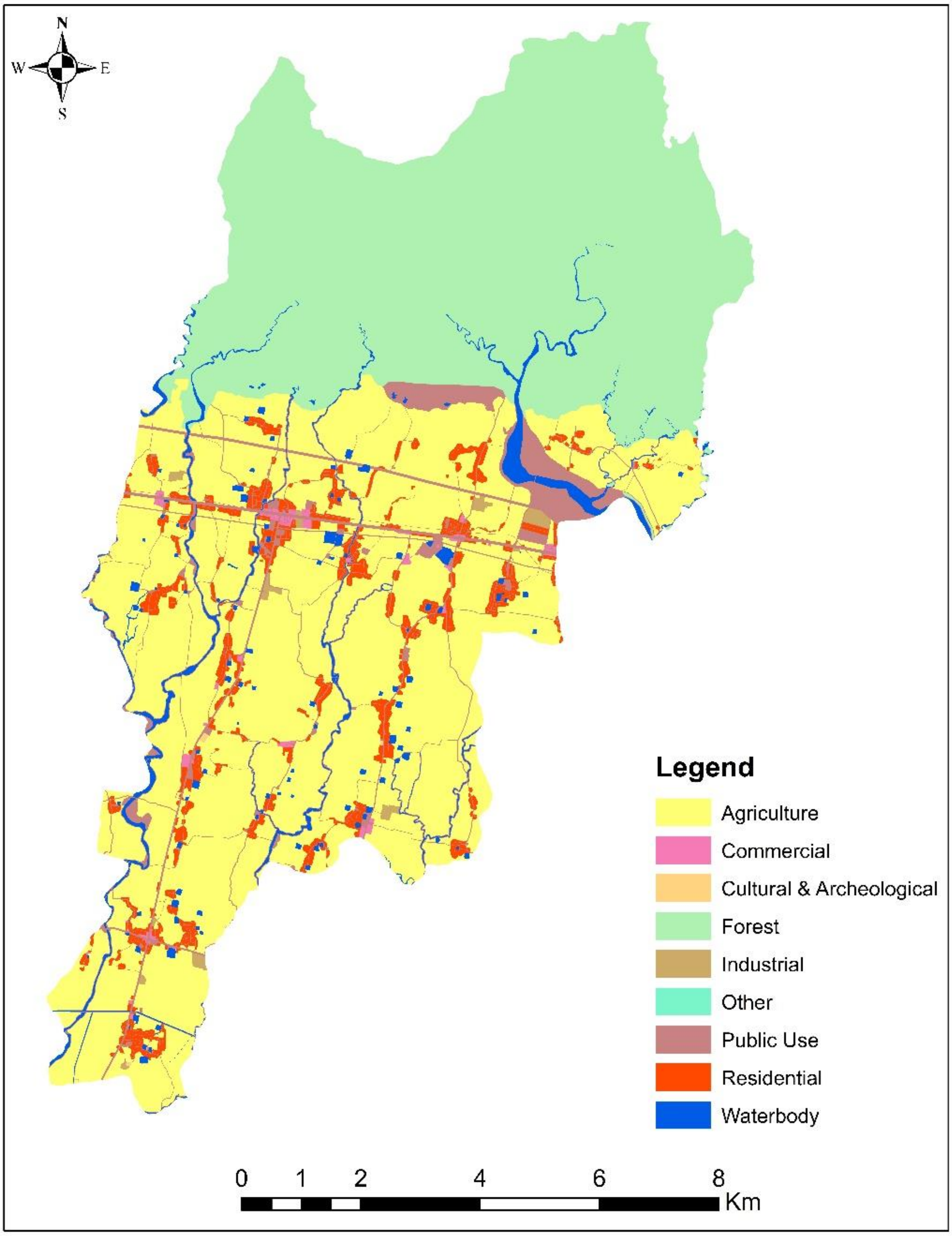


Figure 7.9: Optimal Land Use Plan

The water body land is covered with 3 percent of the municipal area and reduced 28 ha land for public use as dam area, river corridor road and park area for conservation of biodiversity and environmental degradation by preserving wetland and water body feature and its source by plantation of tree in the park area.The allocated land use classes as agriculture, residential, commercial, and industrial in land use plan has found similar pattern in the study of GIS model for land use and development master plan (Tims, 2009) and quantification has varied in nature. The assumption of Hoyts sector theory of urban land use explains that the core business area are developed at the centre part of urban area where as retail business area (commercial zone) and manufacture industries developed outer boundary of the major business area along the developed transportation route, and residential area increased surrounding to central business zone and developed commercial zone and industrial area. The developed optimal land plan in the Shambhunath Municipality flows similar pattern of land use as the assumption of Hoyts sector theory. This land use plan can also be used as a periodic plan to construct the developing basic infrastructure and other land development activities in sustainable manner.

Chapter -8

LAND USE PLAN IMPLEMENTATION STRATEGY

This section describes the implementation strategy of land use plan. It is developed based on the existing legal situation and international practice of land use implementation. It is designed so as to make it feasible at local level to implement the developed optimal land use in reality laid with parcel based cadastral information (PBCI) system, construction code for infrastructure development, construction permit guideline and monitoring mechanism that supports for sustainable land development and management.

8.1 Developing PBCI System

The PBCI system is developed as land information system that contained the correct and accurate land use zone (land use categories of optimal land use plan), cadastral parcel (land tenure security), and related other land information for systematic land use management and urban-rural economic development. In Shambhunath Municipality, total 40 cadastral map sheets cover in the entire municipality area except the forest area. So, all these cadastral maps were registered in actual ground situation through map to map linear transformation with reference to ortho-rectified satellite image in 2017. The registered cadastral maps were adjusted in seamless based on the ward level. Then, the ward level seamless cadastral data were integrated in the seamless cadastral dataset of municipality level with spatial merging operation. The municipality level seamless cadastral dataset were overlaid on the optimal land use plan and interlinked with the parcel of land use class. The each parcel were allocated to proper land use zone through spatial analysis and structure query language having maximum portion of specific land use occurred in that parcel. The cadastral dataset overlaid on land use plan is shown in Figure 8.1.

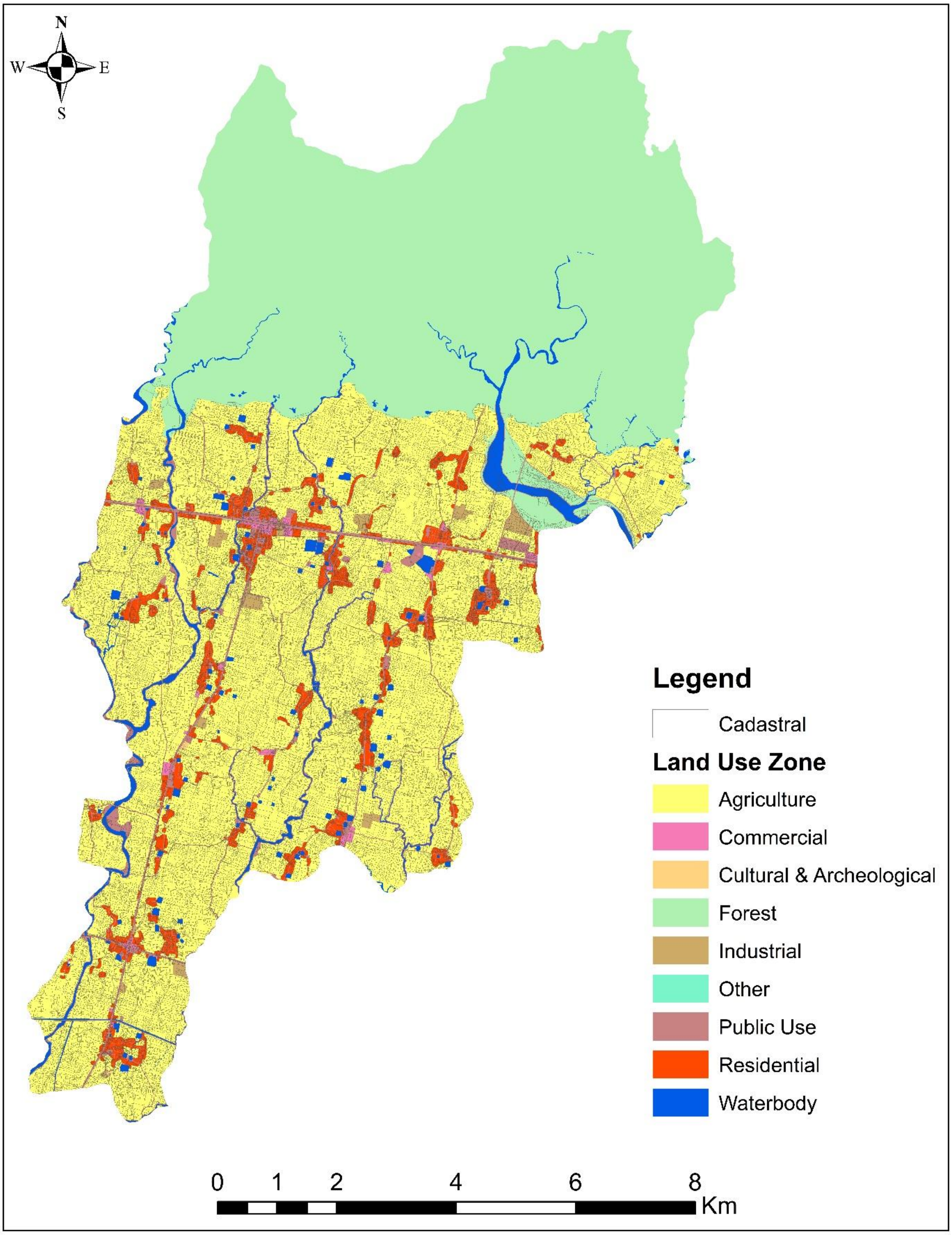


Figure 8.1: Cadastral Dataset Overlaid on Optimal Land Use Plan

The agriculture is the dominant land use zone that covers 33868 (71%) land parcels out of the total 47785 land parcels in the municipality. The coverage of the residential land covers second dominated land use zone with 6294 (13%) land parcels. Similarly, the public use land covers with 4783(10%) land parcels. The coverage of the water body accounts with 1912 (4%) land parcels. The coverage of the commercial land covers 561 (1%) land parcels. The coverage of the industrial land covers 256 (0.54%) land parcels. Total 64 (0.13%) land parcels falls under the forest zone in legal cadastral information except non surveyed forest area. Likewise, the coverage of the cultural and archeological land covers 47 (0.10%) land parcels, which is as well significant. The distribution of land parcel on land use zone is shown in Figure 8.2.

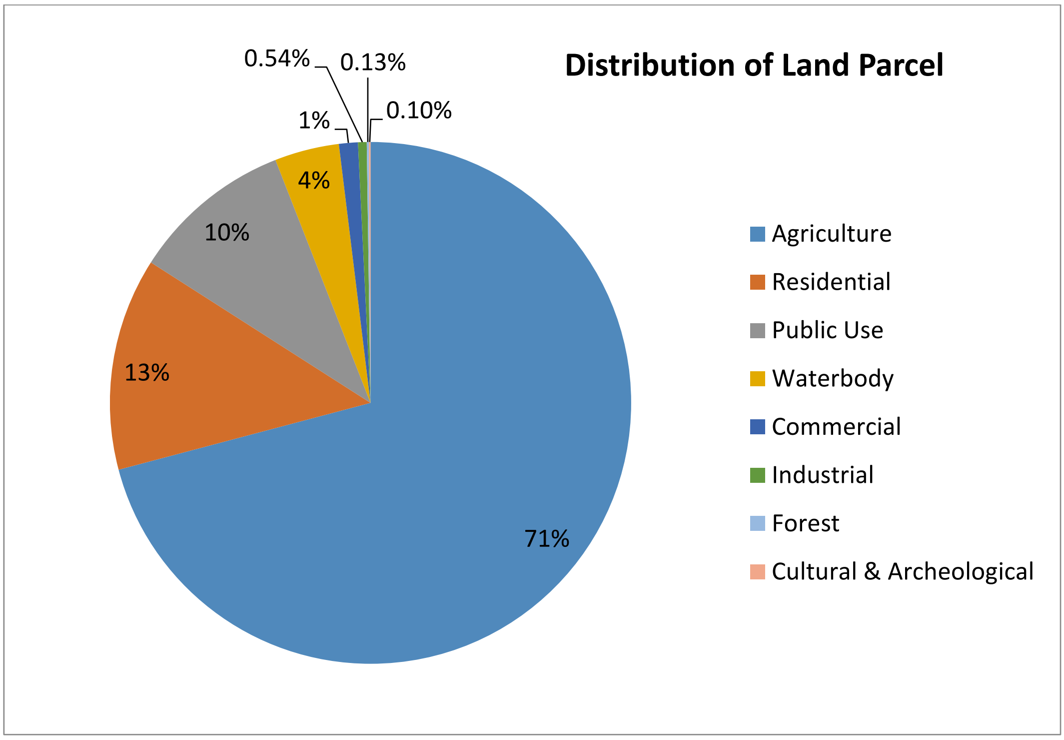


Figure 8.2: Distribution of Land Parcel

The parcel based cadastral data with land use zone needs to be generated from PBCI system and notice to public notice as zoning ordinance by land use implementation committee under local level land use council. Also, land tenure record interlinked with the reference of parcel based land use zone data. Tenants who disagreed with the land use zone in the related parcel might appeal to District Court, and the land use zone decision by the Court should be the final land use zone for these land parcels.

8.2 Development Code

The building bye-law (development code) serves as a control mechanism for the appropriate implementation of land use plan. Generally, the development code needs to be designed on the basis of planning guideline, norms and standard for developing physical infrastructure. The development code should also include the norms of conservation and preservation of environmental and natural resources (forest, shrub, wet lands, hazard prone areas, rivers and rivulets). It should facilitate the sustainable use of land for construction of buildings and open spaces through effective planning and planning controls in cost-effectively way with their best possible advantage. It enables the growth of businesses activities and citizen in an environmentally sustainable manner and make significant economic savings in the municipality. The development code is created with reference to national and international development code as well as laws, polices and directives, and modified in the local context. The proposed development code for land fragmentation is presented in Table 8.1.

Table 8.1: Land Fragmentation Development Code

Land Use Zone	Minimum Plot Size	Minimum Plot Width	Minimum Road Accessibility
Agriculture	600 sq. m.	20 m	Not essential. If required 10 m
Residential	150 sq. m.	9 m	6 m
Commercial	300 sq. m.	12 m	8 m
Industrial	500 sq. m.	15 m	10 m
Public/ Institutional Building	500 sq. m.	15 m	8 m

Land plots should be designed to take full advantage of the topography and landscape, including contours and land form, as much as feasible. Land plot layout must take into account and minimize change to existing drainage patterns, and seek to preserve existing patterns of water flow. Land plots must have a frontage onto access roads and this must be wide enough to allow vehicle access. Land plot lines should as far as possible be perpendicular to streets to maximize available space. Corner edge land plots generally need to be larger than standard plots. The development code for construction of building is presented in the Table 8.2.

Table 8.2: Building Development Code

Land Use Zone	Plot Coverage	Building Setback	Building Height
Agriculture	100 %	Not required	Not required
Residential	60 %	1.5 m	3 storeys (on slopes 2 storeys and a basement will be permitted)
Commercial	75 %	2 m	5 storeys (on slopes 3 storeys and a basement will be permitted)
Industrial	50 %	2 m	3 storeys (on slopes 2 storeys and a basement will be permitted)
Public/ Institutional Building	50 %	2 m	3 storeys (on slopes 2 storeys and a basement will be permitted)

The layout of residential access roads should be such as to discourage through traffic from using them. The length of residential access roads should be kept to a minimum. Cul-de-sacs (dead end) roads should serve no more than 50 m or 10 dwellings. Turning radius should be a minimum of 8 m in residential and 10 m in commercial, industrial and public institution area. Access must be designed to ensure adequate visibility and include provision for vehicle turning spaces on the plot. The 20 sq. m. of public open space should be provided per dwelling on developments over 20 dwellings plots. For multi-family developments, 10 sq. m. per apartment unit and 30 sq. m. per semi-detached, town house unit should be provided. The color code for land use zone should be developed as: yellow for agriculture, purple for residential, gray for commercial, violet for industrial, light red for public use, green for forest area, blue for water body, and dark red for cultural and archeological zone. Based on the color code, poster of land use zone should be generated and placed at major location of public places for notification and aware land use knowledge to people. Likewise, the boundary of land use zone should be demarcated on the ground for actual land use zone implementation. The agriculture land should be protected to ensure food security using traditional cultivation methods (shifting and rotating farming). Natural vegetation (trees, shrubs, grasses) should be carefully planned in the design of sites for an excellent environment for vegetation to grow in forest and open space area. The correct choice of species and its location should be provided greater benefit to meet the demand of vegetation product, providing fruit and surplus wood product. Maintaining vegetation cover should critical for soil and water management for the cooling effects on environment, conserving water reservoirs, providing fruit, sufficient organic material for soil conservation, and preserving soil erosion and slope stability along water body. Storm water drainage plan should be prepared for each development, showing routes of pipes and drainage system, sizes of drainage facilities, and the location of points of discharge.

8.3 Construction Permit

The construction permit should be provided on the basic of land use zoning ordinance only. Construction of any structure on the land should be developed with prior grant permission from the local authority that it controls the land use zone implementation. The aim of the construction permit should meet the need for local development, environmental conservation, livelihoods improvement, food security and other needs. The infrastructure improvements areas should be prioritized for construction with existing and expected concentrated forms of development and consistent with land use zone. The three tire government should actively promote development of the private sector via domestic and inward investment in new businesses, which will facilitate the planned restructuring of the public service and an increase in the proportion of jobs provided by the private sector. Also, the local business endeavors should promote continuously collaboration with local people and stakeholder for general economic development by increasing commercial and industrial activities within the municipality. Provisions of physical development activities should be permitted after the environmental impact assessment if found in safe zone from concerned risk within the area. In a legally binding land use plan or zoning ordinance, local authorities should also allocate the designated areas with their location, community development and warranted by particular environmental values or hazards. The construction permit process should be adopted based on the procedure described in Figure 8.3.

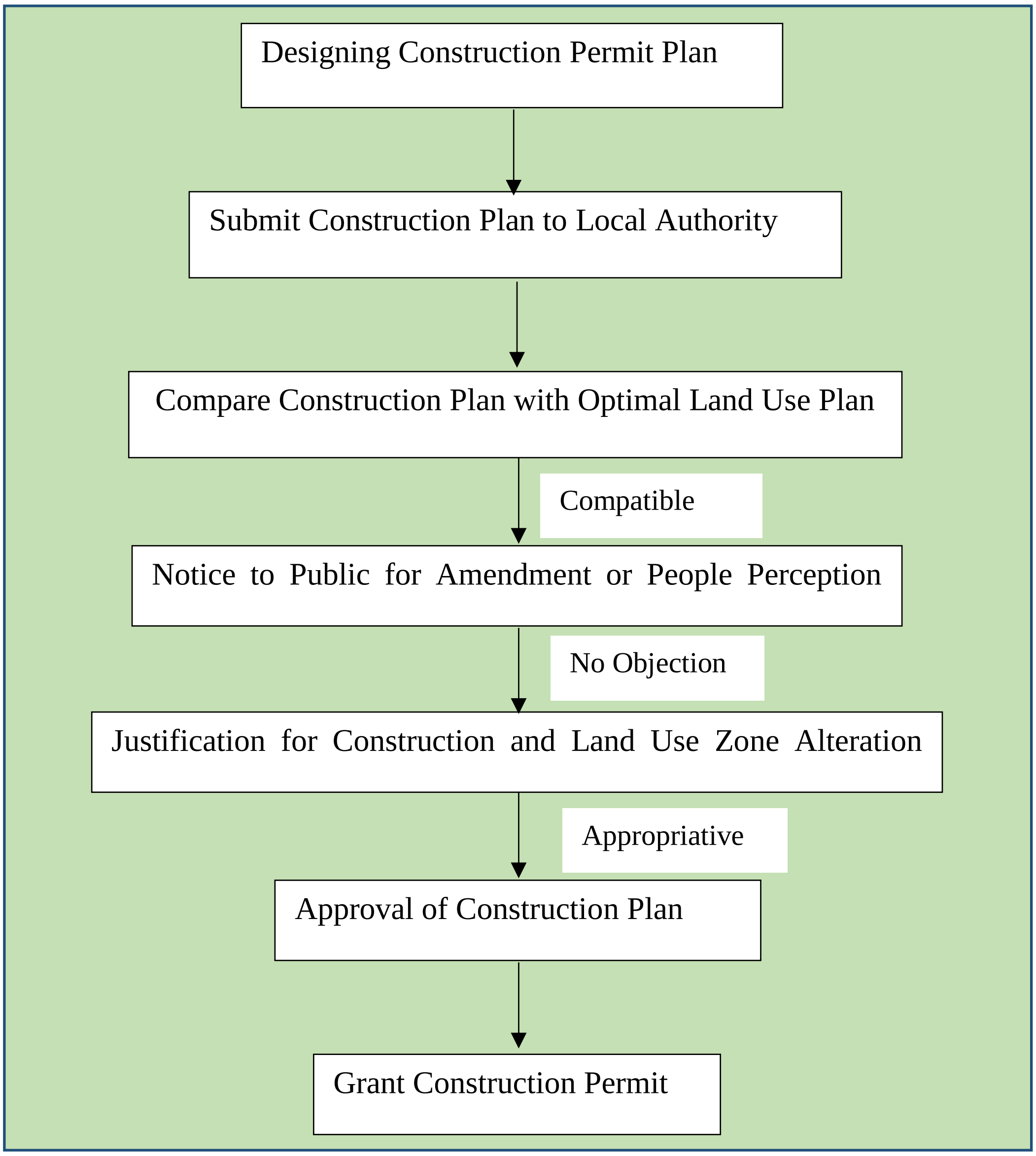


Figure 8.3: Process of Construction Permit

Without approval from the three tires of land use councils, land use zone of land should not be altered. The individual people who want to change the land use that s/he owns should apply application for land use change to the local level land use council. Local level land use implementation committee under local level land use council should analyze the appropriateness of the land use changed or not. If found the proposal for change is appropriate then local level land use implementation committee forwarded to the provincial land use council through local land use council. Provincial land use council should analyze detailed of physical, soil, risk and environmental suitability and if found appropriate to change then need forward to federal land use council. Finally, federal land use council would be approval of land use change then local land use council should provide the permission of grant to change the land use of that land. After permission of change of land use, local land use council should changes the use of proper land and provide construction permit based on land use change.

8.4 Monitoring Mechanism

Formal land use implementation and monitoring institution should be formulated through legislated mandate with clear description of authority and responsibility. Formal institution should be periodically conducted monitoring for the implementation of land use zone compliance with Land Use Policy, 2015; Land Use Act, 2019 and related laws across municipality area or entire program area. The monitoring process should be conducted with the assessment and analysis including empowering statute contains a framework for enforcement of compliance of land use zone and penalties for noncompliance; land substitute for land acquisition, compensation, relocation, rehabilitation and restitution on the basis of land use zone; establishment of rates for land taxation, land transfer fees and stamp duties fair and equitable for good governance in land administration compliance with land use zone; systematic adjudication with location and underlying cause of claims for land use rights in land registration claims for land tenure security; land use allocation maps and records reviewed and accurately updated timely; grants and leases of lands for the government institution in compliance with legal regulations and procedure of land use implementation; communication and cooperation between relevant organizations for construction of infrastructure; environmental and social safeguards considered in impact assessment and protect against illegal land confiscation; and land related laws (National Land Use Policy, 2015, Land Policy, 2019, Land Use Act, 2019 and Land Use Regulation, 2022) harmonized with land use zone. The relevant structure for monitoring mechanism is shown in Figure 8.4.

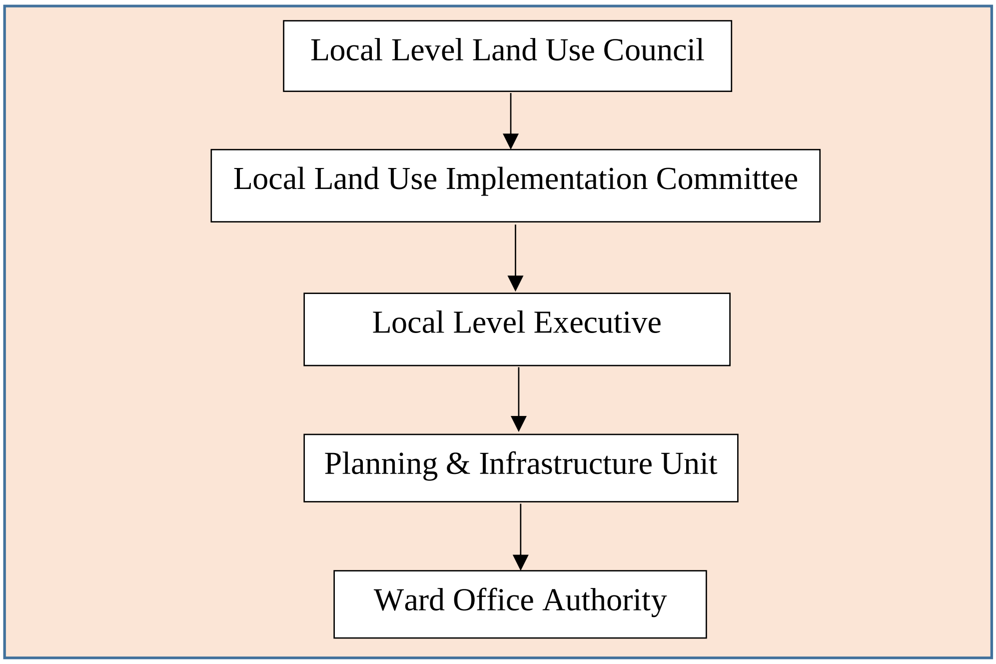


Figure 8.4: Monitoring Mechanism of Local Authority

Local land use council should issue and ensure government compliance with reporting procedures related to land use management, land allocation and quality control of land use implementation process. The monitoring and evaluation report should be prepared based on the accurate and firm evidence from the government administrative organizations, expert organizations, farmers, civil society and other stakeholders. The findings from monitoring and evaluation, assessments, and recommendations should be annually reported to provincial and federal level land use council. Provincial land use council should be reported annually to province parliament, relevant ministries and departments, and public. Federal land use council should be reported annually to federal parliament, relevant ministries and departments.

Chapter – 9

SUMMARY, CONCLUSION AND RECOMMENDATION

The chapter discusses summary, conclusion and recommendation of the research work.

9.1 Summary

Land use planning issue arises to preserve the conversion of arable agriculture land through unplanned urbanization, haphazard infrastructure development for food security. Expansion of urban area due to increased population growth and urban-bound migration has put high pressure in the limited land resources available within urban area. Nepal has mountain eco-environment which is highly sensitive to land use change associated with human activities that impact on natural disasters and climate change. Monitoring of land use change activity is challenging task to land use planners for designing eco-friendly and sustainable land development which could address contemporary economic growth. So, land use issues are closely related with the society, development activities and environment. The dynamic of land uses raise the land use conflicts among different interest groups. There is necessity to resolve land use conflicts for ensuring equitable access and right of land resources in sustainable manner through land use planning. An integrated approach of land use planning may be relevant to manage land resources and address those challenges.

The present research attempts to present the land suitability evaluation process for land use planning. The specific objectives are to analyze the existing land use practices issues and spatio-temporal pattern of land use change since 1986 A.D., to evaluate the suitability of land for different use, to develop framework model for optimum land use plan, and to recommend the appropriate strategy for implementation of land use plan. Also, the research attempts to evaluate the land use at the best option from the land suitability evaluation and land use simulation incorporating physical infrastructure and risk factors in land use planning for sustainable land management.

The available research works carried out by different scholars of the world have associations with change in spatial pattern and determination of causative driving factors on the analysis of land use change; specific site selection for developable urban site, agriculture, industrial and forest with various parameters on the land suitability evaluation; and conducting urban-rural land use planning in different approach, tool and technique for allocation of proper land use. None of the previous research work have attempted to develop implementation strategy. Therefore, this research is an attempt to fulfill the gap through the analysis for identifying the land use influencing factors, finding land use trends and the densification of built-up areas for allocation of land resources. Likewise, the appropriate parameters selected depending upon the location of planning area including risk factors are also incorporated in the suitability evaluation for different land use. Similarly, land use plan is developed and analyzed through the integration of both qualitative and quantitative techniques to make reliable, feasible and implementable at local level. Further, the strategy is also developed to provide the development guideline for infrastructure constructions and to make land use plan implementation easier with monitoring process.

Shambhunath Municipality of Saptari District, Nepal has been chosen as the study area of the present research work. The theoretical background of research is based on logical positivism with spatial planning of urban land use. The research is basically guided by sustainable planning approach and accomplished by taking both quantitative and qualitative techniques. Primary data were collected from field visit, observation, rapid rural appraisal, participatory rural appraisal, key informant interviews, and focus group discussion. Holistic approach was adopted in analysis with six process such as analysis of land use pattern, identification of parameters, spatial modeling for risk layers, land suitability evaluation for land use class, projection of land use, and preparation of optimal land use plan with its implementation strategies.

The land use data/map for 1986 is generated from land utilization map of sheet no. $72\frac{J}{10}$ with the help of GIS tools in digital environment. Based on the classification schema, the land use data/map for 1986 is generated. The land use data/map for 1996 is prepared from topographical base map and its digital databases of topo sheet no. 2686-07B and 2686-07D with the help of GIS tools in digital environment. The land use data/map for 2017 is prepared from secondary source and WorldView-2 satellite image map using supervised image classification technique with MLC algorithm. Land use change analysis from 1986 to 2017 is analyzed through spatial overlay technique and quantification with geospatial tools. The spatial pattern of land use is also determined with trend of changes. The compactness of built-up (residential, commercial and industrial) area is analyzed with the measurement of entropy. Generally, the different risk factors (flood, soil erosion, landslide, and fire risk) acts as constraints in land use planning for mitigating potential disaster risks and build the resilience of communities to cope with such risks. Risk considerations are assessed using GIS-based suitability analysis and modeling, and included as constraint variables in the process of evaluating the suitability of a site for a particular land use. Altogether 27 different criteria are used in land suitability evaluation which were identified based on the existing literatures and those criteria were contextualized through expert and stakeholders knowledge to meet the context of local situation. Land suitability evaluation is conducted with integration of GIS tools and MCE for suitable site of specific land use (agriculture, residential, commercial, industrial, and forest) based on the determined criteria and computing the weight of criteria's through AHP process. The planning guideline is developed based on long terms strategic goals of 20 years with development targets that prerequisites to achieve a stable and diversified economy, and social development. Developing infrastructure is allocated based on land use suitability index map and planning guideline that meet the needs of local people for basic physical infrastructure, land use change and its growing trend. Land use projection is obtained through CA simulation technique to allocate land use options in decision making process of land use planning. Land use plan is developed based on projected land use incorporating developing infrastructure and risk layers, and qualitatively optimized through SWOT (strength, weakness, opportunity, and threat) analysis. Land use implementation strategy is designed based on the existing legal situation with reference to the international practices. In order to make the process of implementing land use straightforward and pleasant, land use zones are superimposed on the cadastral dataset of the PBCI system to indicate that each land parcel has just one category of land use. The developed strategy is feasible to implement optimal land use at local level and acts as development code.

The major findings of the present study are summarized in the following section.

9.1.1 Spatio-temporal Pattern of Land Use

The land use map for year 1986 and 1996 is generated from secondary sources of land use data. The LULC map of year 1986 is prepared by manual digitizing method from land utilization map. The agriculture land is found as the dominated land use within the municipality followed by the forest land in 1986. The residential land and public use land occupy the minimum extent (less than half percent) of municipality area. Similarly, LULC map for the year 1996 is prepared from the digital topographical map. In this also, the agriculture land is found as the dominated land use within the municipality followed by the forest land in 1996, but the residential and public use land has been increased two times accounting nearly one percent of municipality area comparative to the residential and public use land use in 1986. Likewise, LULC map of year 2017 is prepared from WorldView-2 satellite images respectively with MLC algorithm of supervised classification technique. The agriculture land is found as the dominated land use within the municipality followed by the forest land in 2017. These prepared LULC have meet the minimum threshold for land use change analysis.

The change of LULC is analyzed with spatial geospatial tools (spatial overlay and land change modeler) for quantification of land use change pattern. Land use changes from 1986 to 1996 showed that the agriculture, residential, commercial, industrial, and public use land are rapidly increasing in the municipality. But, the forest covered land is rapidly decreasing for agriculture practices. Land use changes from 1996 to 2017 showed that the agriculture land has been decreased gradually resulting rapid increase in the residential, commercial, industrial, and public land. The forest land has also been increased in some area due to conserving practices of water body and tree plantation along river courses. The overall land use changes from 1986 to 2017 depicts that the agriculture land has been increased with 842 ha (17.67%) through deforestation and encroachment of forest, barren land and open space area resulting decreased in the forest land with 135 ha (2.98%). Similarly, the land of water body area decreased with 144 ha (36.44%) because of the construction of embankment and agriculture practices even in low flood plain land along Khando River. Likewise, built-up area (residential, commercial and industrial) rapidly increased (175 ha) in scattered form along the strategic road network and surrounding to existing settlement area. The public use land also increased gradually for construction of road to increase the connectivity from major road to rural settlements. The compactness of built-up area is analyzed with entropy measurement and found 0.14 in 1986 then increased gradually 0.23 in 1996 and

0.44 in 2017 for development of built-up area. The road junction, and surrounding to service center, settlement, and transportation facilities are the spatial causative factor influencing land use changes after land development.

9.1.2 Land Suitability Analysis for Different Land Use

Land suitability analysis required different risks factors as parameters in terms of constraints to restrict the suitable site in risk area. The risk factors (flood, soil erosion, landslide, and fire) map are generated through spatial analysis/modeling and used in land suitability analysis and land use planning. The high flood risk is occurred mainly along the Khando River and lies in the settlement north of East West highway. The moderate flood risk took place along the major river as Kajara, Lukeshar, Mutani, Khadak and Dudhaila. The Chure range's foothills, where the soil is more exposed, and the agricultural land in Tarai are higher rates of soil erosion. The high and medium risk of landslide affected the forest, agricultural and public use land mainly near the Chure foot hill crossing near MFT. A bio-engineering plantation need to maintain the terrain stability from landslide risk. Also, there is high probability of blockage of river channel in Khando River through landslide and probable flash flood in the lower plain through outburst of debris layers. The forest area in north east direction is risky of forest fire. Some settlement having residential, commercial and industrial area are also under fire risk because of the high voltage transmission line that passes through the settlement with thatched house roof. Different types of major risk factors are dominated mostly surrounding to foot of Chure hill and along the Khando River.

The selection of criteria/factors was identified through focus group discussion for land suitability evaluation of agriculture, residential, commercial, and industrial and forest land use. The priority of class within the criteria is evaluated with fuzzy membership with its priority rating. The weight of the criteria/factors is determined through AHP process. The land suitability analysis for agriculture, residential, commercial, and industrial and forest land use is conducted using MCE and WLC in GIS. The suitability index map shows that 3.5 percent of the area is highly suited for forests, followed by 0.40 percent for agricultural, and 1 percent for commercial along with comparatively very less area 0.19 ha for residential and 0.12 ha for industrial land use. Similarly, the suitability index map shows that 28 percent of the area is suited for agricultural, followed by 26 percent for forest, 16 percent for commercial, 15 percent for residential, 16 percent for commercial, and 5 percent for industrial use. Likewise, the suitability index map shows that 35 percent of the area is moderately suited for commercial, followed by 29 percent for agricultural, 17 percent for forest, 15 percent for residential and 5 percent for industrial use. The suitable order of agriculture land is located at low land with flat terrain and gentle slope with high fertility rate and mainly in land capability class I and class II. Unsuitable order agriculture land is located in the undulating terrain of Siwalik hill. The suitable order of residential land is located mainly along the strategic road network and surrounding to the existing settlement in rural area. The suitable order of commercial land located at the intersection of road (junction) along strategic road as East West highway, feeder road and its surrounding nearer commercial area. The suitable order of industrial land is located near at Devdhar settlement, the north of the Rupani Bazar at the foot of Chure range, barren cultivable land near Khando River along agriculture road, and south west of Kathauna along feeder road. The suitable order of forest is located in Siwalik hill and some moderate suitable for forest has observed surrounding river course with the nature of scattered pattern. In a suitable order, the relationship between the current and suitable potential for agriculture, residential, commercial, industrial, and forest use is occurred 97.49 percent, 98.70 percent, 98.40 percent, 98.40 percent and 99.34 percent respectively.

9.1.3 Optimum Land Use Plan

Planning process is required planning guideline for the construction of developing infrastructure and applied in land use planning process too. Planning guideline is needed for developing construction of physical infrastructure plan based on national and international standard. Scientifically designed planning guideline is applicable for constructing physical infrastructure (road, water supply, sanitation, sewerage, solid waste management, electricity, and telecommunication); social infrastructure (educational, health, open space, recreational, library, fire station, old ages home, orphanage, security and other public institutional); and economical infrastructure (market, sport complex, multi-purpose hall, and bus park with transportation system). The road network is proposed 145.25 km for the planned road sharing 5.25 km agriculture road, 30.88 km local road and 109.12 km other road. Total of 11 no. of major bridges are proposed for strengthen the transportation route. One bus park is proposed within the municipality to manage the public vehicle. The total 35.81 km pipeline work is proposed distributed network through three water tower tanks. Likewise, 18.40 km sanitation work and 179.35 km waste water network work is proposed to strengthen the service infrastructure. Two landfill sites with more than 2 ha land are proposed for constructing treatment plant of sanitation and sewerage waste products. Among 33 schools within municipality, 8 community and 7 Private schools are required for upgrading up to secondary school. Additionally, one polytechnic institute and one library is proposed to develop high skill and technical human resource. One community hospital having 15 beds capacity, 8 health posts with birthing center, one old age and one orphan building are also planned to enhance the social basic infrastructure. In addition, 32.5 km electric network distribution transmission line, board band optical fiber telecommunication with one exchange office, mobile telecommunication and limited cable network telecommunication are proposed for strengthening the internet facilities. One fire station and two police stations are proposed to increase the security service area. Total 13 playgrounds, one stadium and one park is proposed for increasing the recreational service facilities. The 24 open space/open area is also proposed for mitigation of any risk (earthquake, fire outbreaks and flood inundation). Total 6 km major dam construction work and 98 km protection embankment as retaining wall is proposed for construction of dam site with bio-engineering greenery to protect the flood risk and conserve the water body feature. Patches of 9 ha land along small river course and 72 ha land along Khando River is proposed for plantation of tree to conserve biodiversity and maintain the environment. The land use for year 2037 is simulated using cellular automata modeling from land use suitability index maps as parameters and existing land use map as base data. The integrated land use plan is generated from simulated land use plan incorporating risk layers and physical infrastructure plan. The integrated land use plan is analyzed qualitatively with SWOT analysis process. The optimal land use plan is generated keeping in mind the strength and opportunity as well as weakness and threats. In optimal land use plan, residential area (201 ha) is additional allocated in safe site/ location with the availability of sufficient physical infrastructure, social service and security service facilities. Also, commercial area (26 ha) and industrial area (3 ha) are additionally allocated along the strategic road network with the availability of public service, security service, and other facilities as bank and financial institutions. The agriculture land is allocated in fertility level high, low land, sufficient drainage condition, and land capability class I and class II surrounding to the residential area and water body. Some land having up land with high fertility and arable land has been allocated for horticulture production in agriculture land. The forest land allocate in the sufficient fertility for growing forest species in high undulating terrain in Siwalik hill and surrounding to the river course for protecting the soil erosion, conserve biodiversity and maintain the environment.

9.1.4 Strategy for Implementation of Land Use Plan

Implementation strategies are designed on the basis of existing legal provision of Nepalese context with reference to international practices. The legal provision of land right and its spatial information is related with cadastral datasets and land records. So, the optimal land use plan is overlaid on the seamless cadastral maps in PBCI system and transferred the land use class as land use zone into the specific cadastral parcel. Based on the cadastral parcel record, these transferred land use data are linked correctly and accurately with the land tenure record and related other land information for systematic land use management in urban-rural economic development. Likewise, the developing guideline code is developed including physical development guideline in terms of Building bye-law for providing construction permit. The construction permit is permitted based on the developing code for construction of any construction either public or private. Without the construction permit, any infrastructure or building should not be constructed in the municipality for control use for proper land use. If constructed without prior permission from authority, the authority would immediately destroy such infrastructures and buildings. The land use changes should be converted with grant permission from the local level land use implementation council. The monitoring mechanism is also developed for the implementation of optimal land use plan in ground reality and to control the land use changes. Implementation strategy is empowered a framework for enforcement of compliance of land use zone and penalties for noncompliance. The formulated strategy is used as guided land development activities for implementation of land use plan at local level.

9.2 Conclusion

Based on results and discussion, the conclusion of this research can be drawn as follows:

The present study used remote sensing, a geographic information system, and related quantitative tools to determine the spatial pattern of land use, changes in land use, trends in future land use, and measure the densification and scattering of built-up area; and found useful. Land use change is happening rapidly in various spatial patterns, mostly in the areas surrounding new physical infrastructure development and existing settlement for expansion of built-up area. Additionally, land use change is occurred around forests and river channels, mostly due to deforestation for agricultural purposes. Changes in land use are largely driven by the spatial characteristics of development infrastructures, and these infrastructure acts as driving factor. With the trend of changing land use, it has been noted that built-up areas are steadily growing denser at a proportionately reasonable rate.

For the analysis of land suitability evaluation, list of criteria were identified in the context of Nepal and local situation of Shambhunath Municipality. These criteria are applicable for land use suitability evaluation to agriculture, residential, commercial, industrial, and forest in different part of Nepal. GIS integrated with MCE-AHP based quantitative technique for land suitability evaluation are more appropriate to evaluate the land quality assessment for different land use. The suitability index map described the suitable site/location for specific land use. These suitability index maps are applicable in developing infrastructure and decision making process of land use planning to resolve land use conflict in proper allocation of specific land use.

The present study found that the effective land use planning takes into account the spatial structure, economic value, physical infrastructure, risk levels, and strategic implications of land. This land use plan takes into account the strengths and opportunities while embracing its weaknesses and limiting its threats. This land use plan is implementable at the local level, socially acceptable to the community by incorporating them in the planning process, and technically practical and reliable. The basic assumption of Hoyts sector theory of urban land use explains that the core business area occurred at the centre part of urban area, developed retail business area (commercial zone) and manufacture industries at the outer boundary of the major business area along the transportation route, and residential area increased surrounding to commercial zone. This land use plan adheres to the fundamental assumptions of Hoyt's theory of land use and sustainable planning for land development in the municipality. This land use plan is also utilized as a periodic plan to construct the necessary physical infrastructure and carry out other land development tasks sustainably.

On the basis of the legislative framework of the Nepalese context and international norms, various implementation tools and techniques are formulated as strategies. The formulated strategies build the relationship between land use classes, land records, and related other land information for the purpose of systematic land use management. The development code strategy is used as a planning guideline for granting construction permits to manage haphazard and uncontrolled development activity. The institution set up is another strategy to implement the land use plan for practice and regulate local land use changes as the monitoring mechanism. The formulated strategy is empowered a framework for enforcement of compliance of land use class as land use zone and penalties for noncompliance through integrating land use in cadastral datasets. So, these formulated strategy is suggested as guideline for land development and assist to implement land use plan at local level.

9.3 Recommendation

Land use planning is carried out based on land use suitability evaluation associate with identified criteria in local context to allocate different land use. Likewise, quantification techniques are used for several weighting and scoring, and qualitative technique for optimization process in land evaluation process in Tarai. So, further research works may ponder into the comparative analysis for different criteria and techniques for land evaluation and land use planning in Mountain and Valley area in Nepal to draw up a common conceptual model of land use planning from the national perspective.

The study has designed methodological framework for land evaluation and land use planning under available geospatial analysis tools and models in GIS environment with semi-automatic process. Based on this framework, customized planning support system tool is not developed with the lacking of comprehensive knowledge and skill related to computer programming language. So, there is essential focus on research to develop planning support system based on the developed method for increasing the efficiency and effectiveness of land use planning process automatically.

The study has only focused on only 2D for land suitability evaluation of land use and horizontal spatial plan for land development activities. It is significant to the planners and decision makers to consider the vertical development activities considered in land use planning process for preparing 3D land use plan that should be efficient and compact utilization of land and infrastructure development. Therefore, it is recommended that the study on developing conceptual framework using geospatial tools and approach to develop 3D land use plan for land development.

The existing cadastral information used in this study only depicts the situation of land plots, but lacking of the infrastructure features like building, roads and other infrastrutures; not matched properly the rivers/streams and forest area; and not represented the real situation of landscape. Also, the cadastral maps has described with parcel number as cadastral interface, whereas, the record of land tenure and land right has stored on the basis of land owner names. Based on this study, it is recommended that there is necessary to prepare parcel based land information system based and title based land registration system with incorporating land use zone in order to monitor land use properly through updated cadastral information regularly, and to prevent haphazard construction of buildings and physical infrastructures.

Land use implementation strategy comprises the initiate guideline for implementation of land use plan in efficient and realistic way at local government to address the local needs. There is required local participation and stakeholder interaction to support and adjust the activities in the implementation process under optimization. The detailed implementation strategies are required at functional operation of land use implementation. So, it is recommended that the study on developing detailed implementation strategies as a guiding legal document to the local government and policy makers for land use planning.

APPENDICES

Appendix-1

Comparison of Characteristic Features in Land Evaluation Tool

Category	Tools and Techniques	Characteristic Features
Land Suitability Evaluation	**Logistic Regression Model**	Simple traditional model Considered dependent variable is discrete and independent variable expressed on the probability function Relationship follows as logistic monotonic curvilinear response between 0 &1 Model based on the single transition occurred at the first period.
	Boolean Logic Model	Simple mathematical Boolean function applied in model Logical combination of binary condition to input and outputs Relationship follows either 1 for satisfactory or 0 for non-satisfactory occurrence Model analysis performed with different query function using spatial analysis
	Fuzzy Logic Model	Rule based model Integrated framework based on the fuzzy set theory Both dependent and independent variable designed with linguistic value with considering the uncertainty Variable associated with fuzzy membership functions on choice of membership value in the different scale range
	Multi-criteria Evaluation	Interactive and flexible tool applied in solving the complex issue modelling Handling large information in consistent way Dependent and independent variables used as criteria with its influencing weights Optimal solution determined through the set of alternative with most preferred option

Land Use Allocation Land Use Allocation	**Multi-criteria Decision Analysis**	Multi-dimensional evaluation tools and weighted sum model with MCE Include wide range of conflicting interests, values and goals Investigate a number of choice possibilities as multiple criteria and conflicting objectives Considered the multi-objective optimization theory among choice alternatives with rule-based decision tree
	Spatial Optimization Model	Mathematical programming tools with genetic algorithm Optimal set of spatial configurations in terms of multiple goals and objectives Computational efficiency using heuristic methods to solve the optimization problem Addressing the variety of sustainability aspects as contiguity, compactness, connectedness and infill development
	Cellular Automata Simulation Model	Multi-agent systems used in dynamic phenomenon modelling Bottom up approach based on Interactions with space and time Interacting with transition rule in simple way and displaying with the complex overall behavior Simulation considered the existing situation with the different suitability factors and neighborhood condition
	Artificial Neural Network Model	Dynamic model with the feedback propagation algorithm using machine learning and neural network process Applicable in large numbers of parameters and difficulty in the calibration of these parameters Computational mechanism able to acquire, represent, and compute from one multivariate space to another through a set of data representation Avoid model over fitting through cross-validation and the output obtained from the average of multiple iteration
	Decision Support System	Customized interactive computer-based tool to assist the planner Flexible knowledge based management system for solving complex issues Simulation of varied scenarios based on factors and constraints and help practitioner for better decision More efficient decision making process based on spatial data analysis without changing any rules

Appendix-2

Check List for Field Data Collection

Following details are collected and verified in extensive field visit.

S.N.	Description	Land Use	Feature Type
1	Cultivation	Agriculture	
		Barren	
		Pasture	
		Open area	
2	Vegetation	Forest	
		Shrub	
		Bushes	
		Orchard	
		Plantation	
		Bamboo	
3	Built-up	Residential	
		Commercial	Market Area
			Hotel
			Private Service Area
			Private Recreation Area
			Government Building
			Storage & Utilities
		Industrial	
		Public Use	Community & Public Service Area
			Security Service Area
			Recreation Area
			Open Space
			Public Institutions
		Cultural, Archeological & Heritage Site	Temple
			Mosque
			Heritage Site
4	Waterbody	Public Use Pond	
		Private Pond	
		Lake	
5	Typonomy & Name		

Appendix-3

Interview with Local Respondents

This tool aimed to collect data for my research work on the Topics Land Suitability Evaluation for Land Use Planning in Shambhunath Municipality, Saptari District, Nepal under Faculty of Humanities and Social Science, Tribhuvan University. Data collected from this questionnaire will only be used in academic purpose and the confidentiality will be guaranteed. Your answers will be very useful and meaningful for the success of this research. Hopefully, findings from my research will contribute to the land use planning process in our country.

Name: Address:

Sex: Occupation:

Welcome for Joining this Interview!

I. Existing Situation of Land Use

1) Do you know about land use?
   a. Yes b. No
2) How much land you have?
   a. Yes b. No
   If yes, ……………………. ha
3) Who is the owner of land?
   a) Own b) Tenant c) Hire d) Government
   e) Public f) Community g) Guthi f) Informal
   If mixed type: Own land ……………….. ha, Tenant land……………. ha; Hire land …….. ha, and Other land …… ha.
4) Which type of land use follow in your land?
   …………….. , ……………….. , ……………………… , ………………….
5) In your land owner/tenant certificate have you seen land use type?
   a. Yes b. No c. Don't care
6) Which authority suggest you to use the land as specific……………… land use?
   ………………………………………………………………………………
7) How much benefit have you got from annually from the land?
   …………………………………………………… per ha.
8) Do you personally use the land?
   a. Yes b. No
   If yes, how much cost you invest to get such benefits annually?
   …………………………………………………… per ha.
   If no, how much rent have you got annually?
   …………………………………………………… per ha.
9) Do you need technical support from other institution for proper use of the land?
   a. Yes b. No

If yes;

- Need Government Institution …………………………………
- INGOs ……………………………………………………….
- NGOs……………………………………………………..
- CBOs……………………………………………………..
- Others……………………………………………………….

10) In your community, have you observed the land use change in your locality in past 10 years?

    a. Yes b. No

    If yes, in which type of land use has converted?

    ……………………………………………………………………………

11) In your community, have you known the unit price of land in last 2 years?

    a. Yes b. No

    If yes, in which type of land has how much prices?

    Agriculture ………………………per ……………………………………..
    Residential ……………………....per………………………………………
    Commercial ………………………,per………………………………………
    Industrial …………………………..per……………………………………….

II. Socio-economic

1) How much wage (labour cost) have to paid to the labour?

    b. ………/daily b. ……../monthly c. ……./yearly

2) Have you access to supply the product to market?

    a. Yes b. No

    If yes, How far the nearest is located as?

    ……………………………………………………………………………

3) Do you have own transport to supply your product in local market?

    a. Yes b. No

    If no, which type of transport facilities have you used?

    ……………………………………………………………………………

4) How much costs have you paid for supply/collect goods from/ to market?

    ……………………………………………………………………………

5) What is your net income in annually?

    Agriculture…………………Residential……………………Commercial……
    Industrial………………….. Remittance/Service……………Others…………

III. Need of Physical Infrastructure

1) In your community/settlement, is there road network exists?

    a. Yes b. No

    If yes;
    Mention its type……………………………………………………………
    Mention its condition………………………………………………………
    Mention its right of way……………………………………………………

2) In your community/settlement, is there available of electricity supply?

    a. Yes b. No

    If yes;
    Mention its phase………………………………………………………….
    Mention its supply condition………………………………………………

3) In your community/settlement, is there pipeline supply available?
   a. Yes b. No
   If yes;
   Mention its type………………………………………………………………
   Mention its condition…………………………………………………………
   If no;
   What is the source of drinking water?
   …………………………………………………
   How far the source of drinking water exists?
   ………………………………………………… in Km.
4) In your community/settlement, is there sewerage/sanitation infrastructure exists?
   a. Yes b. No
   If yes;
   Mention its type………………………………………………………………
   Mention its condition…………………………………………………………
5) In your community/settlement, is there communication infrastructure exists?
   a. Yes b. No
   If yes;
   Mention its type………………………………………………………………
   Mention its condition…………………………………………………………
6) In your community/settlement, is there market centre exists?
   a. Yes b. No
   If yes;
   How far it? ……………………………………… in Km.
   Mention its type ……………………………………………………………
7) In your community/settlement, is there Hospital exists?
   a. Yes b. No
   If yes;
   How far it? ……………………………………… in Km.
   Mention its type ……………………………………………………………...
   How many doctor works there? ………………………………………………
8) In your community/settlement, Is there School exists?
   a. Yes b. No
   If yes;
   How far it? ……………………………………… in Km.
   Mention its type ……………………………………………………………..
   How much student study in this school? ……………………………………
9) In your community/settlement, is there open space available?
   a. Yes b. No
   If yes;
   How far it? ……………………………………… in Km.
   Mention its categories ……………………………………………………..
   Mention its condition…………………………………………………………

IV. Risk and its Mitigation

- **Flood**

1) How far your community/settlement is located from streamline and rivers?
   a. Less than 200 m b. Between 200 to 500 m
   c. Between 500 to 1000 m d. Greater than 1000 m

2) Have you and your settlement has suffered flood hazard in past decade?
   a. Yes b. No

   If yes, which type of loss you and your community happens? Have you and your settlement has suffered flood hazard in past 50 years?
   b. Yes b. No

   If yes, which type of loss you and your community happens?

Family	Community
People ……………	People ……………
Livestock …………	Livestock …………
Property …………	Property …………
Others …………	Others …………

3) What are the causes of flooding?
   ………………………………………………………………………………
   ………………………………………………………………………………
4) How you and your community do mitigate such flood hazard?
   a. Own b. Community
   c. Governmental Institution Support d. INGO / NGO / CBO Support

❖ **Fire**

1) How far your community/settlement is located from High Tension Electricity and Petrol Pump?
   a. Less than 200 m b. Between 200 to 500 m
   c. Between 500 to 1000 m d. Greater than 1000 m
2) Which type of settlement have your community accommodated?
   a. Spare b. Agglomerated
3) Which material have you and your community used for construction of building and house?
   a. Concrete b. Paddy Stalk
   c. Galvanized Iron d. Others……………………….
4) Have you and your settlement has suffered fire hazard in past decade?
   a. Yes b. No

   If yes, which type of loss you and your community happens?

Family	Community
People ……………	People ……………
Livestock …………	Livestock …………
Property …………	Property …………
Others …………	Others …………

5) Have you and your settlement has suffered fire hazard in past 50 years?
   a. Yes b. No
6) Have you and your settlement has suffered fire hazard in past 50 years?
   a. Yes b. No

   If yes, which type of loss you and your community happens?

Family	Community
People ……………	People ……………
Livestock …………	Livestock …………
Property …………	Property …………
Others …………	Others …………

7) What are the causes of fire hazard?
…………………………………………………………………………………
…………………………………………………………………………………
8) How you and your community do mitigate such fire hazard?
a. Own b. Community
c. Governmental Institution Support d. INGO / NGO / CBO Support

❖ **Landslide**

1) Where your settlement is exists?
a. Plain b. Moderate Slope
c. Steeply Slope d. Under the Steeply Slope
2) Which type of landform condition in your settlement?
a. Rocky b. Sandstone
c. Mudstone d. Conglomerate
3) Have you and your settlement has suffered landslide hazard in past decade?
a. Yes b. No
If yes, which type of loss you and your community happens?

Family	Community
People ……………	People ……………
Livestock …………	Livestock …………
Property …………	Property …………
Others …………	Others …………

4) Have you and your settlement has suffered landslide hazard in past 50 years?
a. Yes b. No
If yes, which type of loss you and your community happens?
5) What are the causes of landslide hazard?
…………………………………………………………………………………
…………………………………………………………………………………
6) How you and your community do mitigate such landslide hazard?
a. Own b. Community
c. Governmental Institution Support d. INGO / NGO / CBO Support

❖ **Seismic**

1) Which type of settlement have your community accommodated?
a. Spare b. Agglomerated
2) Have you and your settlement has suffered seismic hazard in past decade?
a. Yes b. No
If yes, which type of loss you and your community happens?

Family	Community
People ……………	People ……………
Livestock …………	Livestock …………
Property …………	Property …………
Others …………	Others …………

3) Have you and your settlement has suffered seismic hazard in past 50 years?
a. Yes b. No

If yes, which type of loss you and your community happens?

Family	Community
People ……………	People ……………
Livestock …………	Livestock …………
Property …………	Property …………
Others …………	Others …………

4) What are the causes of seismic hazard?
………………………………………………………………………………
………………………………………………………………………………
5) How you and your community do mitigate such seismic hazard?
   a. Own   b. Community
   c. Governmental Institution Support   d. INGO / NGO / CBO Support

V. Land Use Planning

1) Do you know about Land Use Planning and Land Use Zoning?
   a. Yes   b. No
2) Are you satisfied with that zoning carried out by Government of Nepal in Shambhunath Municipality ?(If they don't know, showing the map)?
   a. Highly satisfied   b. Satisfied   c. Unsatisfied
3) Do you think current land use of your community is in safe zone?
   a. Yes   b. No   c. I don't know
4) Do you think that risk should be addressed in the land use planning process?
   a. Necessary   b. Better   c. Not necessary
5) Do you think that physical development plan should be guided the land use planning process?
   a. Necessary   b. Better   c. Not necessary
6) How do you think land use planning process essential for land development?
   a. Very important   b. Important   c. Not important
7) In your opinion, how do you think to improve economy by proper land use in the process of land use planning for sustaining land management?
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………………………………………………………………………………

Thank you

Appendix-4

Interaction with Committee Member and Personnel's (Technicians)

This tool is aimed to collect data for my research work on the Topics Land Suitability Evaluation for Land Use Planning in Shambhunath Municipality, Nepal under Faculty of Humanities and Social Science, Tribhuvan University. Data collected from this questionnaire will only be used in academic purpose and the confidentiality will be guaranteed. Your answers will be very useful and meaningful for the success of this research. Hopefully, findings from my research will contribute to the land use planning process in our country.

Name: Section:

Position: Contact No:

Date: Interview No:

Welcome for Joining this Interaction!

1) Does the municipality have the land use plan?
   a. Yes b. No c .I don't Know
   If yes, which type of land use plan should be prepared by the municipality?
   a. Physical development plan b. Master plan
   c. Sectorial infrastructure Plan d. Land Use Zoning
2) How do you prepare ………………………………plan?
   a. By technical assistance b. By Municipality technicians
   c. By participatory approach d. By integrated approach
3) Does the municipality have the land use zoning map/plan?
   a. Yes b. No c. I don't Know
   If yes, how does these land use zoning map should be prepared?
   ……………………………………………………………………………
4) Please specify, the factors/constraints which has considered in land use zoning process?
   ……………………………………………………………………………
   ……………………………………………………………………………
   ……………………………………………………………………………
5) Does disaster prone area and physical infrastructure plan have essential to incorporate in land use planning process?
   a. Yes b. No c. I don't Know
   If yes, which types of disaster risk are included in land use zoning at the land use planning process?
   ……………………………………………………………………………
   ……………………………………………………………………………
   ……………………………………………………………………………

If yes, types of physical infrastructure are included in land use zoning at the land use planning process?

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…………………………………………………………………………………
…………………………………………………………………………………

6) Do you think that citizen and stakeholders should be involved in land use planning process?

   a. Yes b. No c. I don't Know

7) How important do you think land use planning is for sustainable land management?

   a. Very important b. Important c. Unnecessary

8) Which organization is mainly responsible for implementing land use plan?

…………………………………………………………………………………
…………………………………………………………………………………

9) What are the barriers for implementation of land use planning?

…………………………………………………………………………………
…………………………………………………………………………………

10) How can we successfully implement land use planning?

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11) Do you have any suggestions for effective land use planning process?

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Thank you

Appendix-5

Key Informant Interview with Land Use Planning Experts as Professionals

This tool is aimed to collect data for my research work on the Topics Land Suitability Evaluation for Land Use Planning in Shambhunath Municipality, Nepal under Faculty of Humanities and Social Science, Tribhuvan University. Data collected from this questionnaire will only be used in academic purpose and the confidentiality will be guaranteed. Your answers will be very useful and meaningful for the success of this research. Hopefully, findings from my research will contribute to the land use planning process in our country.

Name: Organization:
Position: Contact No:
Date: Interview No:

Welcome for Joining this Interview!

I. Open ended questions:

1) Do you agree with the current practices of land use planning practices in our country?
   a. Agree b. Disagree

   If disagree, what are the activities will be carried out for appropriate land use planning?

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2) In the current practices of developing technology in world, How to determine appropriate land use category in land evaluation process?

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   If some factors are commonly considered in such land evaluation process, what are they?

3) Is there a quantitative technique/tool synthetically asses for suitability of specific land use in land evaluation process?

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………………………………………………………………………………………

   If other technique used in suitability analysis, what are these?

………………………………………………………………………………………
………………………………………………………………………………………

4) How to carry out the suitability analysis for the specific land use class?

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If some factors/constraints are commonly considered in suitability analysis, what are they?

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5) How to use the application of GIS, MCE and AHP technique in the land suitability analysis process?

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6) In which developed modern technique are generally used for the allocation of land use from different suitability map of land use categories?

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Please specify its main advantages:

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7) In the present study, which modern techniques are more appropriate to use for the allocation of proposed land use in decision making process in land use planning?

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8) Which type of vulnerable risk factors are influenced in suitability analysis of specific land use categories and allocation of land use in land use planning process?

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9) How these vulnerable/risk factors are incorporated in the allocated proposed land use in decision making process?

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10) Is it possible to implement the land use plan without involvement of citizen, stakeholders and local developer partner of government institution?
   a. Yes   b. No

If No, in which process the citizen, stakeholders and local developer partner are involved in land use planning process?

………………………………………………………………………………………
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11) Please specify, the way of citizen and stakeholder ideas/views are used for qualitative evaluation of the proposed land use plan?

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12) What are the main problems occurred in the decision making process in land use planning practices?

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13) How these problems are managed to prepare land use plan for implementation at the local level practically?

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II. Identification of Factors:

This part aims to investigate the expert's opinion/views for identification of key factors which are affecting the land suitability evaluation and land use decision making process in land use planning. A set of general criteria are listed below for your reference, please give your answers based on the practices of land use planning in Nepal. After that, you can also provide some comments or suggestion for improvement of criteria in land use planning process.

Criteria for Land Suitability Evaluation and Land Use Decision Making Process

Category	Sub-category	Criterion
Physical	Topography	Elevation
		Slope
		Aspect
		Curvature
	Geology	Structure (Lithology)
		Distance to Fault Line
	Geomorphology	Land Form
		Distance to Drainage
	Climate	Rainfall/Humidity
		Temperature
		Wind Speed
Social	-	Population
		Employment
Economical	-	Growth Domestic Product (GDP)
		Land Value
Environmental	Ecology	Vegetation Index
		Soil Moisture Index
		Soil Quality (Soil Fertility)
	Environment	Air Quality (Dist. from Chimney)
		Noise Pollution (Dist. from Strategic Road)
Cultural	Historical Feature	Heritage Landmark
	Locality	Landscape Uniqueness
Political/Legal	Property Right	Administration Boundary
		Land Tenure
	Land Use Regulation	Use Restriction
		Need for Development
Utilities	Land Use	Former Land Use
		Current Land Use
	Transportation	Strategic Road Network
		Local Road Circulation
	Services	Access to Service Centre (Hospital, Education Centre, Market Centre, Open space, Park)
		Access to Basic Infrastructure for Housing (Electricity, Communication, Sewerage/Sanitation)
Risk/Hazard	-	Flood
	-	Landslide
	-	Soil Erosion
	-	Fire

Please mention your specific comments if you like:
………………………………………………………………………………………
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………………………………………………………………………………………

Please mention your specific suggestion if you like:
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III. Land Use Implementation:

1) In your opinion, which organizations are responsible to implement land use plan at the local level?
   a. Survey Department   b. Provincial Government
   c. Land Revenue Department   d. Local Level Government
2) Do you think current provisions for implementation of land use planning are sufficient?
   a. Perfect   b. Sufficient
   b. Not sufficient   d. Need improvement
3) What could be the major implementation barriers of proposed land use (land use zoning) at parcel level in cadastral documents? Please mention them in hierarchy?
   a.
   b.
   c.
4) What should be the best implementation framework of proposed land use zones?
   a. Legal   b. Organizational
   c. Technical   d. Other
5) Please mention specific requirement to implement land use category in proper land parcel for land use implementation strategy in Nepalese context?
   ………………………………………………………………………………
   ………………………………………………………………………………
   ………………………………………………………………………………
   ………………………………………………………………………………
   ………………………………………………………………………………

Thank you

Appendix-6

Focus Group Discussion

This tool is aimed to collect data for my research work on the Topics Land Suitability Evaluation for Land Use Planning in Shambhunath Municipality, Nepal under Faculty of Humanities and Social Science, Tribhuvan University. Data collected from this Focus Group Discussion will only be used in academic purpose and the confidentiality will be guaranteed. Your answers will be very useful and meaningful for the success of this research. Hopefully, findings from my research will contribute to the land use planning process in our country.

Place:

Date:

Welcome to everyone for Joining in this Discussion!

Discussion on the Factor/Constraints used in Suitable Site Selection

Factors/Priorities	1	2	3	4	5	6	7	8	9
Agriculture									
Residential									
Commercial									
Industrial									
Forest									

Thank you

Focus Group Discussion

This tool is aimed to collect data for my research work on the Topics Land Suitability Evaluation for Land Use Planning in Shambhunath Municipality, Nepal under Faculty of Humanities and Social Science, Tribhuvan University. Data collected from this Focus Group Discussion will only be used in academic purpose and the confidentiality will be guaranteed. Your answers will be very useful and meaningful for the success of this research. Hopefully, findings from my research will contribute to the land use planning process in our country.

Place:

Date:

Welcome to everyone for Joining in this Discussion!

Discussion on Guideline for Preparation of Physical Development Plan

Utilities/Situation	Available	Under Maintenance	On Construction	Future Construction
Road				
Sewerage				
Pipeline				
Electricity				
Telecommunication				
Open space				
Bridge				
Other				

Thank you

Focus Group Discussion

This tool is aimed to collect data for my research work on the Topics Land Suitability Evaluation for Land Use Planning in Shambhunath Municipality, Nepal under Faculty of Humanities and Social Science, Tribhuvan University. Data collected from this Focus Group Discussion will only be used in academic purpose and the confidentiality will be guaranteed. Your answers will be very useful and meaningful for the success of this research. Hopefully, findings from my research will contribute to the land use planning process in our country.

Place:

Date:

Welcome to everyone for Joining in this Discussion!

Discussion on Disaster Management

Disaster/ Situation	Ancient within century	Loss	Recently within Decade	Loss	Mitigation Practices	Preparedness & Management
Flood		Human ………. Livestock………. Properties……… Other…………..		Human ………. Livestock……… Properties……… Other………		
Landslide		Human ………. Livestock………. Properties……… Other…………..		Human ………. Livestock……… Properties……… Other………..		
Seismic		Human ………. Livestock………. Properties……… Other…………..		Human ………. Livestock……… Properties……… Other…………		
Fire		Human ………. Livestock………. Properties……… Other…………..		Human ………. Livestock……… Properties……… Other…………		
Other		Human ………. Livestock………. Properties……… Other…………..		Human ………. Livestock……… Properties……… Other…………		

Thank you

Focus Group Discussion

This tool is aimed to collect data for my research work on the Topics Land Suitability Evaluation for Land Use Planning in Shambhunath Municipality, Nepal under Faculty of Humanities and Social Science, Tribhuvan University. Data collected from this Focus Group Discussion will only be used in academic purpose and the confidentiality will be guaranteed. Your answers will be very useful and meaningful for the success of this research. Hopefully, findings from my research will contribute to the land use planning process in our country.

Place:

Date:

Welcome to everyone for Joining in this Discussion!

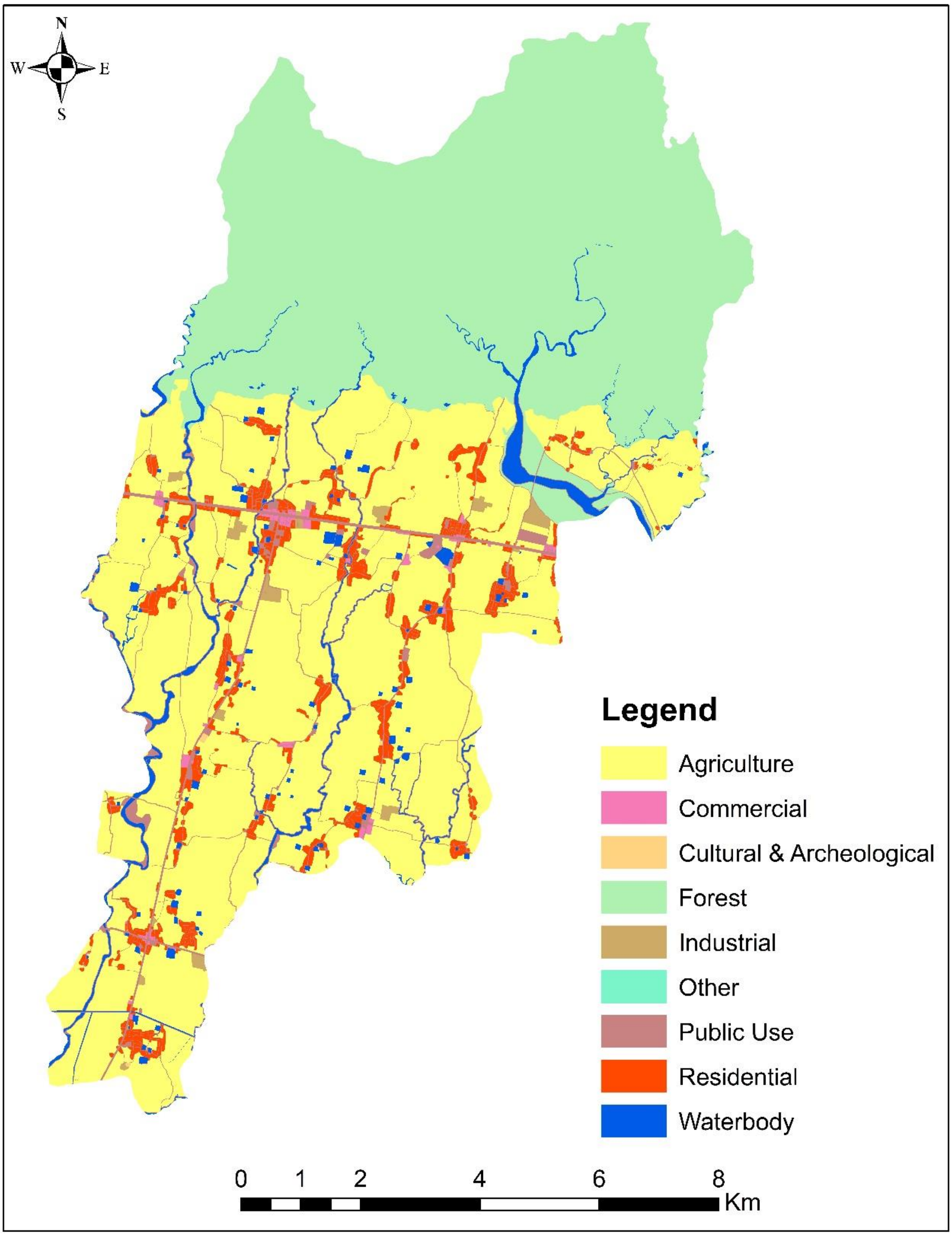
Discussion on the development of construction code

Land Use Class	Minimum plot width & Size	Road width for accessibility	Building height	Construction coverage	Greenery Belt
Agriculture					
Residential					
Commercial					
Industrial					
Forest					

Thank you

SWOT Analysis

Welcome to everyone for Joining in this Discussion!



Please look at the prepared land use plan (land use zoning map) critically, and evaluate its strength, weakness, opportunity and threat for simulation of decision making process in land use planning. Please give your reasons and results of land use decision within 1 hour.

Strength

- ……………………………………………………………………………
- ……………………………………………………………………………
- ……………………………………………………………………………
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Weakness

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Opportunity

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Threat

- ……………………………………………………………………………
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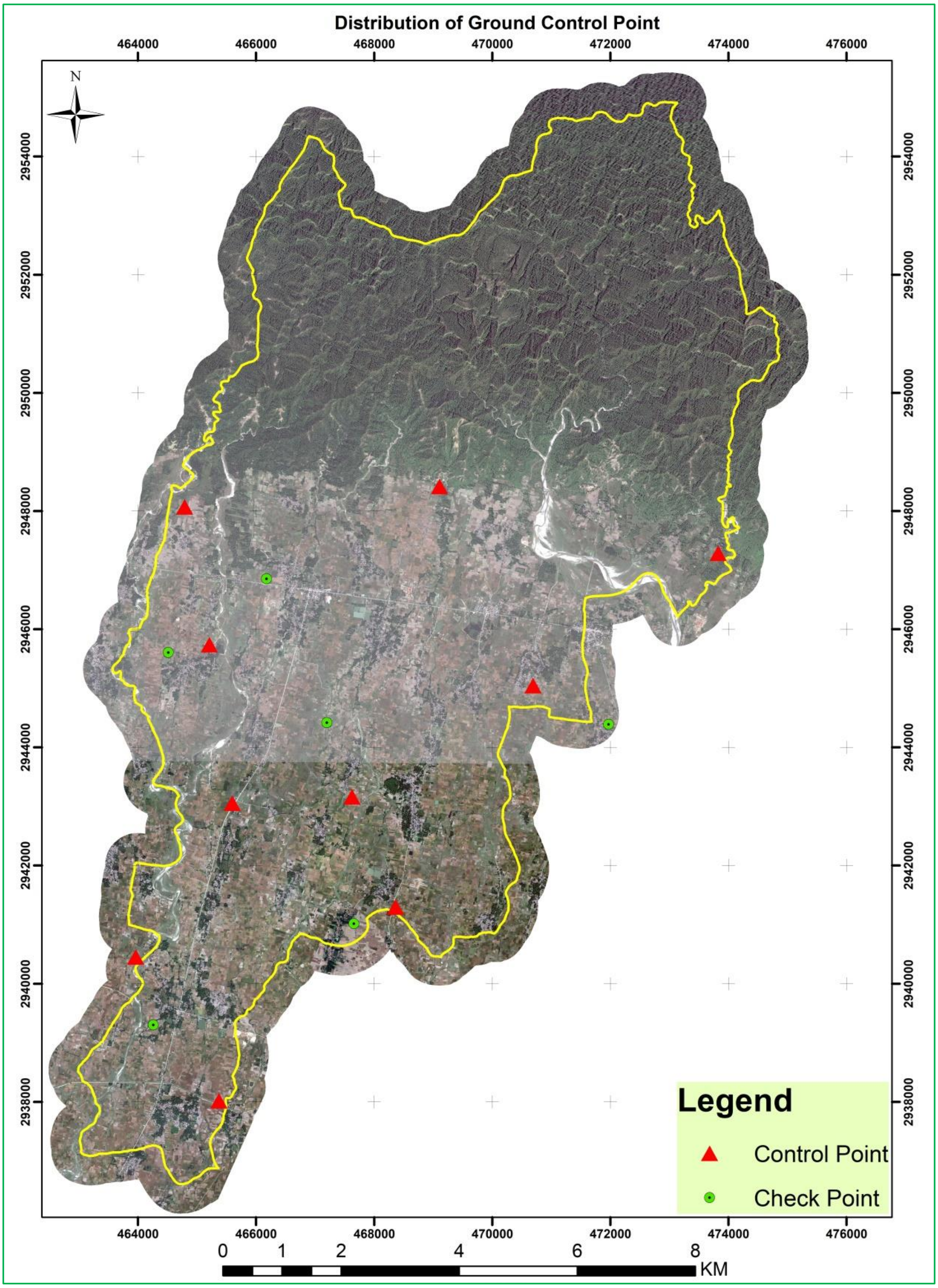
Thank you

Appendix-7

Ground Control Point



Appendix-8

Ortho-rectification Error Report

S.N.	Image Co-ordinate		Ground Co-ordinate			Residual			Control Point Type	Remarks
	X	Y	Easting	Northing	Elevation	X	Y	Total		
1	466956.201	2944586.498	467201.013	2944421.350	108.586	-0.016	0.184	0.185	Check Point	GCP_04
2	464536.249	2947468.521	464792.727	2948071.740	132.902	0.182	0.205	0.274	Control Point	GCP_06
3	473576.646	2946685.350	473828.024	2947285.706	133.255	0.142	0.26	0.296	Control Point	GCP_10
4	463708.364	2939851.160	463963.628	2940453.969	100.560	-0.291	-0.27	0.397	Control Point	GCP_14
5	468854.319	2947815.663	469107.384	2948415.246	140.287	0.265	0.278	0.384	Control Point	GCP_01
6	464018.621	2939471.233	464261.684	2939304.283	87.346	-0.294	0.308	0.426	Check Point	GCP_08
7	465353.078	2943222.363	465597.452	2943056.426	101.134	-0.245	0.328	0.409	Control Point	GCP_15
8	465928.859	2946258.367	466177.847	2946855.242	121.783	0.308	-0.348	0.465	Check Point	GCP_13
9	464272.130	2945773.962	464517.024	2945608.734	109.933	-0.296	0.364	0.469	Check Point	GCP_02
10	471721.793	2943795.879	471971.163	2944390.926	111.203	0.051	0.405	0.408	Check Point	GCP_11
11	467411.804	2941185.107	467656.913	2941018.602	95.108	0.351	-0.422	0.549	Check Point	GCP_16
12	470439.271	2944444.212	470691.218	2945046.586	115.388	0.482	0.468	0.672	Control Point	GCP_03
13	467374.856	2942563.436	467627.582	2943165.078	103.177	-0.214	0.617	0.653	Control Point	GCP_09
14	465114.541	2937412.917	465373.021	2938018.251	99.832	0.529	0.684	0.865	Control Point	GCP_12
15	468111.426	2940696.528	468362.147	2941297.360	95.569	-0.149	-0.819	0.832	Control Point	GCP_05
16	465461.393	2946341.847	465211.229	2945738.688	112.773	0.092	0.888	0.893	Control Point	GCP_07
							RMSE	0.552		

Appendix-9

Accuracy Assessment Report

LU/LU	Agriculture	Forest	Residential	Commercial	Industrial	Public Use	Cultural and Archeological	Water body	Other	Total	User Accuracy	KIA
Agriculture	108	1	0	0	0	0	0	1	0	110	98.18	0.97
Forest	2	22	0	0	0	0	0	0	0	24	91.67	0.91
Residential	0	2	45	0	0	0	0	0	0	47	95.74	0.95
Commercial	0	0	1	20	0	1	0	0	0	22	90.91	0.90
Industrial	0	0	0	0	5	0	0	0	0	5	100.00	1.00
Public Use	2	0	0	0	0	28	0	0	0	30	93.33	0.93
Cultural and Archeological	0	0	0	0	0	0	12	0	0	12	100.00	0.95
Water body	1	1	0	0	0	0	0	19	0	21	90.48	0.90
Other	0	0	0	0	0	0	0	0	1	1	100.00	1.00
Total	113	26	46	20	5	29	12	20	1	272		
Producer Accuracy	95.58	84.62	97.83	100.00	100.00	96.55	100.00	95.00	100.00			

Overall Accuracy = 95.59%

Overall KIA = 0.94

Appendix-10

Detail method adopted for preparation of Risk Layers

Flood Risk

Flood risk analysis has conducted for the assessment of flood and delineation of flood way with its risk and vulnerability in the flood-prone areas. HEC-RAS application tool has used to prepare simulation flood inundation layer with the consideration of discharge for 100 years return period in the steady flow environment. In HEC-RAS, flood analysis has carried out from the flood governing factors as rainfall, runoff, catchment characteristics and return period along with cross-section and longitudinal section of river and hydraulic structure as the probability occurrence of the high volume water discharge in river. The maximum discharge of water volume of river has computed based on the catchment area. So, discharge were computed for different catchment area based on its catchment area using the following Equation.

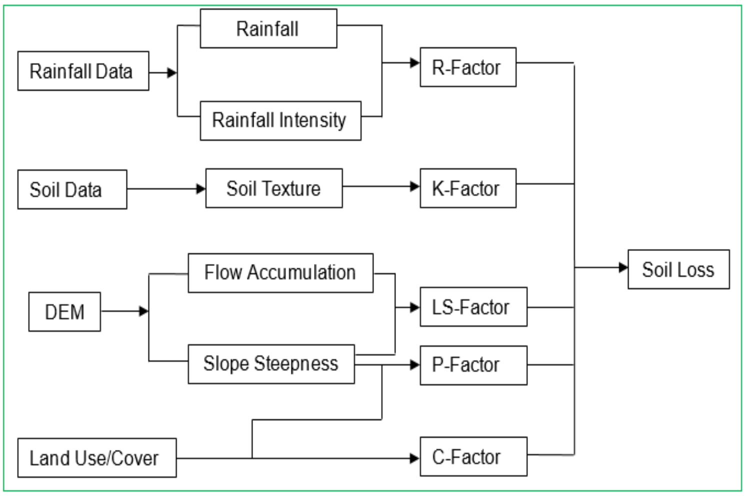
$$Q_2 = 1.8767\ (A + 1)^{0.8783} \quad \text{(i)}$$

$$Q_{100} = 14.639\ (A + 1)^{0.7342} \quad \text{(ii)}$$

where, Q_2 and Q_{100} represents 2 and 100 year return period floods respectively and A is the area of the catchment. In HEC-RAS model, the geometry of river information such as centerline, river banks, and its cross-sections in 3D features with hydraulic structures (embankment, spurs), Manning's roughness coefficient (0.035 for the river channel and 0.04 for the banks), etc. were applied in simulation process. The simulation of flood was carried out to predict flood inundation layer with variation of depth in the evacuation routes of flood inundation depth based on 100 years of the historical flood information and potential future flood events in different probability.

Soil Erosion Risk

Soil erosion has conducted for minimizing the cause of destruction and sustainability of agriculture upland, and ecological restoration through preparing erosion control plans. Soil erosion has removed the fertile topsoil and transports it into the water bodies, reducing the fertility of arable cultivable land and causing the loss of food production. Generally, RUSLE (Revised Universal Soil Loss Equation) model has used for estimation of soil loss with rainfall and surface water flow through rainfall erosivity, soil erodibility, topography, crop management, and conservation practice factors. The methodological procedure of RUSLE Model with associated the parameters of the soil loss estimation is explained in below figure.



The rainfall erosivity factor (R) is computed from the rainfall intensity data that located surrounding to the municipality. The average rainfall map is prepared by the spatial interpolation from the average annual rainfall data using kriging geostatistical technique in GIS. The generated rainfall map was used for estimation of R factor with the following Equation.

$$R = 38.5+0.35\ E \quad \text{(iii)}$$

where, E is the average annual rainfall intensity.

The Soil Erodibility Factor (K) describes the susceptibility quantity of soil in the flow of runoff water that transported through erosion process in a given specific rainfall. In the absence of soil structure and soil permeability value, the K factor was estimated with the following Equation.

$$K = Fcsand * Fsi - cl * Forgc * Fhisand * 0.1317 \quad \text{(iv)}$$

where,

$$Fcsand = [0.2 + 0.3 \exp(-0.0256\ SAN\ (1 - SIL/100))] \quad \text{(v)}$$

$$Fsi - cl = [\frac{SIL}{(Cl+SIL)}]^{0.3} \quad \text{(vi)}$$

$$Forgc = [1.0 - \frac{0.25\ c}{c+\exp(3.72-2.95c)}] \quad \text{(vii)}$$

$$Fhisand = [1.0 - \frac{0.70SN1}{SN1+\exp(-5.51+22.9SN1)}] \quad \text{(viii)}$$

$$SN1 = \frac{1-SAN}{100} \quad \text{(ix)}$$

where, SAN, SiL and Cl are % sand, silt and clay respectively and c is the organic carbon content (organic matter).Fcsand gives a low soil erodibility factor for soil with coarse sand and a high value for soil with little sand content. Fsi-cl gives a low soil erodibility factor with high clay to silt ration. Forgc is the factor that reduces soil erodibility for soil with high organic content. Fhisand is the factor that reduces soil erodibility for soil with extremely high sand content. The sand, silt, clay and organic matter map was generated from the collected soil sample data and soil polygon.

Topographic factor (LS) was computed with the reference of two factors (slope length and slope steepness). In the study, both slope length and slope steepness were derived from DEM and computed from these factors in grid format using following Equation.

$$LS = L * S \quad \text{(x)}$$

where, L is the slope length factor and S is the slope steepness factor. The slope length (L) was computed using the following relation.

$$L = (\frac{\lambda}{22.13})^m \quad \text{(xi)}$$

where, λ is the contributing slope length and m is the variable slope length exponent that varies based on slope steepness. The contributing slope length was derived from flow accumulation map with the size of grid raster factor as base for preparing L-Factor map. The flow accumulation map was generated from DEM using hydrological modeling. The slope length exponent 'm' is related to the ratio of rill erosion to inter rill erosion (caused by raindrop impact). The contributing slope length was measured from the flow accumulation of runoff in water enters a well-defined channel and size of its raster size.

$$m = \frac{F}{1+F} \quad \text{(xii)}$$

$$F = \frac{Sin\theta/_{0.0896}}{3(Sin\theta)^{0.8}+0.56} \quad \text{(xiii)}$$

where, F is the ratio of rill erosion to inter rill erosion;$\theta$is the slope angle in degree. The slope steepness factor (S) was computed from the following relation.

$$S = 10.8 * sin\theta + 0.03, \qquad S < 9\% \; (tan\theta < 0.09)$$

$$S = (\frac{sin\theta}{sin5.143})^{0.6}, \qquad S \geq 9\% \; (tan\theta \geq 0.09) \quad \text{(xiv)}$$

where, θ is the slope angle in degree.

The erosion control practice factor (P-factor) has generated from the existing agriculture practice of land in different slope. Initially, existing land use was categorized into agricultural and other land in major types. Then, agricultural land was sub-divided into six slope classes and assigned p-value for each respective slope class as many management activities reference with highly dependent on slope of the area. The conservation practices factor value (P-values) were assigned in different slope of agriculture practices as described in Table below.

Land Use	**Slope Gradient (%)**	**P-Factor**
Agricultural Land	0-5	0.10
	5-10	0.12
	10-20	0.14
	20-30	0.19
	30-50	0.25
	50-100	0.33
Non-agricultural Land		0.00

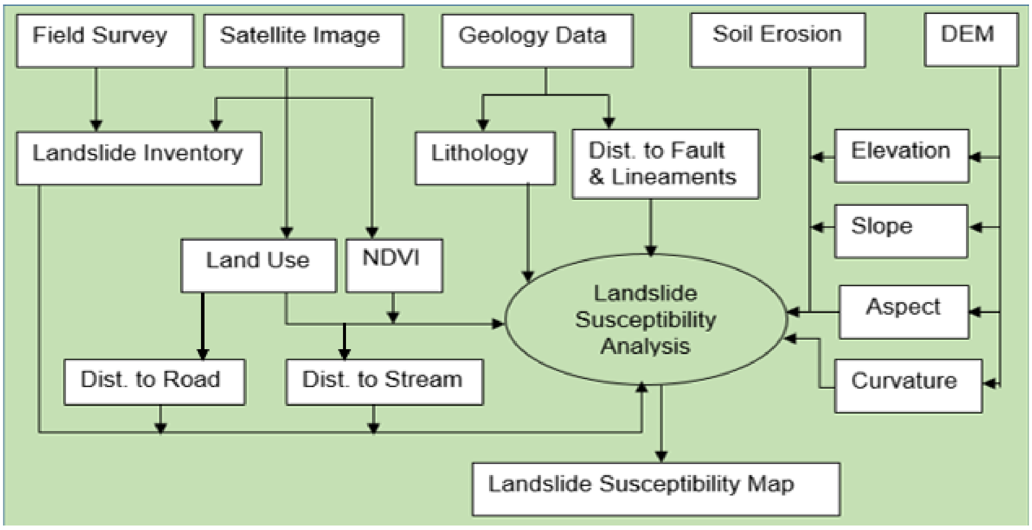
The cover-management factor (C) has normally assigned based on the existing situation of land use and simply assessment of vegetation cover rather than close analysis of agricultural cropping patterns. The cover management factor value (C-values) were assigned in different type of land use practices as described in Table below.

S.N.	Land Use	C-Factor
1	Forest	0.03
2	Shrub land	0.02
3	Grass land	0.01
4	Agriculture	0.21
5	Barren land	0.45
6	Orchard/Plantation	0.02
7	Bamboo	0.02
8	Water body	0.00
9	Built-up	0.00

The potential soil erosion map was produced from R, K, LS, P and C factor map in ArcGIS by raster multiplication through map algebra function.

Landslide Risk

Landslide susceptibility mapping (LSM) is conducted with statistical bivariate analysis using frequency ratio (FR) technique. The conceptual framework of bivariate analysis of FR model with associated the parameters of the LSM is explained in below figure.



Initially, landslide inventory map was prepared based on the on the past landslide occurrences and existing landslide from topographical map and satellite images by field visit. The total of 17 landslides sites (locations) were determined and mapped for preparing the landslide inventory map. The collected inventory landslide data was divided for generating training and validation datasets on the proportion of 70/30 %. So, these inventory data are randomly categorized into two parts; one containing 12 locations

(70%) of landslide occurrences for building the model, as training dataset and another 5 locations (30%) of landslide occurrences for validating the model performance, as the validation dataset that not directly applied in the modeling process of LSM. Landslide causative factors are identified for the assessment of susceptibility of landslides by consultation with expert view and modified with consultation with stakeholders. Total eleven causative factors affecting the occurrence of landslides were determined for LSM based on the literature review and field surveys. Slope degree, slope aspect, curvature, elevation, distance from fault line, lithology, normalized difference vegetation index (NDVI), soil erosion, distance from the stream, distance from the road, and land use were the causative factors maps and used in evaluation process. Firstly, the weight for each causative factor was determined, then landslide susceptibility indexes of these causative factor map were generated by weighted summation of causative factor in GIS environment. The weight of each causative factor is defined as the natural logarithm of the landslide density in the class over the landslide density in the factor map as follows.

$$W_i = \ln\left(\frac{density\ class}{density\ map}\right) = \ln\left(\frac{N_{pix}(S_i)/N_{pix}(N_i)}{\sum N_{pix}(S_i)/\sum N_{pix}(N_i)}\right) \quad \text{(xv)}$$

where, W_i is the priority given to a certain causative class of factor parameter. Density class is the landslide density within the parameter class, Density map is the landslide density of the entire factor map for all classes, Npix (S_i) is the number of landslide pixels in a certain class and Npix (N_i) is the total number of pixels in all classes.

The predicted ratio (PR) is used as entropy index to estimate the difference between the average shares of single causative factor with proportion from the total causative factors used in the whole system. PR of each causative factor parameter is computed based on the information coefficient of parameter with the parameter value to total value ratio.

$$PRj = \frac{FR}{\sum_{j=1}^{n} FR} \quad \text{(xvi)}$$

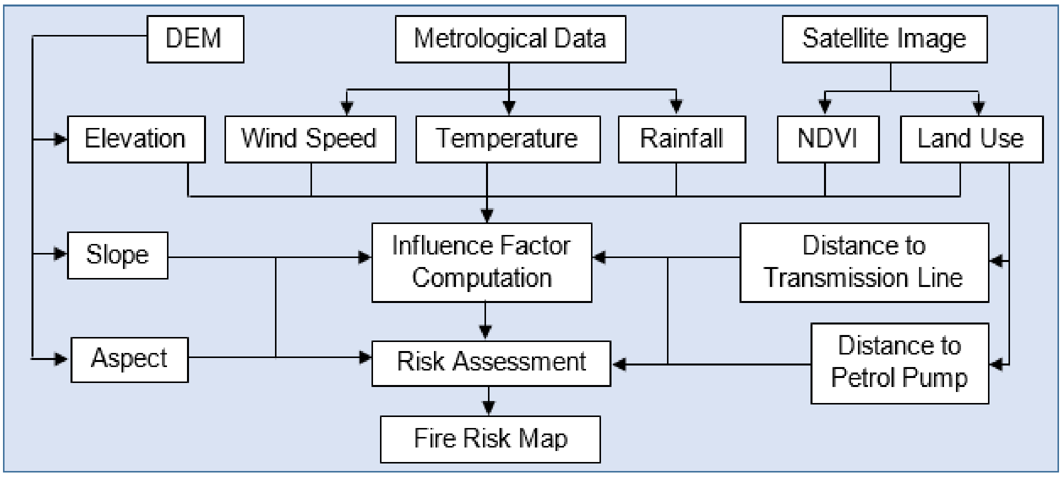
Finally, landslide susceptibility map (LSM) is computed from the frequency ratio (FR) values of parameters classes with influencing landslides as predicted ratio (PR) weight together as follows.

$$LST = \sum_{j=1}^{n} (W_j \ x \ F_i) \quad \text{(xvii)}$$

where, W_j is the weight of causative factor based on PR, F_i is the causative factor map product from FR value of i classes of causative factors j, and n is the number of causative factors. Finally, the performance of LSM has validated through the receiver operating characteristic (ROC) curve and the area under the curve (AUC).

Fire Risk

Fire risk is very important in the land use planning to manage forest resources sustainably and support in planning and management of forest for increasing environmental protection. In recent, various methods and algorithm have been successfully applied in the production of forest fire risk maps using GIS based multi-criteria decision analyses (MCDA) with satellite imaginaries. In this research, fire analysis is carried out using GIS based MCE and AHP technique shown in below figure.



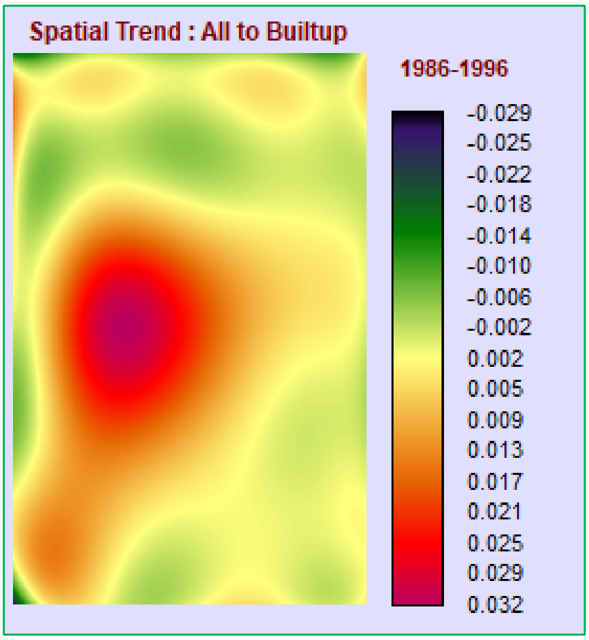
The previous fire locations were collected from the moderate-resolution imaging spectroradiometer (MODIS) satellite images (https://firms.modaps.eosdis.nasa.gov /download/ create.php) and used for the fire incidence. In this study, forest fire assessment was carried out based on the identified four categories of influencing factors such as topography-related, climate-related, vegetation-related, and human activities-related variables. These incidence fire locations were used as reference fire point for correlation process of the influencing factors. Multi-collinearity technique was applied to estimate the correlation between the incident forest fire locations with influencing factors and obtained the priority ranking influencing factors. The obtained priority values of influencing factors were normalized using the fuzzy membership function for ranking the classes within the influencing factor with the following relationship.

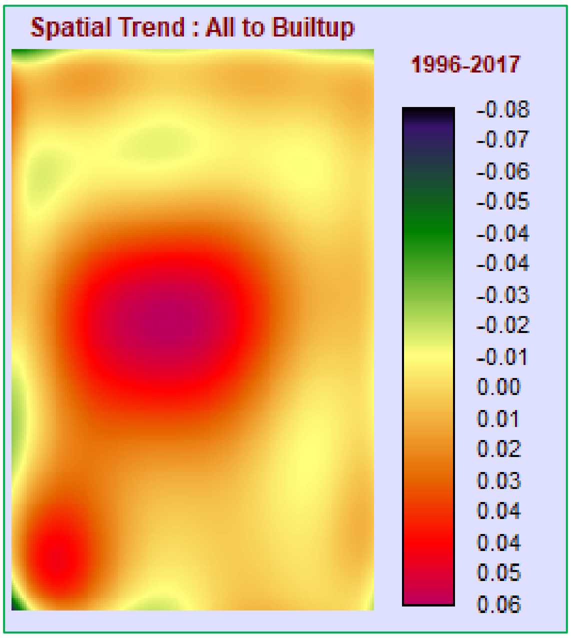
$$\mu_{i,j} = \frac{PR_{i,j}}{Max(PR_{i,j})} \quad \text{(xviii)}$$

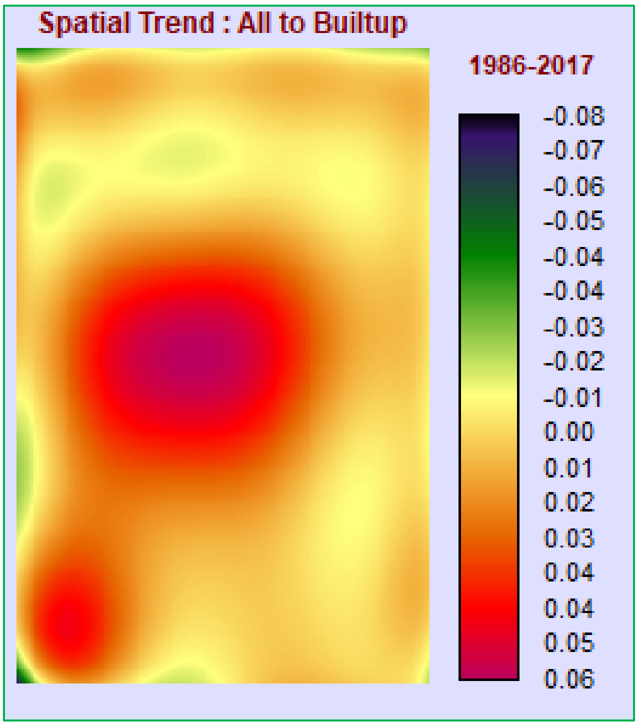
where, $\mu_{i,j}$is the fuzzy membership value of class, i of influencing factor, j and $PR_{i,j}$ is the priority value of influencing factor. Then GIS-MCDA technique was used to analyze the probability occurrence of fire risk.

Appendix-11

Spatial Change Trend in Shambhunath Municipality

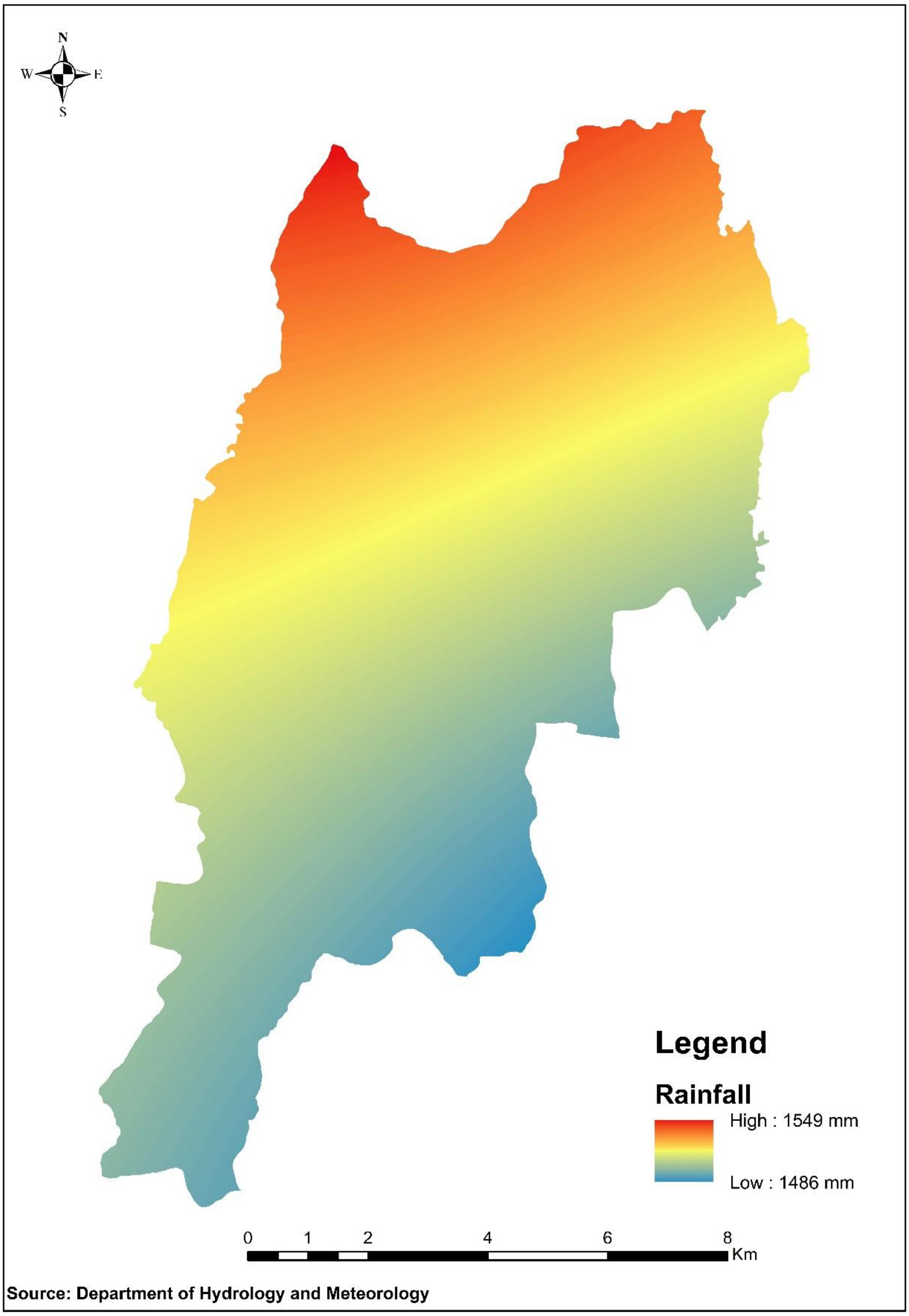






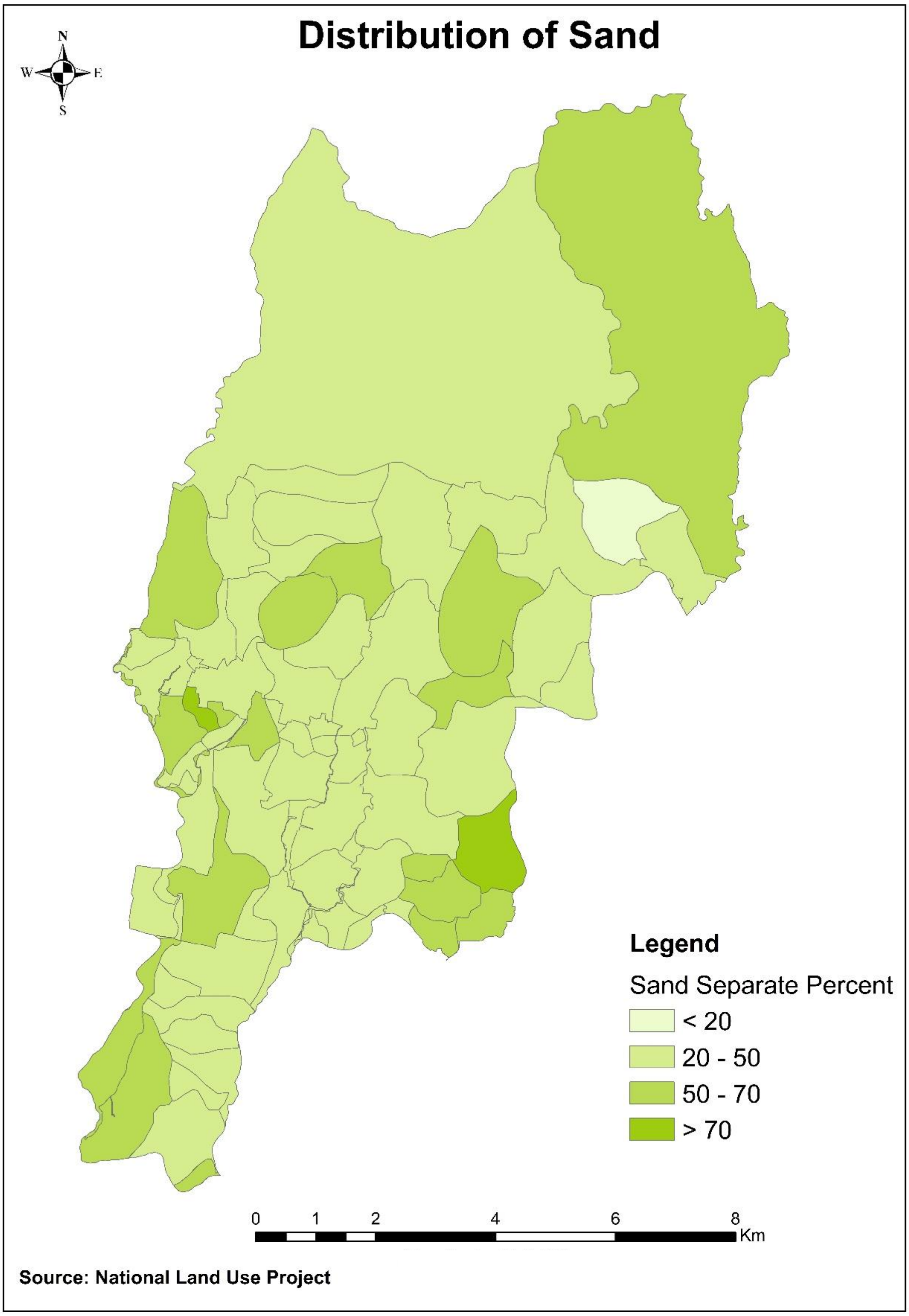
Appendix-12

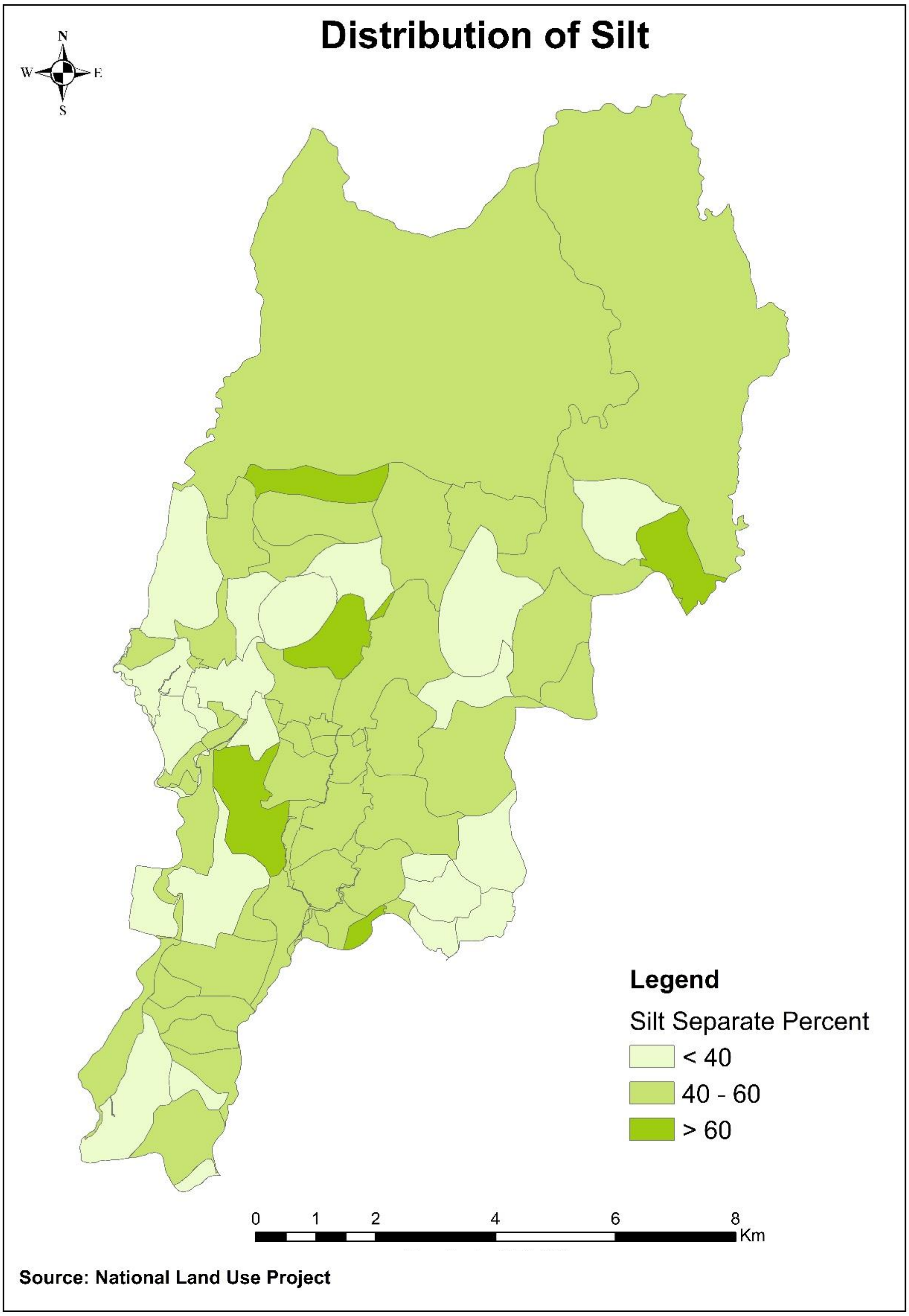
Rainfall Map

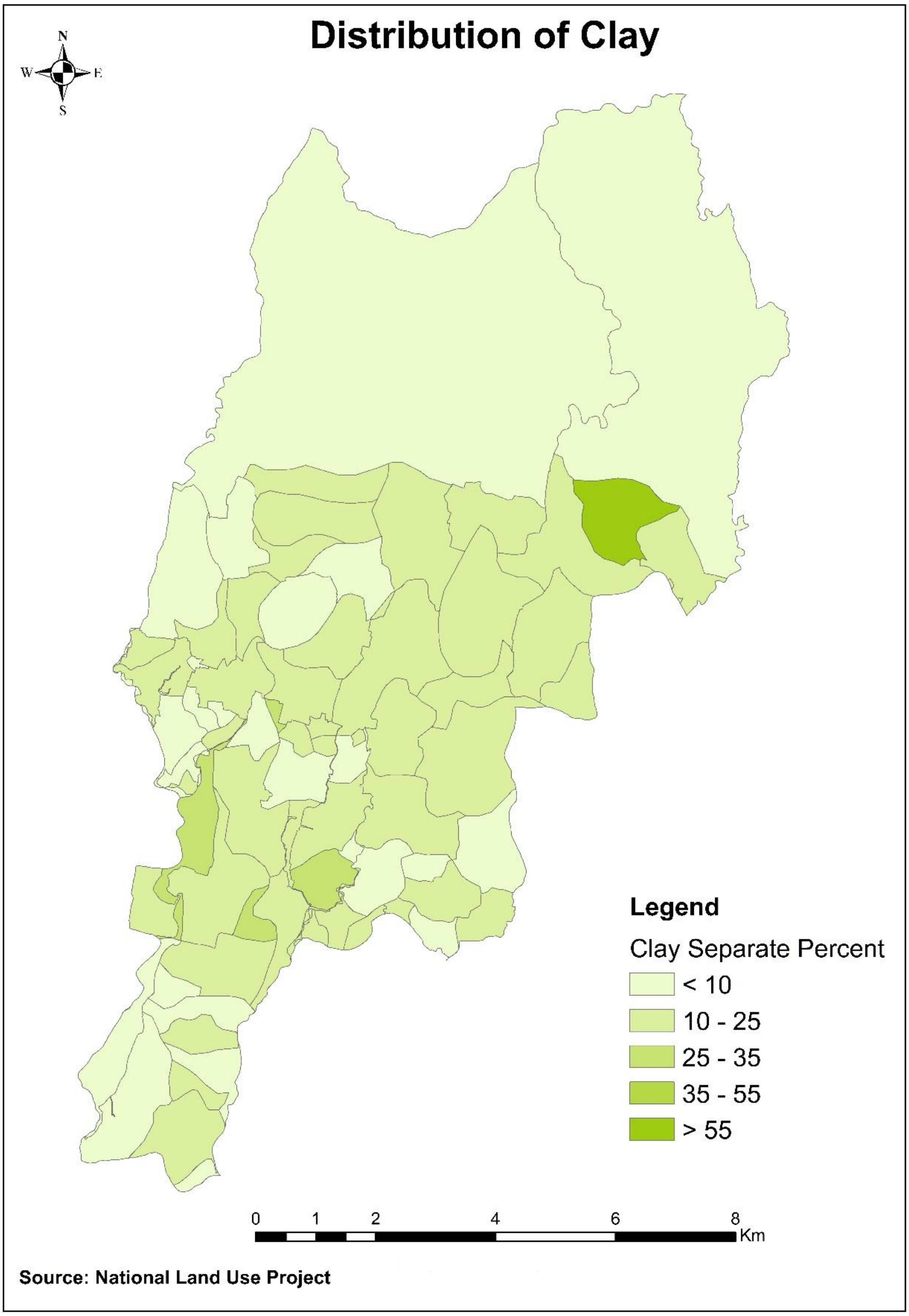


Appendix-13

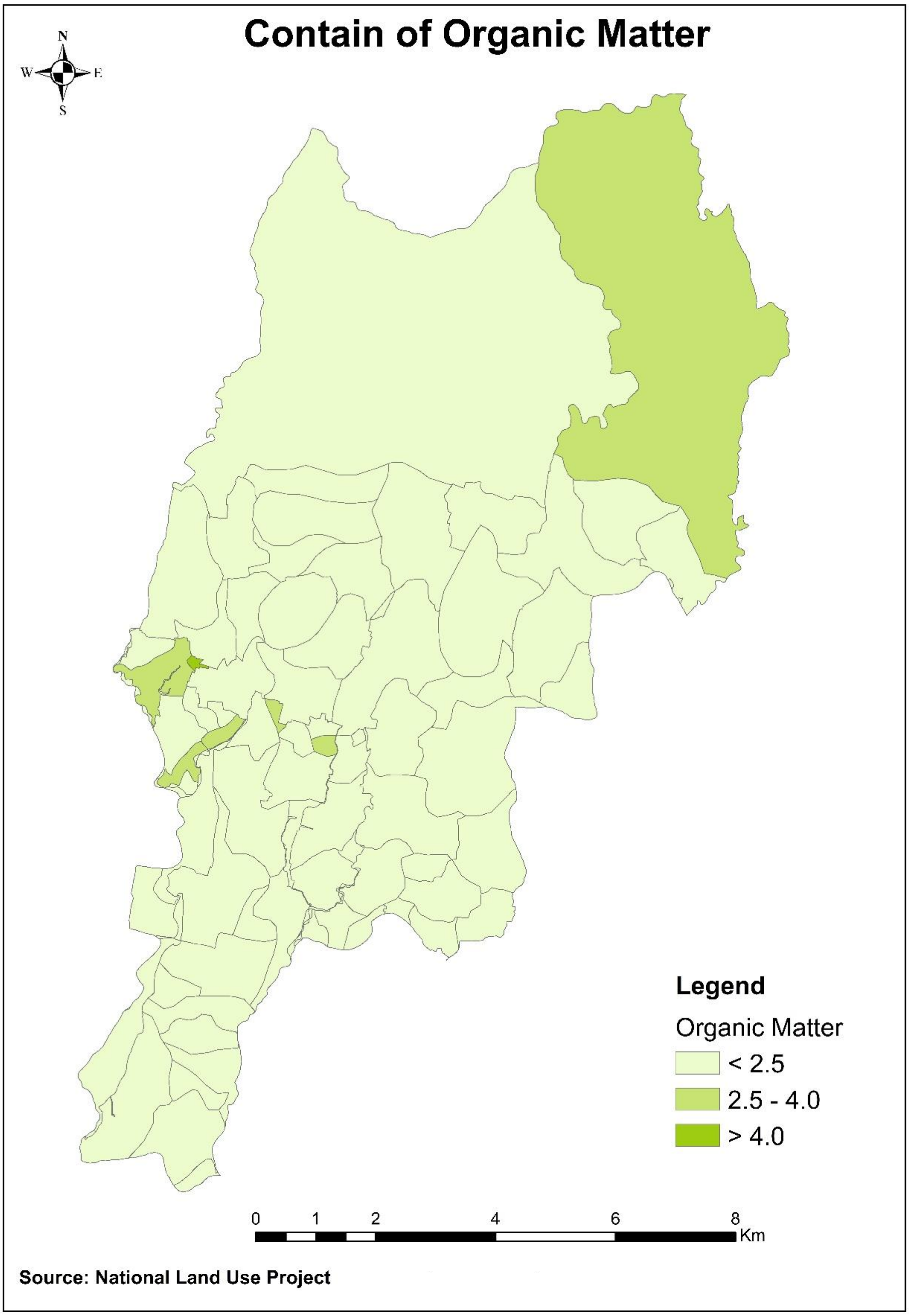
Distribution of Soil Contains




Distribution of Silt
N
W
E
S
Legend
Silt Separate Percent
< 40
40 - 60
> 60
0
1
2
4
6
8
Km
Source: National Land Use Project

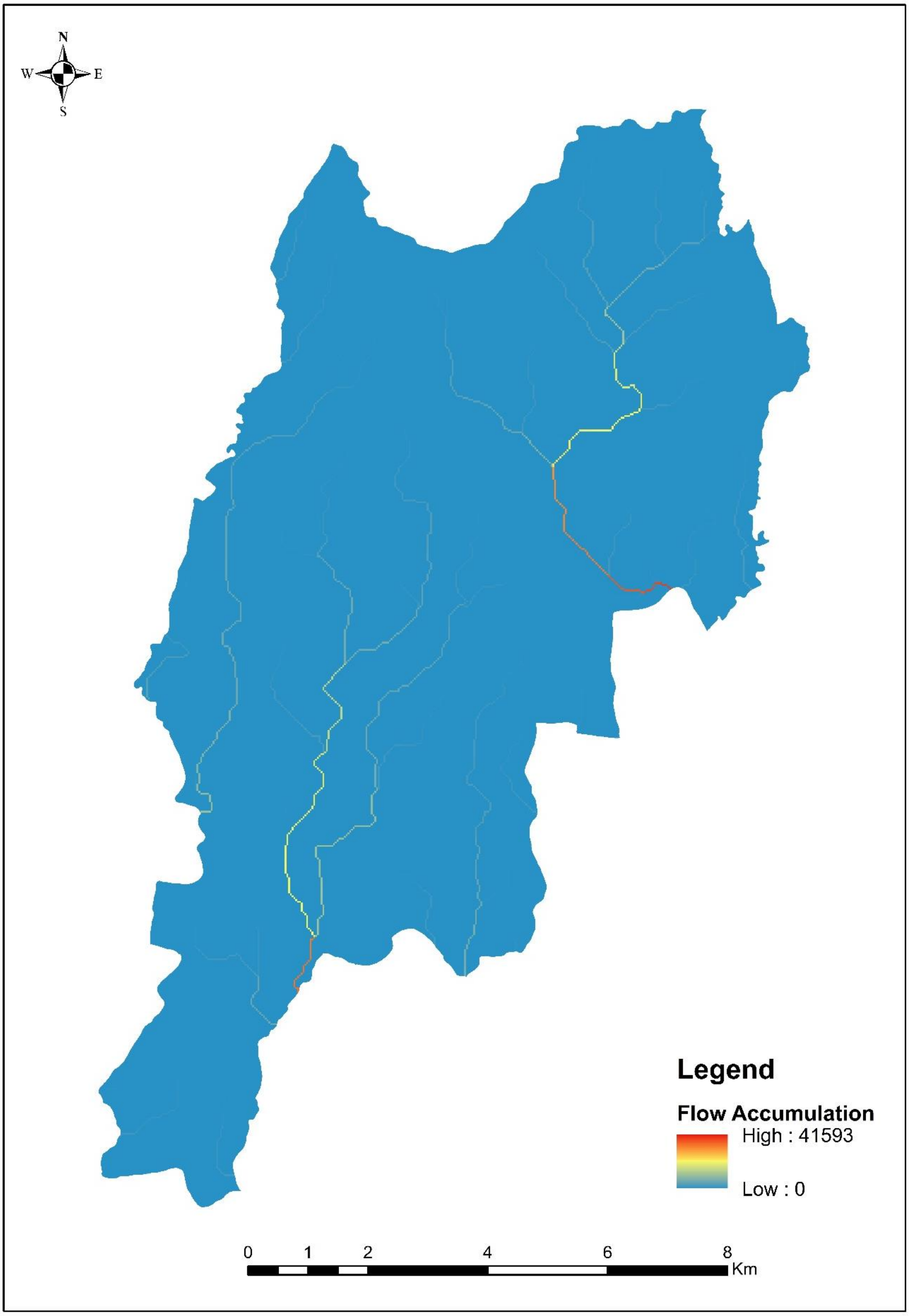


Distribution of Clay
N
W
E
S
Legend
Clay Separate Percent
< 10
10 - 25
25 - 35
35 - 55
> 55
0
1
2
4
6
8
Km
Source: National Land Use Project


Contain of Organic Matter
N
W
E
S
Legend
Organic Matter
< 2.5
2.5 - 4.0
> 4.0
0
1
2
4
6
8
Km
Source: National Land Use Project

Appendix-14

Flow Accumulation



Appendix-15

Weight Computation for Landslide Susceptibility Analysis

S.N.	Causative Factor	Classes	Class Pixel	Landslide Pixel	No. of Landslide	Frequency Ratio (FR)	Relative Frequency (RF)	Predictor Rate (PR)
1	Slope (degree)	0-5	2861836	49275	1971	0.89	0.13	0.15
		5-15	537616	120450	4818	2.01	0.30	
		15-30	614919	56900	2276	1.62	0.24	
		30-45	274736	10925	437	1.26	0.19	
		< 45	54799	1025	41	0.93	0.14	
2	Aspect	North	448957	14375	575	0.00	0.00	0.10
		East	852736	65325	2613	1.54	0.37	
		South	1918358	118325	4733	1.45	0.34	
		West	1123855	40550	1622	1.22	0.29	
3	Curvature	<-0.05	992603	83850	3354	1.58	0.40	0.09
		-0.05-0.05	2430622	21250	850	0.60	0.15	
		>0.05	920681	133475	5339	1.82	0.45	
4	Elevation (m)	< 200	3106363	139500	5580	1.31	0.46	0.07
		200-400	1233811	99075	3963	1.56	0.54	
		>400	3732	0	0	0.00	0.00	
5	Dist. to Fault line (m)	<100	91562	0	0	0.00	0.00	0.15
		100-200	88745	14075	563	1.86	0.28	
		200-500	256983	69375	2775	2.09	0.31	
		500-1000	399944	122700	4908	2.15	0.32	
		>1000	3506672	32425	1297	0.62	0.09	
6	Lithology	Alluvium	2512283	0	0	0.00	0.00	0.06
		Sediment Rock	1511659	6475	259	0.29	0.10	
		Coaly Material	322362	232100	9284	2.52	0.90	
7	Soil Erosion	Low	3122699	87100	3484	1.10	0.24	0.10
		Medium	197377	20525	821	1.68	0.37	
		High	1024060	130950	5238	1.76	0.39	
8	NDVI	<0	53443	450	18	0.58	0.12	0.11
		0-0.30	1414866	88025	3521	1.45	0.30	
		0.30-0.45	1689944	86675	3467	1.37	0.29	
		>0.45	1188050	63425	2537	1.39	0.29	
9	Land Use	Water body	141386	0	0	0.00	0.00	0.04
		Public Use	35661	0	0	0.00	0.00	
		Agriculture	2245860	0	0	0.00	0.00	
		Commercial	3420	0	0	0.00	0.00	
		Residential	101035	0	0	0.00	0.00	
		Other	40379	575	23	0.00	0.01	
		Industrial	15031	0	0	0.00	0.00	
		Forest	1761096	238000	9520	1.79	0.99	
		Cultural & Archeological	268	0	0	0.00	0.00	

S.N.	Causative Factor	Classes	Class Pixel	Landslide Pixel	No. of Landslide	Frequency Ratio (FR)	Relative Frequency (RF)	Predictor Rate (PR)
10	Dist. to Road	<200	1304451	0	0	0.00	0.00	0.08
		200-500	946963	11975	479	0.00	0.00	
		500-1000	440085	73725	5	1.88	0.54	
		>1000	1652407	152875	52	1.62	0.46	
11	Dist. to Stream	<100	2457826	237300	9492	1.64	0.95	0.04
		100-200	709774	1275	51	0.09	0.05	
		200-500	882307	0	0	0.00	0.00	
		500-1000	281989	0	0	0.00	0.00	
		>1000	12010	0	0	0.00	0.00	

Appendix-16

Fuzziness of Rank in Forest Risk Assessment

S.N.	Causative Factor	Classes	Risk	Priority	Rank
1	Slope (degree)	0-5	Very Low	0	0.00
		5-15	Low	1	0.25
		15-30	Moderate	2	0.50
		30-45	High	3	0.75
		< 45	Very High	4	1.00
2	Aspect	North	Low	1	0.25
		East	Moderate	2	0.50
		South	Very High	4	1.00
		West	High	3	0.75
3	Elevation (m)	< 200	High	3	1.00
		200-400	Moderate	2	0.67
		>400	Low	1	0.33
4	Wind Speed (km/h)	<21	Low	1	0.33
		21-23	Moderate	2	0.67
		>23	High	3	1.00
5	Temperature (^{0}C)	<35	Moderate	2	0.67
		>35	High	3	1.00
6	Annual Rainfall (mm)	<1500	Moderate	2	0.67
		>1500	High	3	1.00
7	NDVI	<0	Low	1	0.25
		0-0.30	Moderate	2	0.50
		0.30-0.45	High	3	0.75
		>0.45	Very High	4	1.00
8	Land Use	Water body	Very Low	0	0.00
		Built-up	High	3	0.75
		Agriculture	Moderate	2	0.50
		Open area	Low	1	0.25
		Forest	Very High	4	1.00
9	Dist. to Transmission Line (m)	<25	Very High	4	1.00
		25-50	High	3	0.75
		50-100	Moderate	2	0.50
		>100	Low	1	0.25
10	Dist. to Petrol Pump (m)	<100	Very High	4	1.00
		100-200	High	3	0.75
		200-500	Moderate	2	0.50
		500-1000	Low	1	0.25
		>1000	Very Low	0	0.00

Appendix-17

Weight Computation using AHP for Forest Risk Assessment

S.N.	Factors	Slope	Aspect	Elevation	Wind Speed	Temperature	Rainfall	NDVI	Land Use	Dist. to Transmission Line	Dist. to Petrol Pump	Weight
1	Slope	1	-	-	-	-	-	-	-	-	-	0.1361
2	Aspect	4	1	-	-	-	-	-	-	-	-	0.0375
3	Elevation	3	2	1		-	-	-	-	-	-	0.0343
4	Wind Speed	1	1/4	1/3	1	-	-	-	-	-	-	0.1810
5	Temperature	2	1/6	1/2	3	1	-	-	-	-	-	0.1052
6	Rainfall	4	1	1	4	2	1	-	-	-	-	0.0377
7	NDVI	4	1/4	1/2	5	3	1	1	-	-	-	0.0528
8	Land Use	2	1/2	1/3	6	4	1/2	1	1	-	-	0.0588
9	Dist. to Transmission Line	1/2	1/3	1/5	1	1/3	1/4	1/5	1/3	1	-	0.1824
10	Dist. to Petrol Pump	1/2	1/3	1/6	1	1/4	1/3	1/3	1/2	1	1	0.1742

CR = 0.06 (<0.1 Acceptable)

Appendix-18

Standard Rating of Criteria

Criterion	Land Use	Highly Suitable	Suitable	Moderate Suitable	Poor Suitable	Unsuitable
Slope	Agriculture	< 1	1-5	5-15	15-30	> 30
	Residential	1-5	5-15	< 1	15-30	> 30
	Commercial	1-5	5-15	< 1	15-30	> 30
	Industrial	1-5	5-15	< 1	15-30	>30
	Forest	>30	15-30	10-15	5-10	< 5
Land Use	Agriculture	Agriculture	Others	Forest	Residential, Public Use	Commercial, Industrial, Cultural & Archeological
	Residential	Residential, Commercial	Agriculture Others	Forest	Industrial	Public Use, Cultural & Archeological
	Commercial	Residential, Commercial	Agriculture Others	Industrial	Forest	Public Use, Cultural & Archeological
	Industrial	Residential, Commercial Industrial	Agriculture Others	Forest	Public Use	Cultural & Archeological
	Forest	Forest	Others, Agriculture	Public Use	Residential, Commercial Industrial	Cultural & Archeological
Land Form & Landscape	Agriculture	Lower & Upper Alluvial Fan	Non-dissected Ancient Lake	Dissected Ancient Lake	Moderately to Steeply Slope	River Channel, Steeply to Steeply Slope
	Residential	Non-dissected Ancient Lake	Dissected Ancient Lake	Lower & Upper Alluvial Fan	Moderately to Steeply Slope	River Channel, Steeply to Steeply Slope
	Commercial	Non-dissected Ancient Lake	Dissected Ancient Lake	Lower & Upper Alluvial Fan	Moderately to Steeply Slope	River Channel, Steeply to Steeply Slope
	Industrial	Non-dissected Ancient Lake	Dissected Ancient Lake	Lower & Upper Alluvial Fan	Moderately to Steeply Slope	River Channel, Steeply to Steeply Slope

Criterion	**Land Use**	**Highly Suitable**	**Suitable**	**Moderate Suitable**	**Poor Suitable**	**Unsuitable**
Land Capability	Agriculture	Class I	Class II	Class III	Class IV, Class V	Class VI, Class VII
	Residential	Class IV, Class V	Class III	Class II	Class I	Class VI, Class VII
	Commercial	Class IV, Class V	Class III	Class II	Class I	Class VI, Class VII
	Industrial	Class IV, Class V	Class III	Class II	Class I	Class VI, Class VII
Geology (Lithology)	Agriculture	Alluvial	Quaternary Sediments	Conglomer ate	Shale, Limestone, Schist	Metamorphic Rock
	Forest	Alluvial	Quaternary Sediments	Conglomer ate	Shale, Limestone, Schist	Metamorphic Rock
Distance to Fault Line	Residential	<10000	<5000-10000	2000-5000	1000-2000	<1000
	Commercial	<10000	<5000-10000	2000-5000	1000-2000	<1000
	Industrial	<10000	<5000-10000	2000-5000	1000-2000	<1000
Surrounding Settlement/ Commercial (m)	Residential		<200	200-500	500-1000	>1000
	Commercial		<200	200-500	500-1000	>1000
	Industrial		>1000	500-1000	<500	
	Forest		>1000	500-1000	<500	
Access to Infrastructure (m)	Residential	<200	200-500	500-1000	1000-2000	>2000
	Commercial	<200	200-500	500-1000	1000-2000	>2000
	Industrial	>1000	500-1000	<500		
	Forest	>1000	500-1000	<500		
Access to Service Centre(m)	Residential	<200	200-500	500-1000	1000-2000	>2000
	Commercial	<200	200-500	500-1000	1000-2000	>2000
Strategic Road Network(m)	Residential		>500	200-500	<200	
	Forest	>1000	500-1000	<500		
Proximity to Stream Line	Agriculture	<200	200-500	500-1000	1000-2000	>2000
	Forest	<500	500-1000	100-2000	>2000	
Population (Person per sq. km)	Residential	>2000	1000-2000	500-1000	200-500	<200
	Commercial	>10000	5000-10000	2000-5000	500-2000	<500
	Industrial	>5000	5000-2000	1000-2000	<2000	
Employment (Person per sq. km)	Residential	>500	200-500	100-200	<100	
	Commercial	>1000	500-1000	200-500	100-200	<100
	Industrial	>5000	2000-5000	1000-2000	<1000	
Soil Type	Agriculture	Mollisols	Alfisols	Inceptisols	Entisols	
	Forest	Mollisols	Alfisols	Inceptisols	Entisols	

Criterion	Land Use	Highly Suitable	Suitable	Moderate Suitable	Poor Suitable	Unsuitable
Soil Quality (Soil Fertility)	Agriculture	Very High	High	Moderate	Low	Very Low
	Forest	Very High	High	Moderate	Low	Very Low
Temperature	Agriculture	>35	25-35	15-25	5-15	<5
NDWI	Agriculture	<-0.25	-0.25-0.00	<-0.25	0.00-0.25	>0.25
NDVI	Forest	>0.45	0.30-0.45	0.00-0.30	<0	
Soil Erosion	Agriculture	Slight	Moderate	High	Very High	Serve
	Forest	Serve	Very High	High	Moderate	Slight
Heritage Landmark	Industrial	<1000	500-1000	200-500	<200	
	Forest		<500	500-1000	1000-2000	>2000
Land Value (per sq.m)	Commercial	>10000	5000-10000	2000-5000	<2000	
	Industrial	>5000	2000-5000	2000-1000	<1000	
Local Road Circulation	Commercial	<200	200-500	500-1000	1000-2000	>2000
Air Quality (Dist. from Chimney)	Residential	<1000	500-1000	200-500	<200	
Pollution (Dist. from Strategic Road)	Residential		>500	200-500	<200	
Flood	Agriculture		Low	Moderate	High	
	Forest		Low	Moderate	High	
Rainfall	Agriculture	<1000	1000-1500	1500-2000	>2000	
Soil Strength	Industrial		Stable	Moderate Stable	Poor Stable	Unstable

Appendix-19

Rating Level of Criteria for Agriculture

S.N.	Influencing Criteria	Classes	Priority	Ranking
1	Slope	<1	Highly Suitable	9
		1-5	Suitable	7
		5-15	Moderate Suitable	5
		15-30	Poor Suitable	3
		>30	Unsuitable	1
2	Soil Fertility	High	Suitable	7
		Medium	Moderate Suitable	5
		Low	Poor Suitable	3
3	Land Use	Agriculture	Highly Suitable	9
		Residential	Poor Suitable	3
		Commercial	Restricted	
		Industrial	Restricted	
		Forest	Moderate Suitable	5
		Public Use	Poor Suitable	3
		Cultural & Archeological	Restricted	
		Water body	Unsuitable	1
		Others	Suitable	7
4	NDWI	Vegetation (<-0.25)	Moderate Suitable	5
		Built-up/ Soil (-0.25-0.00)	Suitable	7
		Wetland (0.00-0.25)	Poor Suitable	3
		Waterlogging (>0.25)	Unsuitable	1
5	Land Capability	Class I	Highly Suitable	9
		Class II	Suitable	7
		Class III	Moderate Suitable	5
6	Soil Type	Mollisols	Highly Suitable	9
		Alfisols	Suitable	7
		Inceptisols	Moderate Suitable	5
		Entisols	Poor Suitable	3
7	Soil Erosion	Slight	Highly Suitable	9
		Moderate	Suitable	7
		High	Moderate Suitable	5
		Very High	Poor Suitable	3
		Serve	Unsuitable	1
8	Proximity to Water Source	<200	Highly Suitable	9
		200-500	Suitable	7
		500-1000	Moderate Suitable	5
		>1000	Poor Suitable	3

S.N.	Influencing Criteria	Classes	Priority	Ranking
9	Land Form	River Channel	Unsuitable	1
		Lower Alluvial Fan	Highly Suitable	9
		Upper Alluvial Fan	Highly Suitable	8
		Non-dissected Ancient Lake	Moderate Suitable	6
		Dissected Ancient Lake	Moderate Suitable	5
		Moderately to Steeply Mountain	Poor Suitable	4
		Steeply to Steeply Mountain	Unsuitable	2
10	Temperature	> 35^0c	Highly Suitable	9
		<35^0c	Suitable	7
11	Geology	Alluvial	Highly Suitable	9
		Coaly Material	Suitable	7
		Sediment Material	Moderate Suitable	5
12	Rainfall	>1500 mm	Poor Suitable	6
		< 1500 mm	Moderate Suitable	4

Appendix-20

Pairwise Comparison with AHP Method for Agriculture

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Weight
C1	1	-	-	-	-	-	-	-	-	-	-	-	0.1565
C2	1/3	1	-	-	-	-	-	-	-	-	-	-	0.0329
C3	1/2	2	1	-	-	-	-	-	-	-	-	-	0.0515
C4	1/3	1	1	1	-	-	-	-	-	-	-	-	0.0349
C5	1	2	3	3	1	-	-	-	-	-	-	-	0.0996
C6	1	3	5	4	1	1	-	-	-	-	-	-	0.1509
C7	1	4	2	3	1	1/3	1	-	-	-	-	-	0.0900
C8	1/3	3	2	2	1	1	2	1	-	-	-	-	0.1067
C9	1/4	2	3	3	1/2	1/2	1	1/2	1	-	-	-	0.0638
C10	1/2	3	2	2	3	1/3	2	1	2	1	-	-	0.1121
C11	1/4	2	1	2	1/3	1/2	1/3	1/3	1	1/3	1	-	0.0470
C12	5	1/2	3	1/2	1	3	2	3	1/2	2	1	1	0.0540

Consistency Ratio = 0.06< 0.10 (Acceptable)

C1 - Slope, C2 - Geology, C3 - Land Form, C4 - Temperature, C5 - NDWI, C6 -Soil Fertility, C7 -Soil Type, C8 -Land Capability, C9 –Soil Erosion, C10 -Land Use, C11 - Proximity to Water Source, & C12 - Rainfall

Appendix-21

Rating Level of Criteria for Residential

S.N.	Influencing Criteria	Classes	Priority	Ranking
1	Slope	< 1	High Suitable	9
		1-5	Suitable	7
		5-15	Moderate Suitable	5
		15-30	Poor Suitable	3
		>30	Unsuitable	1
2	Land Use	Agriculture	Suitable	7
		Residential	High Suitable	9
		Commercial	High Suitable	8
		Industrial	Moderate Suitable	5
		Forest	Poor Suitable	3
		Public Use	Unsuitable	1
		Cultural & Archeological	Unsuitable	1
		Water body	Unsuitable	1
		Others	Suitable	6
3	Proximity to Settlement/ Commercial Area	<200	Suitable	7
		200-500	Moderate Suitable	5
		500-1000	Poor Suitable	3
		>1000	Unsuitable	1
4	Proximity to Infrastructure Facilities	<200	High Suitable	9
		200-500	Suitable	7
		500-1000	Moderate Suitable	5
		1000-2000	Poor Suitable	3
		>2000	Unsuitable	1
5	Land Capability	Class III	Suitable	7
		Class II	Moderate Suitable	5
		Class I	Poor Suitable	3
6	Proximity to Service Area	<200	High Suitable	9
		200-500	Suitable	7
		500-1000	Moderate Suitable	5
		1000-2000	Poor Suitable	3
		>2000	Unsuitable	1

S.N.	Influencing Criteria	Classes	Priority	Ranking
7	Land Form	Non-dissected Ancient Lake	High Suitable	9
		Lower & Upper Alluvial Fan	Suitable	7
		Dissected Ancient Lake	Moderate Suitable	5
		Moderately to Steeply Slope	Poor Suitable	3
		River Channel, Steeply to Steeply Slope	Unsuitable	1
8	Proximity to Strategic Road	>500	Suitable	7
		200-500	Moderate Suitable	5
		<200	Poor Suitable	3
9	Proximity to Greenery Area/Recreation	<500	Suitable	7
		500-1000	Moderate Suitable	5
		>1000	Poor Suitable	3
10	Proximity to Fault line	>5000	High Suitable	9
		2000-5000	Suitable	7
		1000-2000	Moderate Suitable	5
		500-1000	Poor Suitable	3
		<500	Unsuitable	1
11	Proximity to Pollution (Air/Noise)	<1000	Suitable	7
		500-1000	Moderate Suitable	5
		200-500	Poor Suitable	3
		<200	Unsuitable	1
12	Population Density (Person Per sq.km)	>2000	High Suitable	9
		1000-2000	Suitable	7
		500-1000	Moderate Suitable	5
		200-500	Poor Suitable	3
		<200	Unsuitable	1

Appendix-22

Pairwise Comparison with AHP Method for Residential

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Weight
C1	1	-	-	-	-	-	-	-	-	-	-	-	0.1872
C2	1/7	1	-	-	-	-	-	-	-	-	-	-	0.0501
C3	1/3	1	1	-	-	-	-	-	-	-	-	-	0.0468
C4	1/2	3	3	1	-	-	-	-	-	-	-	-	0.1130
C5	1/3	4	3	1	1	-	-	-	-	-	-	-	0.0907
C6	1/2	4	1/3	1/2	1	1	-	-	-	-	-	-	0.0712
C7	1/2	3	3	2	2	2	1	-	-	-	-	-	0.0983
C8	1/2	3	2	1	3	3	1/2	1	-	-	-	-	0.1188
C9	1/3	1/2	3	1/3	2	2	1/3	1/2	1	-	-	-	0.0602
C10	1/4	1/3	1/2	1/2	1	1/2	1/4	1/3	1/2	1	-	-	0.0359
C11	1/5	1/2	1/2	1/2	1	1/2	1/5	1/3	1/3	1	1	-	0.0437
C12	1/3	1	1	1/2	1/2	1	1/2	3	3	2	2	1	0.0841

Consistency Ratio = 0.09< 0.10 (Acceptable)

C1- Slope, C2- Land Form, C3- Land Capability, C4 - Proximity to Service Area, C5 - Proximity to Infrastructure Facilities, C6 - Proximity to Strategic Road Network, C7 - Land Use, C8 - Proximity to Settlement and Commercial Area, C9 - Proximity to Greenery and Recreation Area, C10 - Proximity to Pollution (Air/Noise), C11 - Proximity to Fault line, & C12 - Population Density

Appendix-23

Rating Level of Criteria for Commercial

S.N.	Influencing Criteria	Classes	Priority	Ranking
1	Slope	< 1	High Suitable	9
		1-5	Suitable	7
		5-15	Moderate Suitable	5
		15-30	Poor Suitable	3
		>30	Unsuitable	1
2	Land Use	Agriculture	Suitable	7
		Residential	High Suitable	9
		Commercial	High Suitable	8
		Industrial	Moderate Suitable	5
		Forest	Poor Suitable	3
		Public Use	Unsuitable	1
		Cultural & Archeological	Unsuitable	1
		Waterbury	Unsuitable	1
		Others	Suitable	6
3	Proximity to Settlement Area	<200	Suitable	7
		200-500	Moderate Suitable	5
		500-1000	Poor Suitable	3
		>1000	Unsuitable	1
4	Proximity to Infrastructure Facilities	<200	High Suitable	9
		200-500	Suitable	7
		500-1000	Moderate Suitable	5
		1000-2000	Poor Suitable	3
		>2000	Unsuitable	1
5	Land Capability	Class III	Suitable	7
		Class II	Moderate Suitable	5
		Class I	Poor Suitable	3
6	Proximity to Service Area	<200	High Suitable	9
		200-500	Suitable	7
		500-1000	Moderate Suitable	5
		1000-2000	Poor Suitable	3
		>2000	Unsuitable	1
7	Land Form	Non-dissected Ancient Lake	High Suitable	9
		Lower & Upper Alluvial Fan	Suitable	7
		Dissected Ancient Lake	Moderate Suitable	5
		Moderately to Steeply Slope	Poor Suitable	3
		River Channel, Steeply to Steeply Slope	Unsuitable	1

S.N.	Influencing Criteria	Classes	Priority	Ranking
8	Proximity to Local Road Circulation	<200	High Suitable	9
		200-500	Suitable	7
		500-1000	Moderate Suitable	5
		1000-2000	Poor Suitable	3
		>2000	Unsuitable	1
9	Land Value	>10000	High Suitable	9
		5000-10000	Suitable	7
		2000-5000	Moderate Suitable	5
		<2000	Poor Suitable	3
10	Proximity to Fault line	>5000	High Suitable	9
		2000-5000	Suitable	7
		1000-2000	Moderate Suitable	5
		500-1000	Poor Suitable	3
		<500	Unsuitable	1
11	Proximity to Air Quality	<1000	Suitable	7
		500-1000	Moderate Suitable	5
		200-500	Poor Suitable	3
		<200	Unsuitable	1
12	Population Density (Person Per sq.km)	>10000	High Suitable	9
		5000-10000	Suitable	7
		2000-5000	Moderate Suitable	5
		500-2000	Poor Suitable	3
		<500	Unsuitable	1
13	Employment(Person Per sq.km)	>1000	High Suitable	9
		500-1000	Suitable	7
		200-500	Moderate Suitable	5
		100-200	Poor Suitable	3
		<100	Unsuitable	1

Appendix-24

Pairwise Comparison with AHP Method for Commercial

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Weight
C1	1	-	-	-	-	-	-	-	-	-	-	-	0.1833
C2	1/7	1	-	-	-	-	-	-	-	-	-	-	0.0552
C3	1/3	1	1	-	-	-	-	-	-	-	-	-	0.0589
C4	1/2	3	3	1	-	-	-	-	-	-	-	-	0.1059
C5	1/3	4	3	1	1	-	-	-	-	-	-	-	0.0775
C6	1/2	4	1/3	1/2	1	1	-	-	-	-	-	-	0.0662
C7	1/2	3	3	2	2	2	1	-	-	-	-	-	0.1488
C8	1/2	3	2	1	3	3	1/2	1	-	-	-	-	0.1095
C9	1/3	1/2	3	1/3	2	2	1/3	1/2	1	-	-	-	0.0698
C10	1/4	1/3	1/2	1/2	1	1/2	1/4	1/3	1/2	1	-	-	0.0333
C11	1/5	1/2	1/2	1/2	1	1/2	1/5	1/3	1/3	1	1	-	0.0373
C12	1/3	1	1	1/2	1/2	1	1/2	2	0	0	1	1	0.0544

Consistency Ratio = 0.07< 0.10 (Acceptable)

C1 - Slope, C2 - Land Form, C3 - Land Capability, C4 –Land Value, C5 - Proximity to Infrastructure Facilities, C6 - Proximity to Commercial Route, C7 - Land Use, C8 - Proximity to Settlement Area, C9 - Proximity to Greenery and Recreation Area, C10 - Proximity to Pollution (Air Quality), C11 - Proximity to Fault line, & C12 - Population Density/Employment

Appendix-25

Rating Level of Criteria for Industrial

S.N.	Influencing Criteria	Classes	Priority	Ranking
1	Slope	< 1	High Suitable	9
		1-5	Suitable	7
		5-15	Moderate Suitable	5
		15-30	Poor Suitable	3
		>30	Unsuitable	1
2	Land Use	Agriculture	Suitable	7
		Residential	High Suitable	9
		Commercial	High Suitable	8
		Industrial	High Suitable	5
		Forest	Poor Suitable	3
		Public Use	Unsuitable	1
		Cultural & Archeological	Unsuitable	1
		Waterbury	Unsuitable	1
		Others	Moderate Suitable	6
3	Proximity to Settlement/ Commercial Area	>1000	Suitable	7
		500-1000	Moderate Suitable	5
		<500	Poor Suitable	3
4	Proximity to Infrastructure Facilities	<500	High Suitable	9
		500-1000	Suitable	7
		>500	Moderate Suitable	5
5	Land Capability	Class III	Suitable	7
		Class II	Moderate Suitable	5
		Class I	Poor Suitable	3
6	Load Capacity	Stable	Suitable	7
		Moderate Stable	Moderate Suitable	5
		Poor Stable	Poor Suitable	3
		Unstable	Unsuitable	1
7	Land Form	Non-dissected Ancient Lake	High Suitable	9
		Lower & Upper Alluvial Fan	Suitable	7
		Dissected Ancient Lake	Moderate Suitable	5
		Moderately to Steeply Slope	Poor Suitable	3
		River Channel, Steeply to Steeply Slope	Unsuitable	1
8	Proximity to Strategic Road Network	<500	High Suitable	9
		500-1000	Suitable	7
		1000-2000	Moderate Suitable	5
		>2000	Poor Suitable	3
9	Land Value	>5000	High Suitable	9
		2000-5000	Suitable	7
		2000-1000	Moderate Suitable	5
		<1000	Poor Suitable	3

S.N.	Influencing Criteria	Classes	Priority	Ranking
10	Proximity to Fault line	>5000	High Suitable	9
		2000-5000	Suitable	7
		1000-2000	Moderate Suitable	5
		500-1000	Poor Suitable	3
		<500	Unsuitable	1
11	Proximity to Conservation Area/ Heritage Site	>1000	High Suitable	9
		500-1000	Suitable	7
		200-500	Moderate Suitable	5
		<200	Poor Suitable	3
12	Population Density (Person Per sq.km)	>5000	High Suitable	9
		5000-2000	Suitable	7
		1000-2000	Moderate Suitable	5
		<2000	Poor Suitable	3
13	Employment (Person Per sq.km)	>5000 (non-industrial)	High Suitable	9
		2000-5000	Suitable	7
		1000-2000	Moderate Suitable	5
		<100	Poor Suitable	3

Appendix-26

Pairwise Comparison with AHP Method for Industrial

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Weight
C1	1	-	-	-	-	-	-	-	-	-	-	-	0.1884
C2	1/5	1	-	-	-	-	-	-	-	-	-	-	0.0649
C3	1/2	1/2	1	-	-	-	-	-	-	-	-	-	0.0509
C4	1/2	2	2	1	-	-	-	-	-	-	-	-	0.1034
C5	1/5	2	3	1/2	1	-	-	-	-	-	-	-	0.0904
C6	1/3	2	2	1/2	1	1	-	-	-	-	-	-	0.1000
C7	1/2	1	3	2	2	2	1	-	-	-	-	-	0.1214
C8	1/4	3	2	1/2	1/3	1/3	1/3	1	-	-	-	-	0.0763
C9	1/2	1/3	2	1/2	1/4	1/3	1/2	1/2	1	-	-	-	0.0636
C10	1/2	1	1/2	1/2	1	1/3	1/2	1/2	1/2	1	-	-	0.0514
C11	1/3	1/2	1/2	1/2	1	1/4	1/2	1/2	1/3	1	1	-	0.0453
C12	1/3	1	1	1/2	1/2	1	1/2	1/3	1/2	1/2	1/2	1	0.0439

Consistency Ratio = 0.09< 0.10 (Acceptable)

C1 - Slope, C2 - Land Form, C3 - Load Capacity, C4 - Land Capability, C5 - Proximity to Infrastructure Facilities, C6 - Proximity to Strategic Road Network, C7 - Land Use, C8 - Proximity to Settlement/Commercial Area, C9 - Land Value, C10 - Proximity to Conservation Area/Heritage Site, C11 - Proximity to Fault line, & C12 - Population Density/Employment

Appendix-27

Rating Level of Criteria for Forest

S.N.	Influencing Criteria	Classes	Priority	Ranking
1	Slope	<5	Unsuitable	1
		5-10	Poor Suitable	3
		10-15	Moderate Suitable	5
		15-30	Suitable	7
		>30	Highly Suitable	9
2	Soil Fertility	High	Suitable	7
		Medium	Moderate Suitable	5
		Low	Poor Suitable	3
3	Land Use	Agriculture	Highly Suitable	7
		Residential	Poor Suitable	3
		Commercial	Restricted	
		Industrial	Restricted	
		Forest	Moderate Suitable	9
		Public Use	Poor Suitable	3
		Cultural & Archeological	Restricted	
		Water body	Unsuitable	1
		Others	Suitable	7
4	NDVI	Dense Vegetation (> 0.45)	Highly Suitable	9
		Sparse Vegetation (0.30-0.45)	Suitable	7
		Built-up/ Soil/Agriculture (-0.25-0.00)	Moderate Suitable	5
		Waterbody (>0.00)	Poor Suitable	3
5	Flood Plain	High	Unsuitable Suitable	1
		Moderate	Poor Suitable	3
		Low	Moderate Suitable	5
		No Risk	Suitable	7
6	Soil Type	Mollisols	Highly Suitable	9
		Alfisols	Suitable	7
		Inceptisols	Moderate Suitable	5
		Entisols	Poor Suitable	3
7	Soil Erosion	Serve	Highly Suitable	9
		Very High	Suitable	7
		High	Moderate Suitable	5
		Moderate	Poor Suitable	3
		Slight	Unsuitable	1
8	Proximity to Stream Network	<200	Highly Suitable	9
		200-500	Suitable	7
		500-1000	Moderate Suitable	5
		>1000	Poor Suitable	3

S.N.	Influencing Criteria	Classes	Priority	Ranking
9	Land Form	River Channel	Unsuitable	1
		Lower Alluvial Fan	Poor Suitable	3
		Upper Alluvial Fan	Poor Suitable	3
		Non-dissected Ancient Lake	Moderate Suitable	5
		Dissected Ancient Lake	Moderate Suitable	5
		Moderately to Steeply Mountain	Suitable	7
		Steeply to Steeply Mountain	Suitable	6
10	Proximity to Strategic Road Network	>1000	Suitable	7
		500-1000	Moderate Suitable	5
		<500	Poor Suitable	3
11	Geology	Alluvial	Poor Suitable	3
		Coaly Material	Suitable	7
		Sediment Material	Highly Suitable	9
12	Proximity to Settlement Area/ Heritage Site	<500	Suitable	7
		500-1000	Moderate Suitable	5
		>1000	Poor Suitable	3

Appendix-28

Pairwise Comparison with AHP Method for Forest

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Weight
C1	1	0	0	0	0	0	0	0	0	0	0	0	0.1447
C2	1/7	1	0	0	0	0	0	0	0	0	0	0	0.0871
C3	1/3	1	1	0	0	0	0	0	0	0	0	0	0.0434
C4	1/2	3	3	1	0	0	0	0	0	0	0	0	0.0480
C5	1/3	4	3	1	1	0	0	0	0	0	0	0	0.0691
C6	1/2	4	1/3	1/2	1	1	0	0	0	0	0	0	0.0998
C7	1/2	3	3	2	2	2	1	0	0	0	0	0	0.0911
C8	1/2	3	2	1	3	3	1/2	1	0	0	0	0	0.0382
C9	1/3	1/2	3	1/3	2	2	1/3	1/2	1	0	0	0	0.0778
C10	1/4	1/3	1/2	1/2	1	1/2	1/4	1/3	1/2	1	0	0	0.0364
C11	1/5	1/2	1/2	1/2	1	1/2	1/5	1/3	1/3	1	1	0	0.0954
C12	2	1	3	2	3	3	2	4	3	5	2	1	0.1690

Consistency Ratio = 0.07 < 0.10 (Acceptable)

C1 - Slope, C2 - Soil, C3 - Geology, C4 - Land Form, C5 - Flood Plain, C6 - Soil Erosion, C7 - Land Use, C8 - Proximity to Strategic Road Network, C9 - Proximity to Stream Network, C10 - Proximity to Settlement Area/Heritage Site, C11 – NDVI, & C12 – Soil Fertility

Appendix-29

Planning Guideline for Physical Development Plan

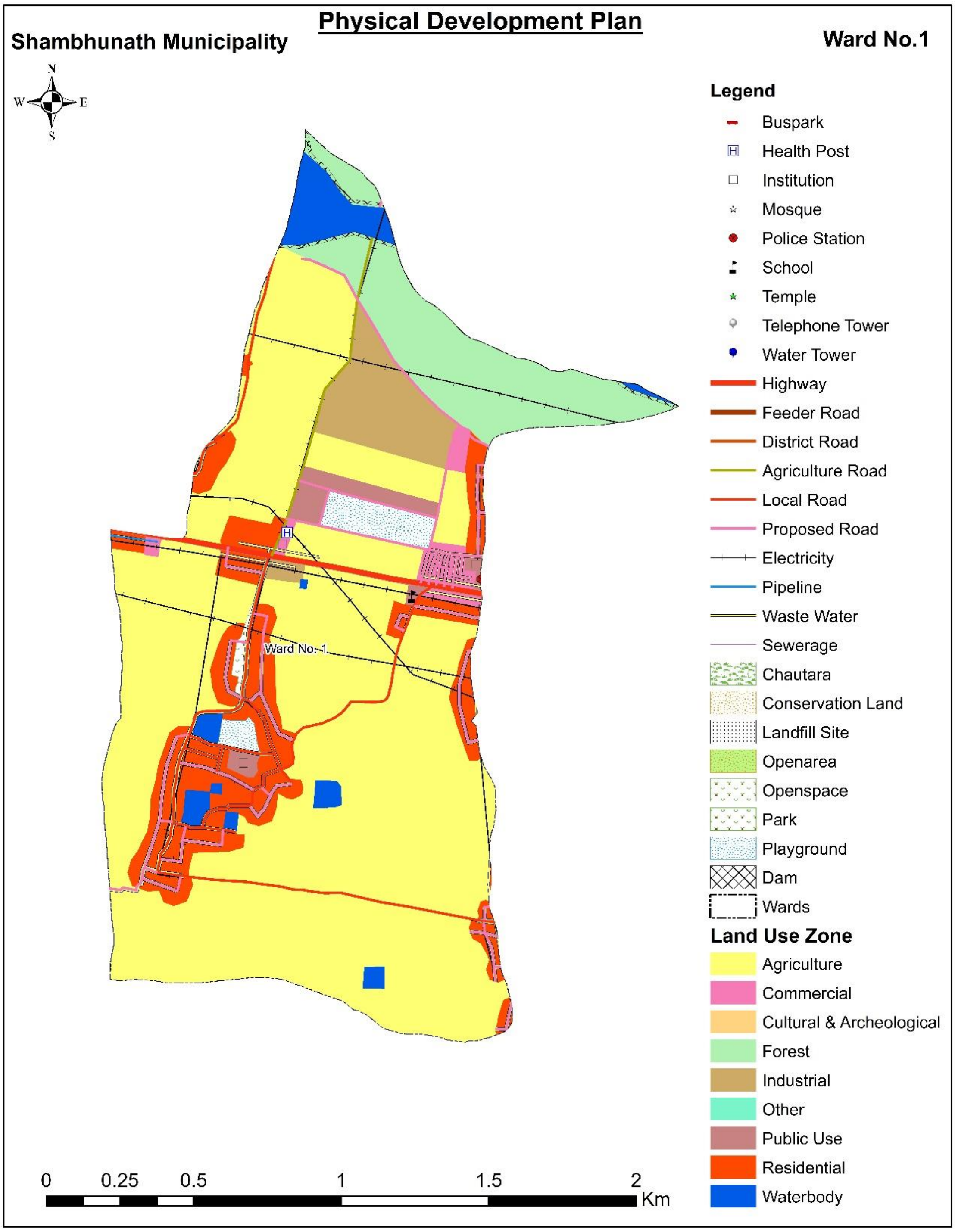
S.N.	Type of Infrastructure	Norms	Standards			Space Requirement	Source
A. Physical Infrastructure							
1	Road	Highway, Feeder, District, Agriculture/Development, Local and Street; All or 90% of household are within 1km from motor able road	Type	ROW	Setback	20% of the total built up area	
			Highway	50	6		Nepal Road Standard, 2070
			Feeder	30	6		
			District	20	6		
			Agriculture / Development	15	3		Nepal Rural Road Standard, 2071
			Local	10	1.5		Nepal Urban Road Standard, 2076
			Street	6	1.5		Settlement, Development, Urban Planning and Building Construction Primary Guideline, 2072
2	Water Supply	80% household have metered house connection and distribution	Quantity: 80-100 lpcd				Planning Norms and Standards, 2013
			Minimum diameter of distribution pipe: 80mm				
		Overhead water tank with Treatment Plant (lab, dosing and guardhouse) with storage facility: Reservoir (24hrs requirement)				0.5 ha per site	

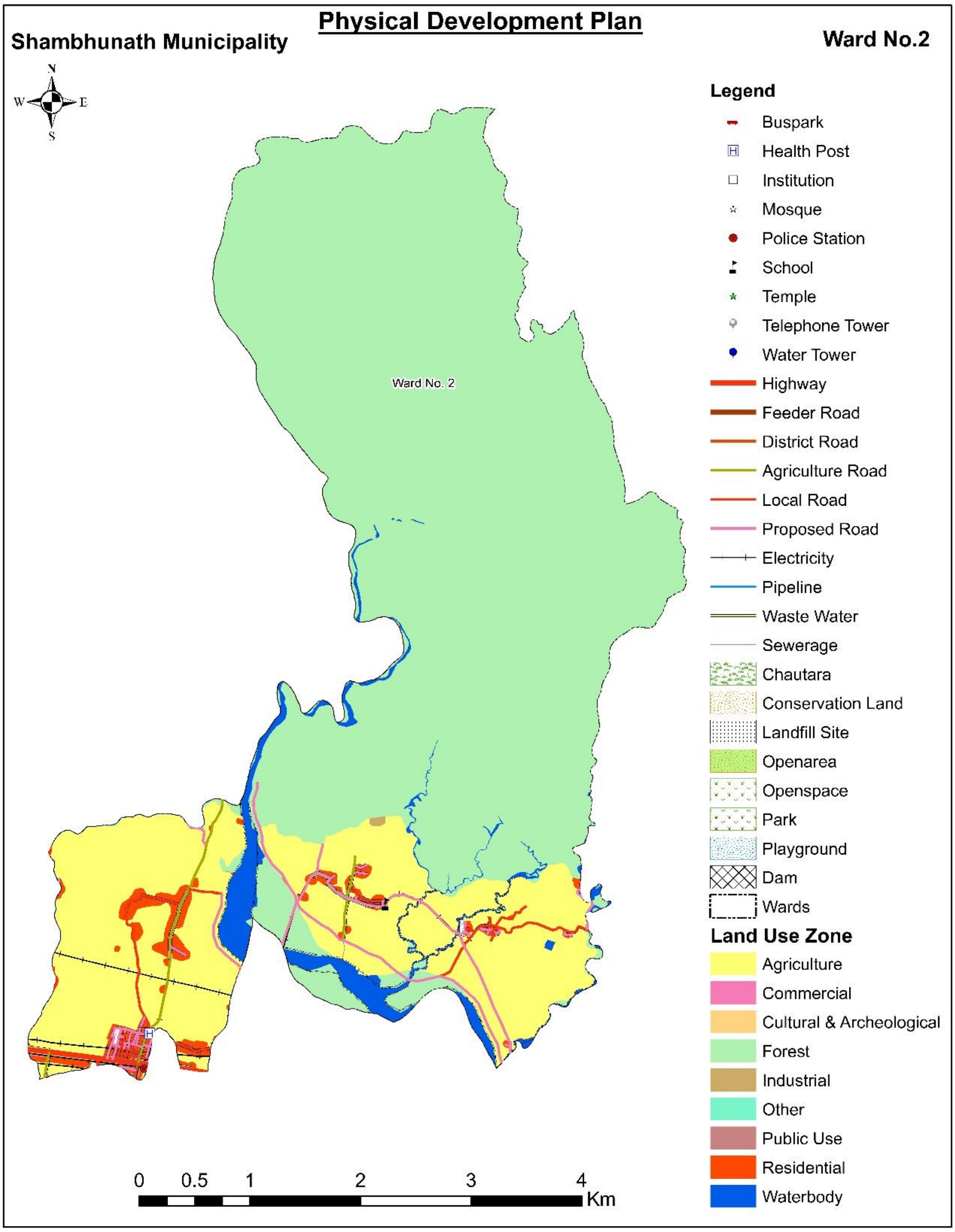
3	Sanitation / Sewerage system Storm Water Drainage system	Public sewer system (septic tanks)	Min diameter of trunk line: 200mm	0.01ha – 0.02ha per site	Planning Norms and Standards, 2013
		Treatment plant		1 ha per site	
4	Solid Waste Management System	Sanitary Landfill Site (Small as Transfer Station)	1 Station for 1 Ward	1 ha per site (if there are recycling platform, compost plant and window composting etc)	Planning Norms and Standards,2013
5	Electricity Supply System	National grid supply line	Power access to 100% coverage		Planning Norms and Standards, 2013
			Transmission Tower	80 - 100 sq. m	
			Distribution Tower	20 - 25 sq. m	
		Alternative energy (panels, battery 400AH)	150 – 200 Watt Solar Home System		
6	Tele-communication	Landline/mobile	100% coverage Telephone Exchange with a capacity of 6500 line Capacity	0.02 ha per site	Planning Norms and Standards, 2013
B. Social Infrastructure					
7	Educational Institution	Primary	1 per 3000 population at a distance of 0.4–0.8 km	0.2 ha per site	Planning Norms and Standards, 2013
		Secondary	1 per 7500 population at a distance of 30min in public transportation	0.65 ha per site	
		Campus	1 per 25000 population at a distance of 45 min in public transportation	1 ha per site	
8	Health Institution	Health post	1 per 5000 population	0.15 ha per site	Planning Norms and Standards,2013
		Primary Health Center	1 per 20000 population (5-15 beds)	0.25 ha per site	
		Hospital	1per 50000 population (25-50 beds)	1.3 ha per site	

9	Open Space	Total Coverage	5% of total built-up area		Planning Norms and Standards,2013
		Neighborhood Park (with play equipment)	1 per 800 population	0.4 ha per site	
		Local Park	1 per 10000 population	1 ha per site	
		Community Park	1 per 20000 population	1.5 ha per site	
		Parade Ground	1	2 ha per site	Planning Norms and Standards,2013
10	Fire Stations	Central Level	1 fire station	1 ha per site	Planning Norms and Standards, 2013
11	Security	Police Post	1 per 10,000 population	0.1 ha per site	Planning Norms and Standards, 2013
		Police Station	1 per 40,000 population	0.5 ha per site	
12	Old age home, Orphanage	Community level	1 per 10000 population	0.3 ha per site	Planning Norms and Standards, 2013
		Central Level	1 per 25000 population	0.5 ha per site	
13	Library	Community level	1 per 10000 population	0.5 ha per site	Planning Norms and Standards, 2013
		Central Level	1 per 50000 population	1 ha per site	
C. Economic Infrastructure					
14	Multipurpose Hall	Central Level	1 per 10000 population	0.2 ha per site	Planning Norms and Standards, 2013
15	Sport Complex	Central Level (Football ground, Volleyball, Swimming Pool, etc.)	1 per 50,000 population	1 ha – 3 ha per site	Planning Norms and Standards, 2013
16	Vegetable Market	Neighborhood Level	1 Wholesale	0.5 ha per site	Planning Norms and Standards, 2013
			1 Retail	0.2 ha per site	
			1 Slaughter House for 6000 population	0.3 ha per site	
17	Transportation system	Bus Terminal	1 parking lot for 100 buses	2 ha per site	Planning Norms and Standards, 2013

Appendix-30

Physical Development Plan

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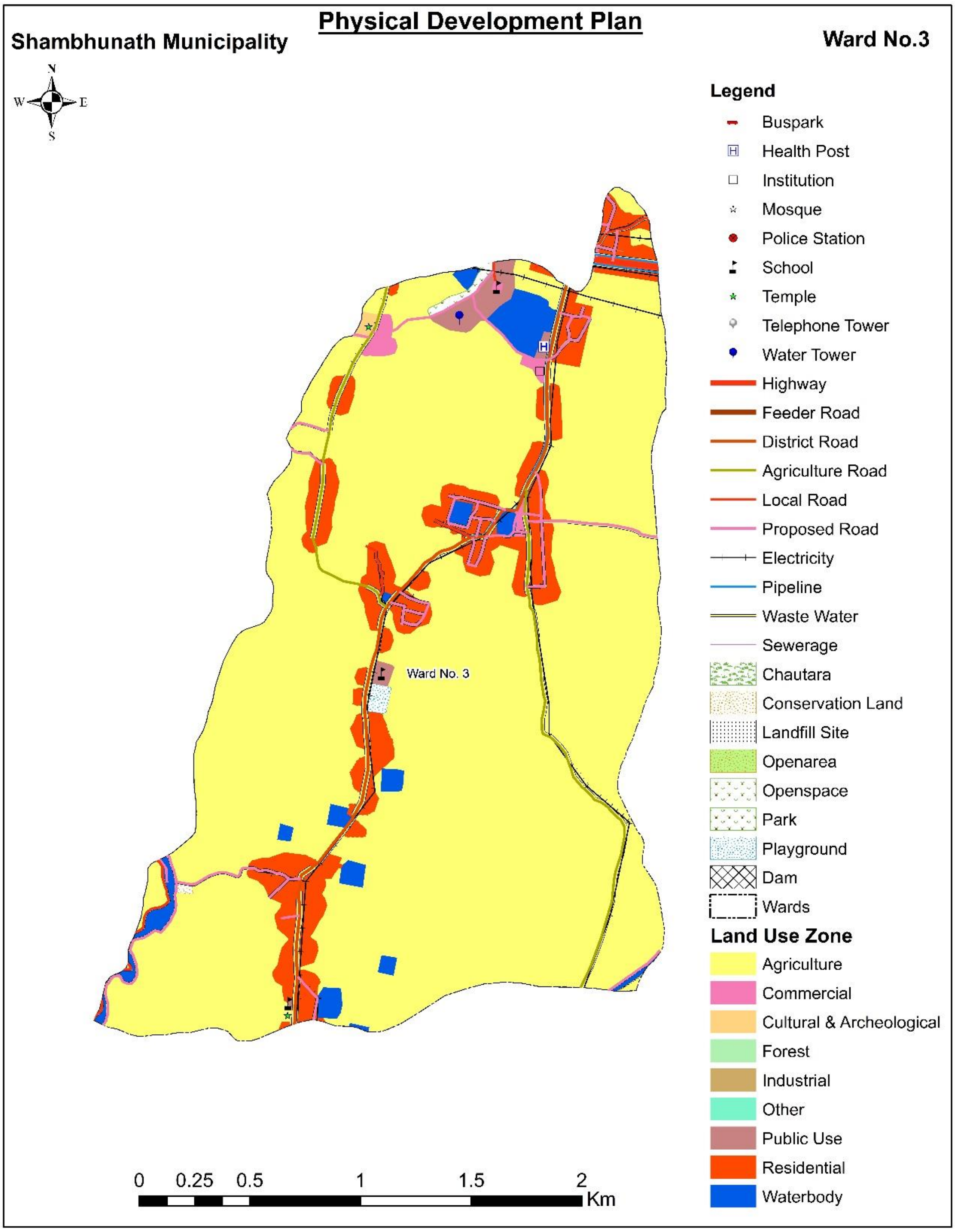
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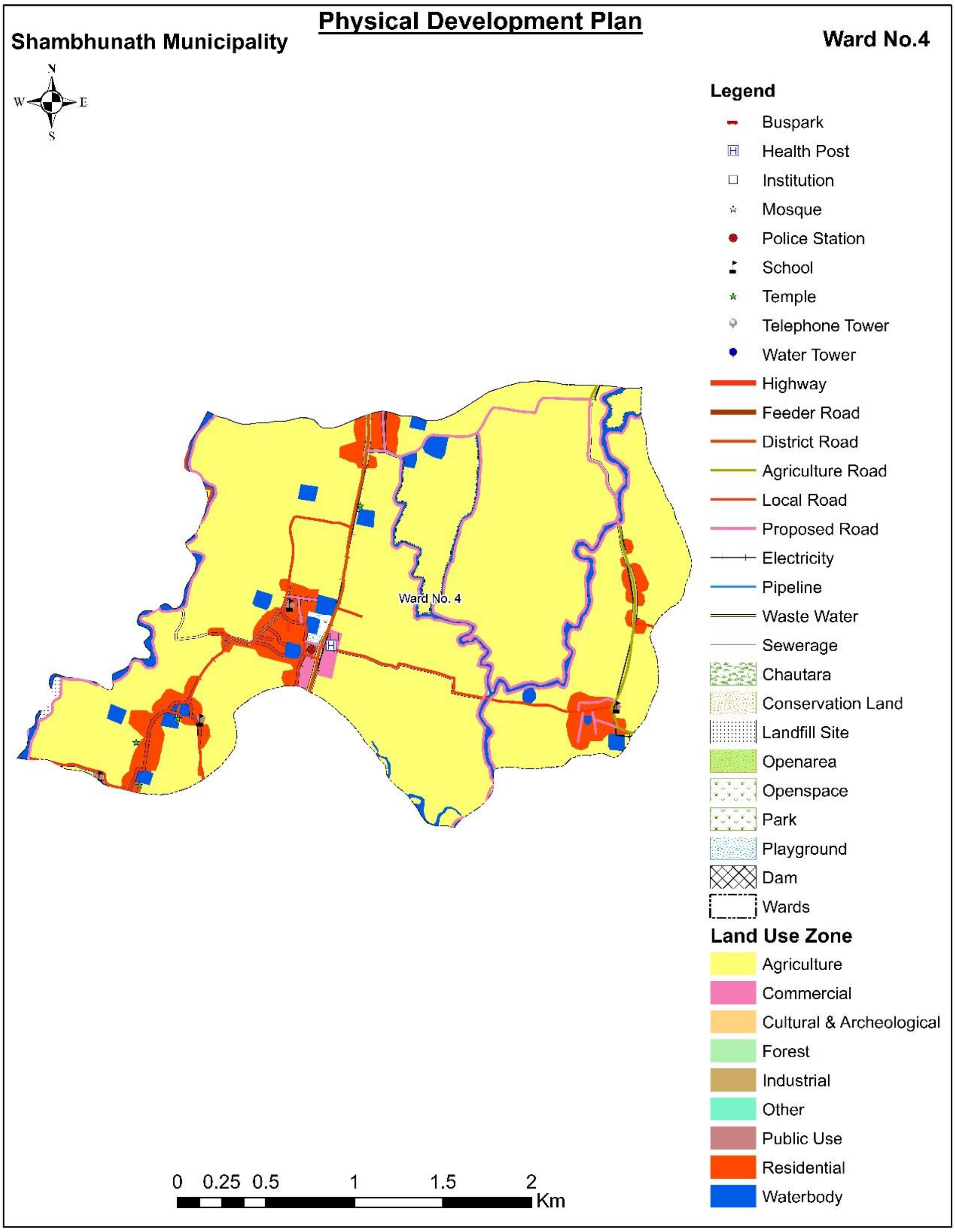

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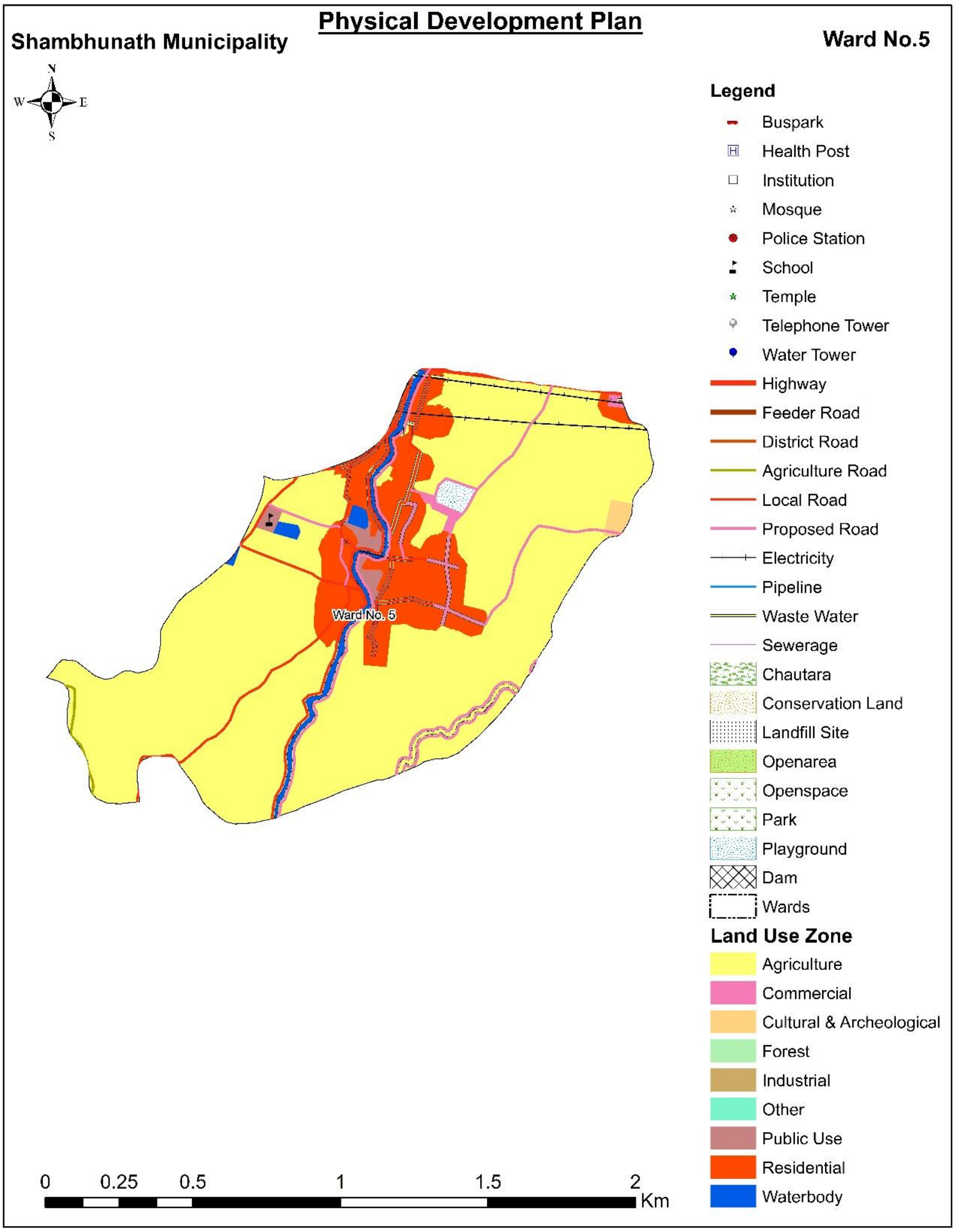
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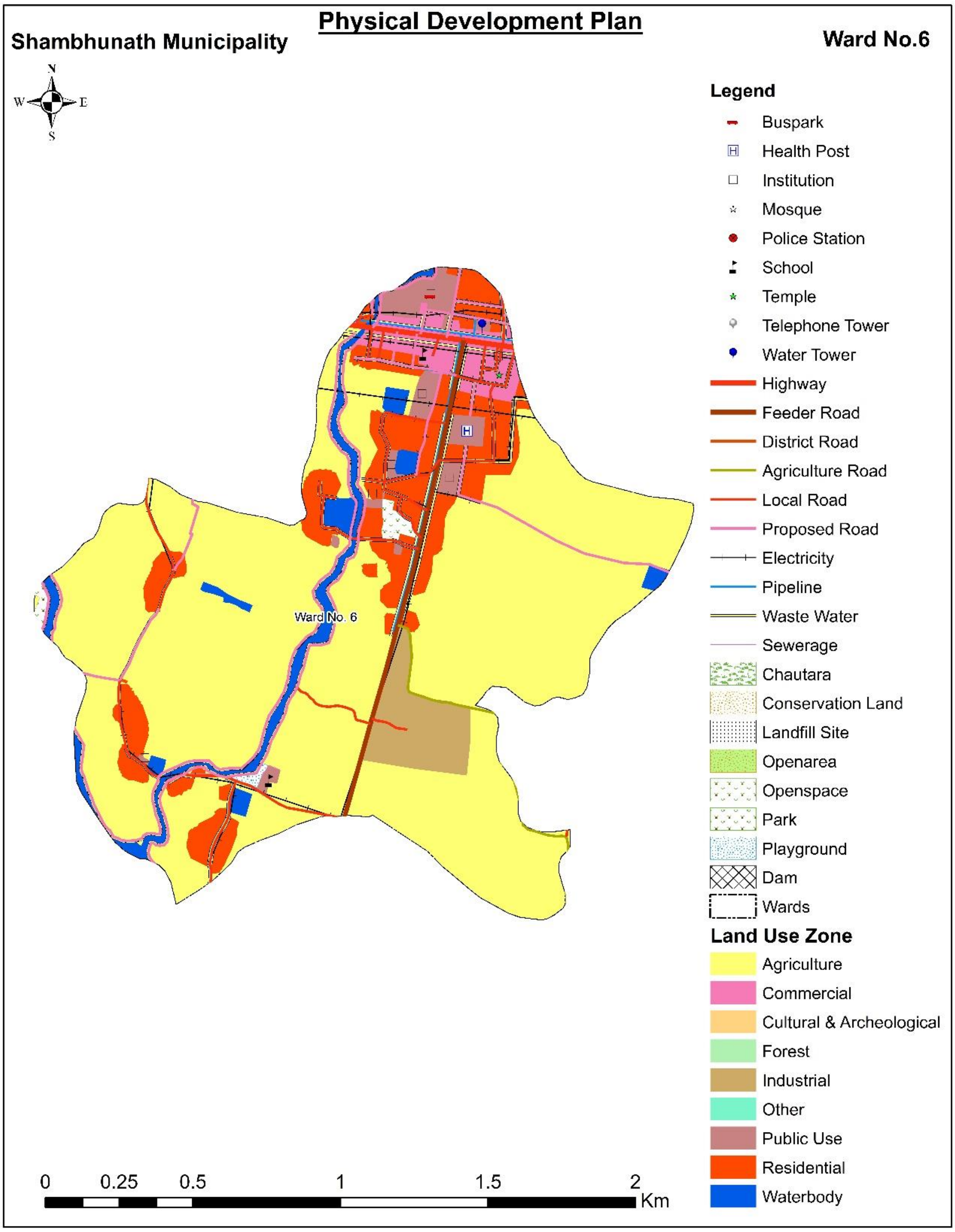
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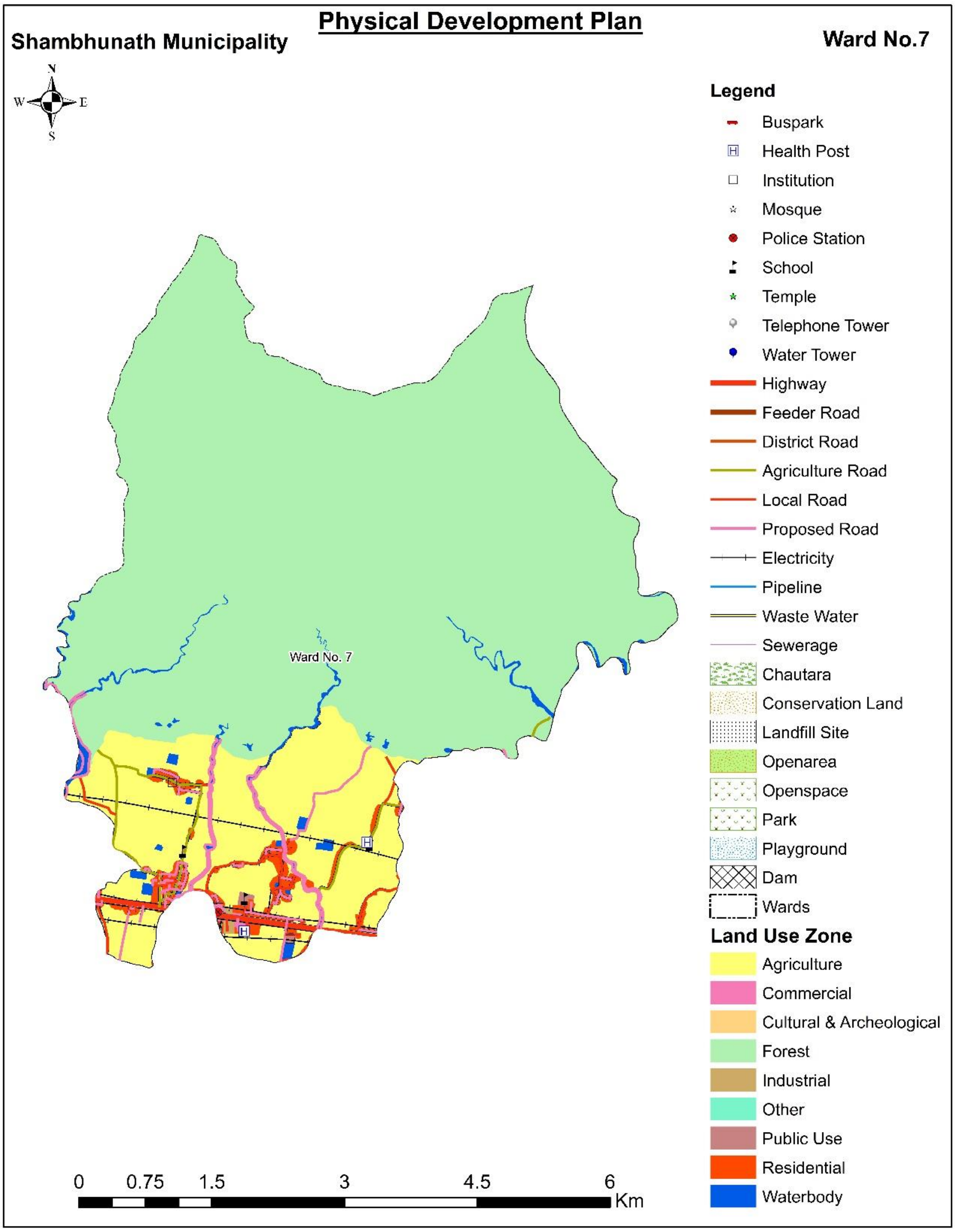
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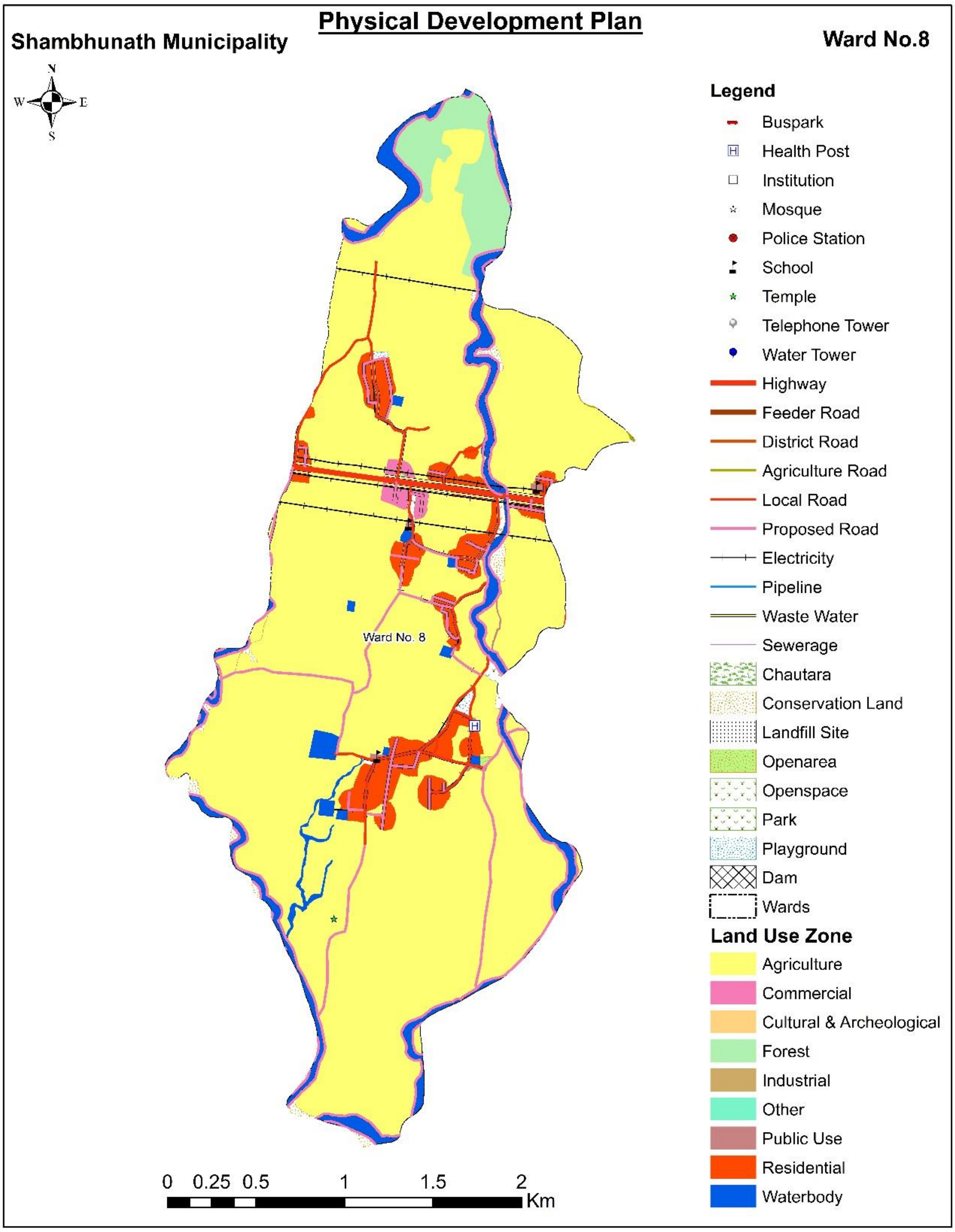

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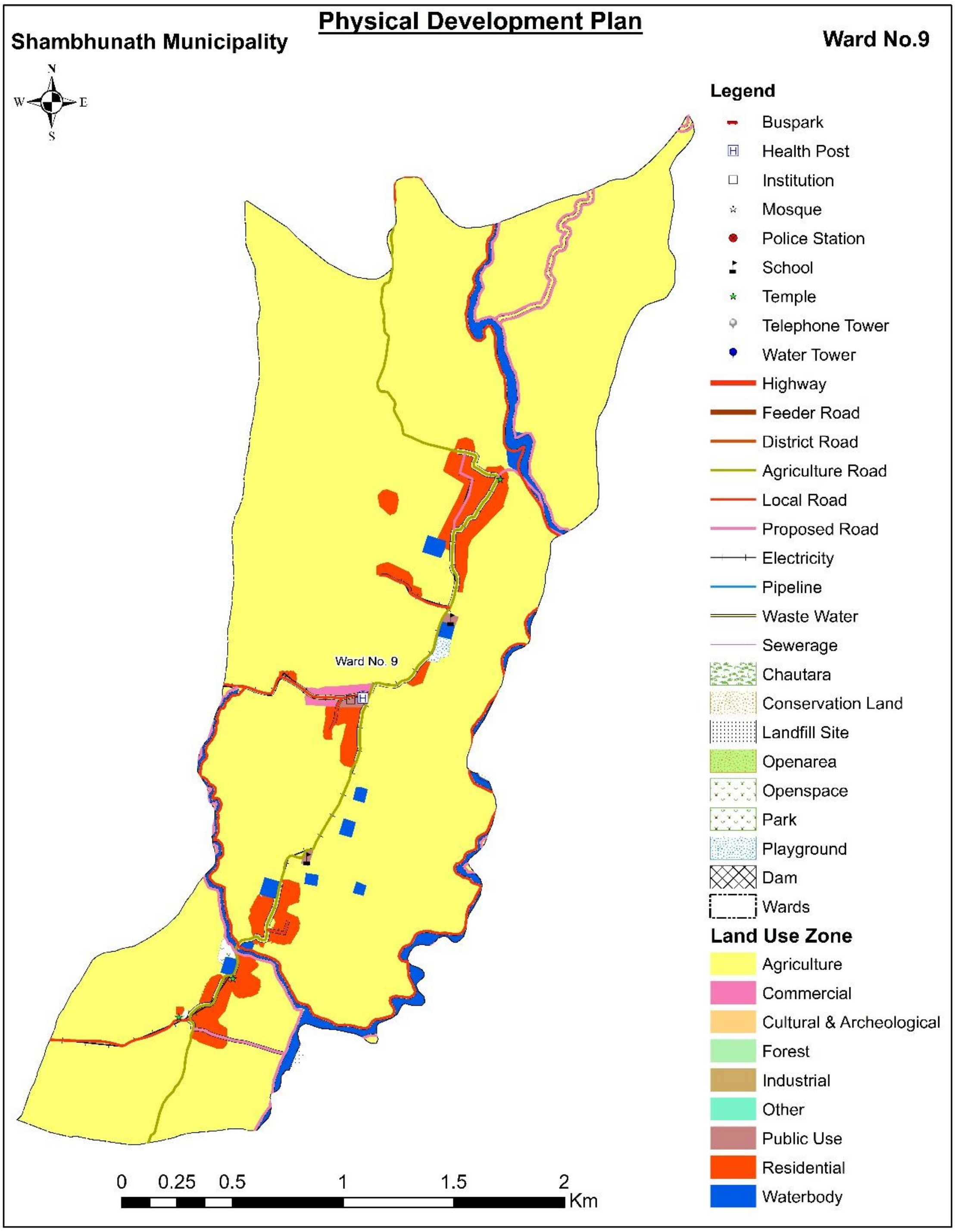
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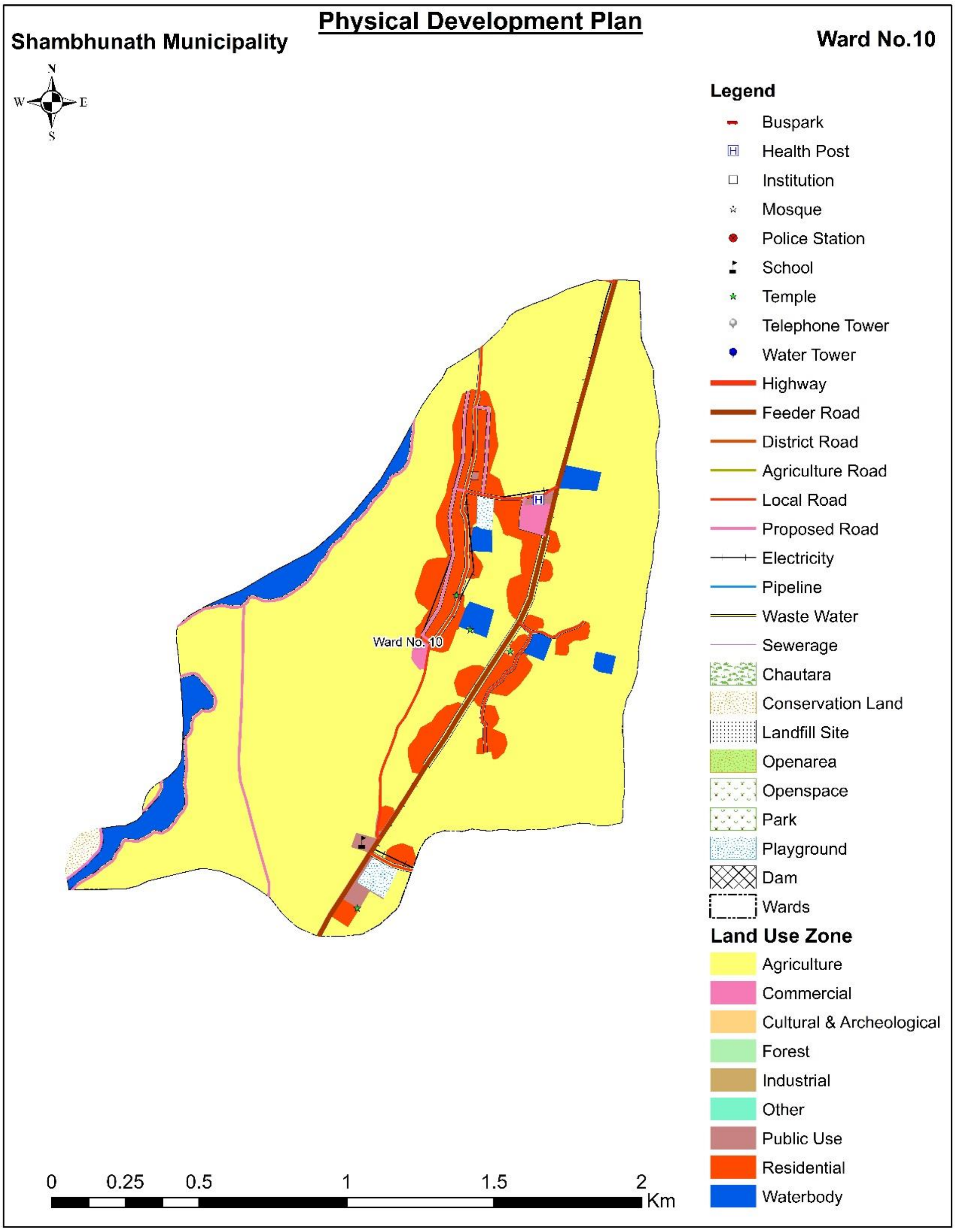
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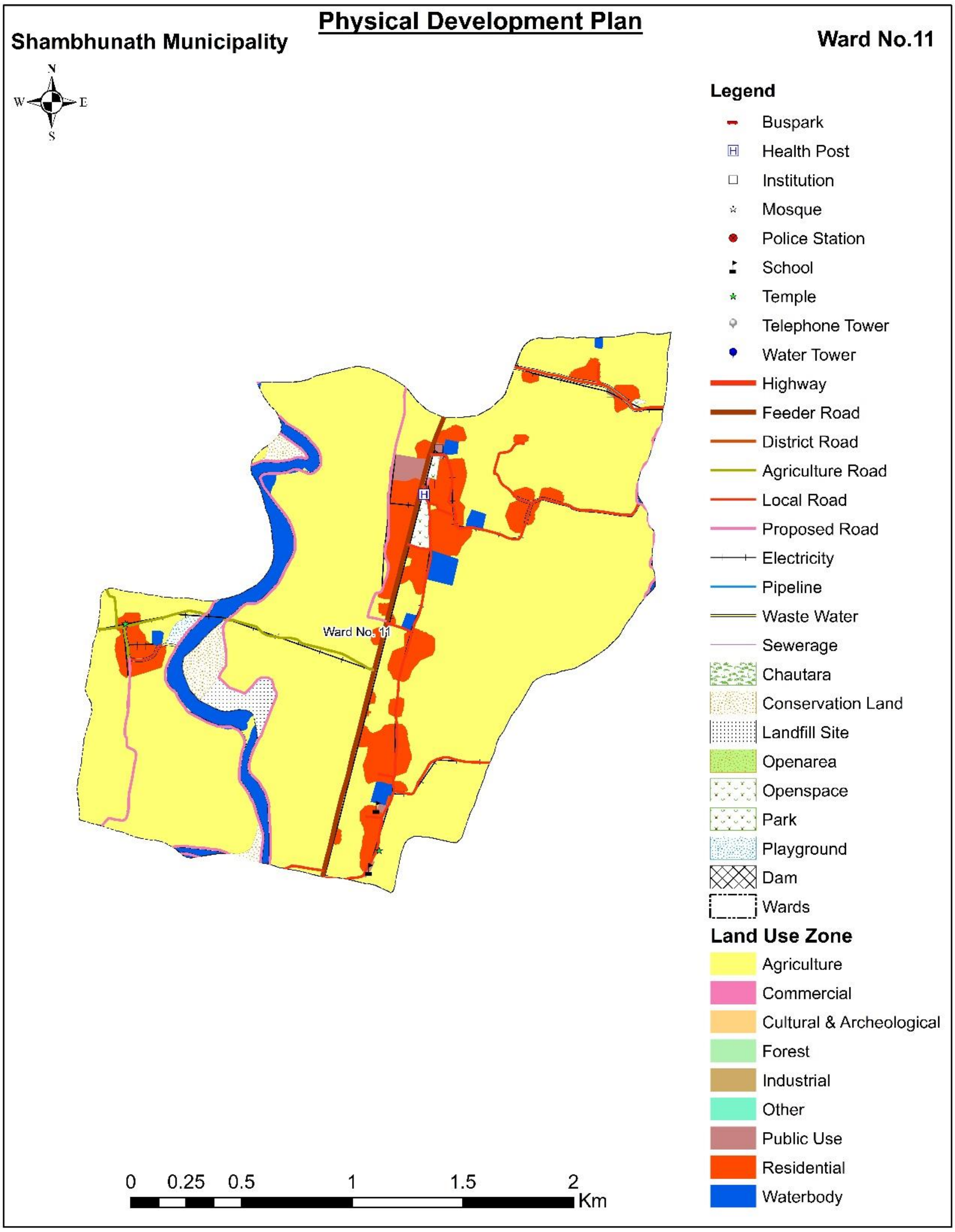
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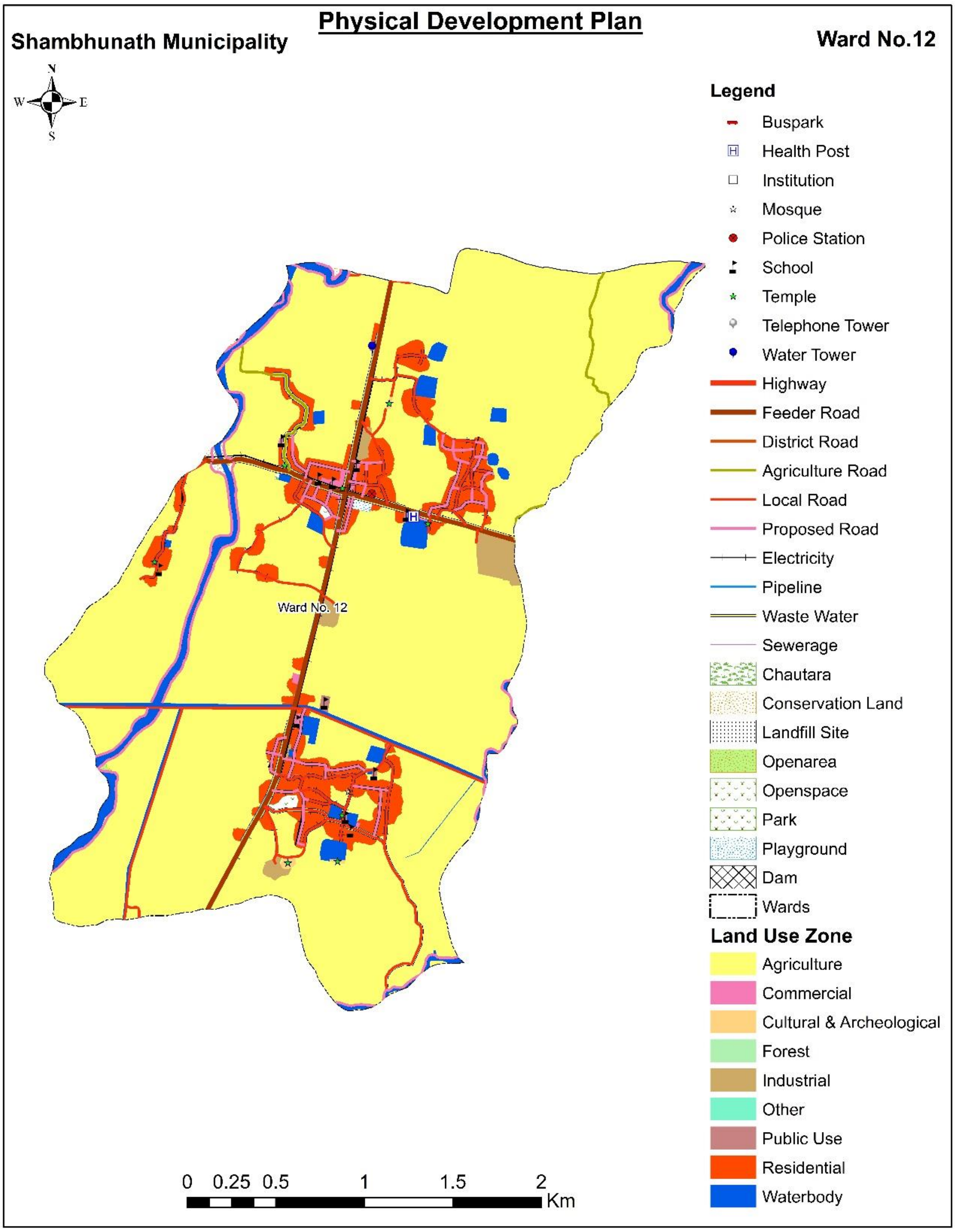
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LAND SUITABILITY

EVALUATION FOR LAND USE PLANNING IN SHAMBHUNATH **MUNICIPALITY OF SAPTARI DISTRICT, NEPAL** A **Dissertation Submitted to**

the Faculty of Humanities and Social Science of Tribhuvan University in fulfillment of the Requirements for the Degree of Doctor of Philosophy in GEOGRAPHY By BIKASH KUMAR KARNA Ph. D. Regd. No. 06/072 Magh T.U. Regd. No. 30499-94 Tribhuvan University Kathmandu, Nepal January, 2024 ABSTRACT Land use pattern is an outcome of natural and socio-economic factors and their utilization by humans in time and

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